Tcl and the Tk Toolkit

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Note to readers:
This manuscript is a partial draft of a book to be published in early 1994 by Addison-Wesley (ISBN 0-201-63337-X). Addison-Wesley has given me permission to make drafts of the book available to the Tcl community to help meet the need for introductory documentation on Tcl and Tk until the book becomes available. Please observe the restrictions set forth in the copyright notice above: you're welcome to make a copy for yourself or a friend but any sort of large-scale reproduction or reproduction for profit requires advance permission from Addison-Wesley.

I would be happy to receive any comments you might have on this draft; send them to me via electronic mail at `ouster@cs.berkeley.edu`. I'm particularly interested in hearing about things that you found difficult to learn or that weren't adequately explained in this document, but I'm also interested in hearing about inaccuracies, typos, or any other constructive criticism you might have.

Chapter 1
Introduction

1.1 Introduction

This book is about two packages called Tcl and Tk. Together they provide a programming system for developing and using graphical user interface (GUI) applications. Tcl stands for “tool command language” and is pronounced “tickle”; is a simple scripting language for controlling and extending applications. It provides generic programming facilities that are useful for a variety of applications, such as variables and loops and procedures. Furthermore, Tcl is *embeddable*: its interpreter is implemented as a library of C procedures that can easily be incorporated into applications, and each application can extend the core Tcl features with additional commands specific to that application.

One of the most useful extensions to Tcl is Tk. It is a toolkit for the X Window System, and its name is pronounced “tee-kay”. Tk extends the core Tcl facilities with additional commands for building user interfaces, so that you can construct Motif user interfaces by writing Tcl scripts instead of C code. Like Tcl, Tk is implemented as a library of C procedures so it too can be used in many different applications. Individual applications can also extend the base Tk features with new user-interface widgets and geometry managers written in C.

Together, Tcl and Tk provide four benefits to application developers and users. First, Tcl makes it easy for any application to have a powerful scripting language. All that an application needs to do is to implement a few new Tcl commands that provide the basic features of that application. Then the application can be linked with the Tcl interpreter to produce a full-function scripting language that includes both the commands provided by Tcl (called the *Tcl core*) and those implemented by the application (see Figure 1.1).

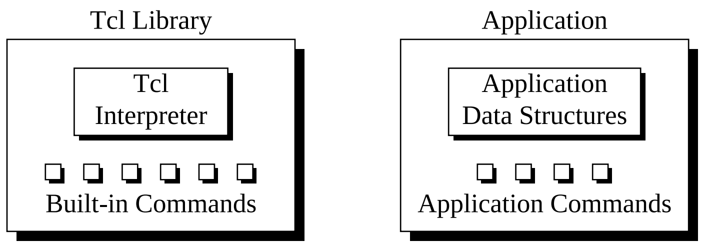


Figure 1.1. To create a new application based on Tcl, an application developer designs new C data structures specific to that application and writes C code to implement a few new Tcl commands. The Tcl library provides everything else that is needed to produce a fully programmable command language. The application can then be modified and extended by writing Tcl scripts.

For example, an application for reading electronic bulletin boards might contain C code that implements one Tcl command to query a bulletin board for new messages and another Tcl command to retrieve a given message. Once these commands exist, Tcl scripts can be written to cycle through the new messages from all the bulletin boards and display them one at a time, or keep a record in disk files of which messages have been read and which haven't, or search one or more bulletin boards for messages on a particular topic. The bulletin board application would not have to implement any of these additional functions in C; they could all be written as Tcl scripts, and users of the application could write additional Tcl scripts to add more functions to the application.

The second benefit of Tcl and Tk is rapid development. For example, many interesting windowing applications can be written entirely as Tcl scripts with no C code at all, using a windowing shell called `wish`. This allows you to program at a much higher level than you would in C or C++, and many of the details that C programmers must address are hidden from you. Compared to toolkits where you program entirely in C, such as Xt/Motif, there is much less to learn in order to use Tcl and Tk and much less code to write. New Tcl/Tk users can often create interesting user interfaces after just a few hours of learning, and many people have reported ten-fold reductions in code size and development time when they switched from other toolkits to Tcl and Tk.

Another reason for rapid development with Tcl and Tk is that Tcl is an interpreted language. When you use a Tcl application such as `wish` you can generate and execute new scripts on-the-fly without recompiling or restarting the application. This allows you to test out new ideas and fix bugs very rapidly. Since Tcl is interpreted it executes more slowly than compiled C code, of course, but modern workstations are surprisingly fast. For example, you can execute scripts with hundreds or even thousands of Tcl commands on each movement of the mouse with no perceptible delay. In the rare cases where performance becomes an issue, you can re-implement the most performance-critical parts of your Tcl scripts in C.

The third benefit of Tcl is that it makes an excellent “glue language”. Because it is embeddable, it can be used for many different purposes in many different programs. Once this happens, it becomes possible to write Tcl scripts that combine the features of all the programs. For example, any windowing application based on Tk can issue a Tcl script to any other Tk application. This feature makes multi-media effects much more accessible: once audio and video applications have been built with Tk (and there exist several already), any Tk application can issue “record” and “play” commands to them. In addition, spreadsheets can update themselves from database applications, user-interface editors can modify the appearance and behavior of live applications as they run, and so on. Tcl provides the *lingua franca* that allows application to work together.

The fourth benefit of Tcl is user convenience. Once a user learns Tcl and Tk, he or she can write scripts for any Tcl and Tk application merely by learning the few application-specific commands for the new application. This should make it possible for more users to personalize and enhance their applications.

1.2 Organization of the book

Chapter 2 uses several simple scripts to provide a quick overview of the most important features of Tcl and Tk. It is intended to give you the flavor of the systems and convince you that they are useful without explaining anything in detail. The remainder of the book goes through everything again in a more comprehensive fashion. It is divided into four parts:

- **Part I** introduces the Tcl scripting language. After reading this section you will be able to write scripts for Tcl applications.
- **Part II** describes the additional Tcl commands provided by Tk, which allow you to create user-interface widgets such as menus and scrollbars and arrange them in windowing applications. After reading this section you’ll be able to create new windowing application as `wish` scripts and write scripts to enhance existing Tk applications.
- **Part III** discusses the C procedures in the Tcl library and how to use them to create new Tcl commands. After reading this section you’ll be able to write new Tcl packages and applications in C.
- **Part IV** describes Tk’s library procedures. After reading this section you’ll be able to create new widgets and geometry managers in C.

Each of these major parts contains about ten short chapters. Each chapter is intended to be a self-contained description of a piece of the system, and you need not necessarily read the chapters in order. I recommend that you start by reading through Chapters 3-9 quickly, then skip to Chapters XXX-YYY, then read other chapters as you need them.

Not every feature of Tcl and Tk is covered here, and the explanations are organized to provide a smooth introduction rather than a terse reference source. A separate set of reference manual entries is available with the Tcl and Tk distributions. These are much more terse but they cover absolutely every feature of both systems.

This book assumes that you are familiar with the C programming language as defined by the ANSI C standard, and that you have some experience with UNIX and X11. In order to understand Part IV you will need to understand many of the features provided by the Xlib interface, such as graphics contexts and window attributes; however, these details are not necessary except in Part IV. You need not know anything about either Tcl or Tk before reading this book; both of them will be introduced from scratch.

1.3 Notation

Throughout the book I use a `Courier` font for anything that might be typed to a computer, such as variable names, procedure and command names, Tcl scripts, and C code. The examples of Tcl scripts use notation like the following:

```
   set a 44
⇒  44
```

Tcl commands such as "`set a 44`" is the example appear in Courier and their results, such as "*`44`*" in the example, appear in Courier oblique. The ⇒ symbol before the result indicates that this is a normal return value. If an error occurs in a Tcl command then the error message appears in Courier oblique, preceded by a ∅ symbol to indicate that this is an error rather than a normal return:

```
   set a 44 55
∅  wrong # args: should be "set varName ?newValue?"
```

When describing the syntax of Tcl commands, Courier oblique is used for formal argument names. If an argument or group of arguments is enclosed in question marks it means that the arguments are optional. For example, the syntax of the `set` command is as follows:

```
   set varName ?newValue?
```

This means that the word `set` would be entered verbatim to invoke the command, while *`varName`* and *`newValue`* are the names of `set`'s arguments; when invoking the command you would type a variable name instead of *`varName`* and a new value for the variable instead of *`newValue`*. The *`newValue`* argument is optional.

Chapter 2
An Overview of Tcl and Tk

This chapter introduces Tcl and Tk with a series of scripts that illustrate the main features of the systems. Although you should be able to start writing simple scripts after reading this chapter, the explanations here are not intended to be complete. All of the information in this chapter will be revisited in more detail in later chapters, and several important aspects of the systems, such as their C interfaces, are not discussed at all in this chapter. The purpose of this chapter is to show you the overall structure of Tcl and Tk and the kinds of things they can do, so that when individual features are discussed in detail you'll be able to see why they are useful.

2.1 Getting started

In order to invoke Tcl scripts you must run a Tcl application. If Tcl is installed on your system then there should exist a simple Tcl shell application called `tclsh`, which you can use to try out some of the examples in this chapter (if Tcl has not been installed on your system then refer to Appendix A for information on how to obtain and install it). Type the command

```
tclsh
```

to your shell to invoke `tclsh`; `tclsh` will start up in interactive mode, reading Tcl commands from its standard input and passing them to the Tcl interpreter for evaluation. For starters, type the following command to `tclsh`:

```
expr 2 + 2
```

`Tclsh` will print the result "`4`" and prompt you for another command.

This example illustrates several features of Tcl. First, Tcl commands are similar in form to shell commands. Each command consists of one or more *words* separated by spaces or tabs. In the example there are four words: `expr`, `2`, `+`, and `2`. The first word of each command is its name: the name selects a C procedure in the application that will carry out the function of the command. The other words are *arguments* that are passed to the C procedure. `Expr` is one of the core commands built into the Tcl interpreter, so it exists in every Tcl application. It concatenates its arguments into a single string and evaluates the string as an arithmetic expression.

Each Tcl command returns a result string. For the `expr` command the result is the value of the expression. Results are always returned as strings, so `expr` converts its numerical result back to a string in order to return it. If a command has no meaningful result then it returns an empty string.

From now on I will use notation like the following to describe examples:

```
  expr 2 + 2
⇒ 4
```

The first line is the command you type and the second line is the result returned by the command. The ⇒ symbol indicates that the line contains a return value; the ⇒ will not actually be printed out by `tclsh`. I will omit return values in cases where they aren't important, such as sequences of commands where only the last command's result matters.

Commands are normally terminated by newlines, so when you are typing to `tclsh` each line normally becomes a separate command. Semi-colons also act as command separators, in case you wish to enter multiple commands on a single line. It is also possible for a single command to span multiple lines; you'll see how to do this later.

The `expr` command supports an expression syntax similar to that of expressions in ANSI C, including the same precedence rules and most of the C operators. Here are a few examples that you could type to `tclsh`:

```
  expr 3 << 2
⇒ 12
  expr 14.1*6
⇒ 84.6
  expr (3 > 4) || (6 <= 7)
⇒ 1
```

The first example illustrates the bitwise left-shift operator `<<`. The second example shows that expressions can contain real values as well as integer values. The last example shows the use of relational operators `>` and `<=` and the logical or operator `||`. As in C, boolean results are represented numerically with 1 for true and 0 for false.

To leave `tclsh`, invoke the `exit` command:

```
  exit
```

This command will terminate the application and return you to your shell.

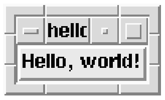


Figure 2.1. The “hello world” application. All of the decorations around the “Hello, world!” button are provided by the `mwm` window manager. If you use a different window manager then your decorations may be different.

2.2 Hello world with Tk

Although Tcl provides a full set of programming features such as variables, loops, and procedures, it is not intended to be a stand-alone programming environment. Tcl is intended to be used as part of applications that provide their own Tcl commands in addition to those in the Tcl core. The application-specific commands provide interesting primitives and Tcl is used to assemble the primitives into useful functions. Tcl by itself isn’t very interesting and it is hard to motivate all of Tcl’s facilities until you have seen some interesting application-specific commands to use them with.

Tk provides a particularly interesting set of commands to use with Tcl’s programming tools. Most of the examples in the book will use an application called `wish`, which is similar to `tclsh` except that it also includes the commands defined by Tk. Tk’s commands allow you to create graphical user interfaces. If Tcl and Tk have been installed on your system then you can invoke `wish` from your shell just like `tclsh`; it will display a small empty window on your screen and then read commands from standard input. Here is a simple `wish` script:

```
button .b -text "Hello, world!" -command exit
pack .b
```

If you type these two Tcl commands to `wish` the window’s appearance will change to what is shown in Figure 2.1. If you then move the pointer over the window and click mouse button 1, the window will disappear and `wish` will exit.

There are several things to explain about this example. First let us deal with the syntactic issues. The example contains two commands, `button` and `pack`, both of which are implemented by Tk. Although these commands look different than the `expr` command in the previous section, they have the same basic structure as all Tcl commands, consisting of one or more words separated by white space. The `button` command contains six words and the pack command contains two words.

The fourth word of the `button` command is enclosed in double quotes. This allows the word to include white space characters: without the quotes “`Hello,`” and “`world!`” would be separate words. The double-quotes are not part of the word itself; they are removed by the Tcl interpreter before the word is passed to the command as an argument.

For the `expr` command the word structure doesn't matter much since `expr` concatenates all its arguments together. However for the `button` and `pack` commands, and for most Tcl commands, the word structure is important. The `button` command expects its first argument to be the name of a window and the following arguments to come in pairs, where the first argument of each pair is the name of a *configuration option* and the second argument is a value for that option. Thus if the double-quotes were omitted the value of the `-text` option would be "`Hello,`" and "`world!`" would be treated as the name of a separate configuration option. Since there is no option defined with the name "`world!`" the command would return an error.

Now let us move on to the behavior of the commands. The basic building block for a graphical user interface in Tk is a *widget*. A widget is a window with a particular appearance and behavior (the terms "widget" and "window" are used synonymously in Tk). Widgets are divided into classes such as buttons, menus, and scrollbars. All the widgets in the same class have the same general appearance and behavior. For example, all button widgets display a text string or bitmap and execute a particular Tcl command when they are invoked with the mouse.

Widgets are organized hierarchically in Tk, with names that reflect their position in the hierarchy. The *main widget*, which appeared on the screen when you started `wish`, has the name ".". The name `.b` refers to a child of the main widget. Widget names in Tk are like file names in UNIX except that they use "`.`" as a separator character instead of "`/`". Thus `.a.b.c` refers to a widget that is a child of widget `.a.b`, which in turn is a child of `.a`, which is a child of the main widget.

Tk provides one command for each class of widgets, which you invoke to create widgets of that class. For example the `button` command creates button widgets. All of the widget creation commands have the same form: the first argument is the name of a new widget to create and additional arguments specify configuration options. Different widget classes support different sets of options. Widgets typically have many options (there are about 20 different options defined for buttons, for example), and default values are provided for the options that you don't specify. When a widget creation command like `button` is invoked it creates a new window by the given name and configures it as specified by the options.

The `button` command in the example specifies two options: `-text`, which is a string to display in the button, and `-command`, which is a Tcl script to execute when the user invokes the button. In this example the `-command` option is `exit`. Here are a few other button options that you can experiment with:

`-background`	The background color for the button.
`-foreground`	The color of the text in the button.
`-font`	The name of the font to use for the button, such as `*-times-medium-r-normal--*-120-*` for a 12-point Times Roman font.

The `pack` command makes the button widget appear on the screen. Creating a widget does not automatically cause it to be displayed. Independent entities called *geometry managers* are responsible for computing the sizes and locations of widgets and making them appear on the screen. The `pack` command in the example asks a geometry manager called the *packer* to manage `.b`. The command asks that `.b` fill the entire area of its parent window; furthermore, if the parent has more space than needed by its child, as in the example, the parent is shrunk so that it is just large enough to hold the child. Thus when you typed the `pack` command the main window shrunk from its original size to the size that appears in Figure 2.1.

2.3 Script files

In the examples so far you have typed Tcl commands interactively to `tclsh` or `wish`. You can also place commands into script files and invoke the script files just like shell scripts. To do this for the hello world example, place the following text in a file named `hello`:

```
#!/usr/local/bin/wish -f
button .b -text "Hello, world!" -command exit
pack .b
```

This script is the same as the one you typed earlier except for the first line. As far as `wish` is concerned this line is a comment but if you make the file executable (type "`chmod 775 hello`" to your shell, for example) you can then invoke the file directly by typing `hello` to your shell. When you do this the system will invoke `wish`, passing it the file as a script to interpret. `Wish` will display the same window shown in Figure 2.1 and wait for you to interact with it. In this case you will not be able to type commands interactively to wish; all you can do is click on the button.

Note: This script will only work if `wish` is installed in `/usr/local/bin`. If `wish` has been installed somewhere else then you'll need to change the first line to reflect its location on your system.

In practice users of Tk applications rarely type Tcl commands; they interact with the applications using the mouse and keyboard in the usual ways you would expect for graphical applications. Tcl works behind the scenes where users don't normally see it. The `hello` script behaves just the same as an application that has been coded in C with a toolkit such as Motif and compiled into a binary executable file.

During debugging, though, it is common for application developers to type Tcl commands interactively. For example, you could test out the `hello` script by starting `wish` interactively (type `wish` to your shell instead of `hello`). Then type the following Tcl command:

```
source hello
```

`Source` is a Tcl command that takes a file name as argument. It reads the file and evaluates it as a Tcl script. This will generate the same user interface as if you had invoked `hello` directly from your shell, but you can now type Tcl commands interactively too. For example, you could edit the script file to change the `-command` option to

```
-command "puts Good-bye!; exit"
```

then type the following commands interactively to `wish` without restarting the program:

```
destroy .b
source hello
```

The first command will delete the existing button and the second command will recreate the button with the new `-command` option. Now when you click on the button the `puts` command will print a message on standard output before `wish` exits.

2.4 Variables and substitutions

Tcl allows you to store values in variables and use those values in commands. For example, consider the following script, which you could type to either `tclsh` or `wish`:

```
     set a 44
⇒    44
     expr $a*4
⇒    176
```

The first command assigns the value "`44`" to variable `a` and returns the variable's value. In the secon command t he `$` causes Tcl to perform *variable substitution*: the Tcl interpreter replaces the dollar-sign and the variable name following it with the value of the variable, so that the actual argument received by `expr` is "`44*4`". Variables need not be declared in Tcl; they are created automatically when assigned to. Variable values are stored as strings and arbitrary string values of any length are allowed. Of course, in this example an error will occur in `expr` if the value of `a` doesn't make sense as an integer or real number (try other values and see what happens).

Tcl also provides *command substitution*, which allows you to use the result of one command in an argument to another command:

```
     set a 44
     set b [expr $a*4]
⇒    176
```

Square brackets invoke command substitution: everything inside the brackets is evaluated as a separate Tcl script and the result of that script is substituted into the word in place of the bracketed command. In this example the second argument of the second command will be "`176`".

2.5 Control structures

The next example uses variables and substitutions along with some simple control structures to create a Tcl procedure `power` that raises a base to an integer power:

```
proc power {base p} {
    set result 1
    while {$p > 0} {
        set result [expr $result*$base]
        set p [expr $p-1]
    }
    return $result
}
```

If you type the above lines to `wish` or `tclsh`, or if you enter them into a file and then `source` the file, a new command `power` will become available. The command takes two arguments, a number and an integer power, and its result is the number raised to the power:

```
   power 2 6
⇒  64
   power 1.15 5
⇒  2.01136
```

This example uses one additional piece of Tcl syntax: braces. Braces are like double-quotes in that they can be placed around a word that contains embedded spaces. However, braces are different from double-quotes in two respects. First, braces nest. The last word of the `proc` command starts after the open brace on the first line and contains everything up to the close brace on the last line. The Tcl interpreter removes the outer braces and passes everything between them, including several nested pairs of braces, to `proc` as an argument. The second difference between braces and double-quotes is that no substitutions occur inside braces, whereas they do inside quotes. All of the characters between the braces are passed verbatim to `proc` without any special processing.

The `proc` command takes three arguments: the name of a procedure, a list of argument names separated by white space, and the body of the procedure, which is a Tcl script. `Proc` enters the procedure name into the Tcl interpreter as a new command. Whenever the command is invoked, the body of the procedure will be evaluated. While the procedure body is executing it can access its arguments as variables: `base` will hold the first argument to power and `p` will hold the second argument.

The body of the `power` procedure contains three Tcl commands: `set`, `while`, and `return`. The `while` command does most of the work of the procedure. It takes two arguments, an expression "`$p > 0`" and a body, which is another multi-line Tcl script. The `while` command evaluates its expression argument and if the result is non-zero then it evaluates the body as a Tcl script. It repeats this process over and over until eventually the expression evaluates to zero. In the example, the body of the `while` command multiplies the result value by `base` and then decrements `p`. When `p` reaches zero the result contains the desired power of `base`.

The `return` command causes the procedure to exit with the value of variable `result` as the procedure's result. If it is omitted then the return value of the procedure will be the result of the last command in the procedure's body. In the case of `power` this would be the result of `while`, which is always an empty string.

The use of braces in this example is crucial. The single most difficult issue in writing Tcl scripts is managing substitutions: making them happen when you want them and preventing them from happening when you don't want them. Braces prevent substitutions or defer them until later. The body of the procedure must be enclosed in braces because we don't want variable and command substitutions to occur at the time the body is passed to `proc` as an argument; we want the substitutions to occur later, when the body is evaluated as a Tcl script. The body of the `while` command is enclosed in braces for the same reason: rather than performing the substitutions once, while parsing the `while` command, we want the substitutions to be performed over and over, each time the body is evaluated. Braces are also needed in the "`{$p > 0}`" argument to `while`. Without them the value of variable `p` would be substituted when parsing the `while` command; the expression would have a constant value and `while` would loop forever (you can try replacing some of the braces in the example with double quotes to see what happens).

In the examples in this book I use a stylized syntax where the open brace for an argument that is a Tcl script appears at the end of one line, the script follows on successive lines indented, and the close brace is on a line by itself after the script. Although I think that this makes for readable scripts, Tcl doesn't require this particular syntax. Script arguments are subject to the same syntax rules as any other arguments; in fact the Tcl interpreter doesn't even know that an argument is a script at the time it parses it. One consequence of this is that the open parenthesis must be on the same line as the preceding portion of the command. If the open brace is moved to a line by itself then the newline before the open brace will terminate the command.

By now you have seen nearly the entire Tcl language syntax. The only remaining syntactic feature is backslash substitution, which allows you to enter special characters such as dollar-signs into a word without enclosing the entire word in braces. Note that `while` and `proc` are not special syntactic elements in Tcl. They are just commands that take arguments just like all Tcl commands. The only special thing about `while` and `proc` is that they treat some of their arguments as Tcl scripts and cause the scripts to be evaluated. Many other commands also do this. The `button` command was one example (its `-command` option is a Tcl script), and you'll read about several other control structures later on, such as `for`, `foreach`, `case`, and `eval`.

One final note about procedures. The variables in a procedure are normally local to that procedure and will not be visible outside the procedure. In the `power` example the local variables include the arguments `base` and `p` as well as the variable `result`. A fresh set of local variables is created for each call to a procedure (arguments are passed by copying their values), and when a procedure returns its local variables are deleted. Vari-

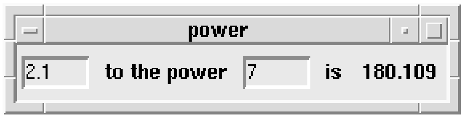


Figure 2.2. A graphical user interface that computes powers of a base.

ables named outside any procedure are called *global variables*; they last forever unless explicitly deleted. You'll find out later how a procedure can access global variables and the local variables of other active procedures.

2.6 Event bindings

The next example provides a graphical front-end for the `power` procedure. In addition to demonstrating two new widget classes it illustrates Tk's *binding* mechanism. A binding causes a particular Tcl script to be evaluated whenever a particular event occurs in a particular window. The `-command` option for buttons is an example of a simple binding implemented by a particular widget class. Tk also includes a more general mechanism that can be used to extend the behavior of arbitrary widgets in nearly arbitrary ways.

To run the example, copy the following script into a file `power` and invoke the file from your shell.

```
#!/usr/local/bin/wish -f
proc power {base p} {
    set result 1
    while {$p > 0} {
        set result [expr $result*$base]
        set p [expr $p-1]
    }
    return $result
}
entry .base -width 6 -relief sunken -textvariable base
label .label1 -text "to the power"
entry .power -width 6 -relief sunken -textvariable power
label .label2 -text "is"
label .result -textvariable result
pack .base .label1 .power .label2 .result \
        -side left -padx 1m -pady 2m
bind .base <Return> {set result [power $base $power]}
bind .power <Return> {set result [power $base $power]}
```

This script will produce a screen display like that in Figure 2.2. There are two entry widgets in which you can click with the mouse and type numbers. If you type return in either of the entries, the result will appear on the right side of the window. You can compute different results by modifying either the base or the power and then typing return again.

This application consists of five widgets: two entries and three labels. Entries are widgets that display one-line text strings that you can edit interactively. The two entries, `.base` and `.power`, are used for entering the numbers. Each entry is configured with a `-width` of 6, which means it will be large enough to display about 6 digits, and a `-relief` of `sunken`, which gives the entry a depressed appearance. The `-textvariable` option for each entry specifies the name of a global variable to hold the entry's text: any changes you make in the entry will be reflected in the variable and vice versa.

Two of the labels, `.label1` and `.label2`, hold decorative text and the third, `.result`, holds the result of the power computation. The `-textvariable` option for `.result` causes it to display whatever string is in global variable `result` whereas`.label1` and `.label2` display constant strings.

The `pack` command arranges the five widgets in a row from left to right. The command occupies two lines in the script; the backslash at the end of the first line is a line-continuation character: it causes the newline to be treated as a space. The `-side` option means that each widget is placed at the left side of the remaining space in the main widget: first `.base` is placed at the left edge of the main window, then `.label1` is placed at the left side of the space not occupied by `.base`, and so on. The `-padx` and `-pady` options make the display a bit more attractive by arranging for 1 millimeter of extra space on the left and right sides of each widget, plus 2 millimeters of extra space above and below each widget. The "`m`" suffix specifies millimeters; you could also use "`c`" for centimeters, "`i`" for inches, "`p`" for points, or no suffix for pixels.

The `bind` commands connect the user interface to the `power` procedure. Each `bind` command has three arguments: the name of a window, an event specification, and a Tcl script to invoke when the given event occurs in the given window. `<Return>` specifies an event consisting of the user typing the return key on the keyboard. Here are a few other event specifiers that you might find useful:

`<Button-1>`	Mouse button 1 is pressed.
`<ButtonRelease-1>`	Mouse button 1 is released.
`<Double-Button-1>`	Double-click on mouse button 1.
`<1>`	Short-hand for `<Button-1>`.
`<Key-a>`	Key "`a`" is pressed.
`<a>` or `a`	Short-hand for `<Key-a>`.
`<Motion>`	Pointer motion with no buttons or modifier keys pressed.
`<B1-Motion>`	Pointer motion with button 1 pressed.
`<Any-Motion>`	Pointer motion with any (or no) buttons or modifier keys pressed.

The scripts for the bindings invoke `power`, passing it the values in the two entries, and they store the result in `result` so that it will be displayed in the `.result` widget. These bindings extend the generic built-in behavior of the entries (editing text strings) with application-specific behavior (computing a value based on two entries and displaying that value in a third widget).

The script for a binding has access to several pieces of information about the event, such as the location of the pointer when the event occurred. For an example, start up `wish` interactively and type the following command to it:

```
bind . <Any-Motion> {puts "pointer at %x,%y"}
```

Now move the pointer over the window. Each time the pointer moves a message will be printed on standard output giving its new location. When the pointer motion event occurs, Tk scans the script for % sequences and replaces them with information about the event before passing the script to Tcl for evaluation. `%x` is replaced with the pointer's x-coordinate and `%y` is replaced with the pointer's y-coordinate.

2.7 Subprocesses

Normally Tcl executes each command by invoking a C procedure in the application to carry out its function; this is different from a shell program like `sh` where each command is normally executed in a separate subprocess. However, Tcl also allows you to create subprocesses, using the `exec` command. Here is a simple example of `exec`:

```
   exec grep #include tk.h
⇒ #include <tcl.h>
   #include <X11/Xlib.h>
   #include <stddef.h>
```

The `exec` command treats its arguments much like the words of a shell command line. In this example `exec` creates a new process to run the `grep` program and passes it "`#include`" and "`tk.h`" as arguments, just as if you had typed

```
grep #include tk.h
```

to your shell. The `grep` program searches file `tk.h` for lines that contain the string `#include` and prints those lines on its standard output. However, `exec` arranges for standard output from the subprocess to be piped back to Tcl. `Exec` waits for the process to exit and then it returns all of the standard output as its result. With this mechanism you can execute subprocesses and use their output in Tcl scripts. `Exec` also supports input and output redirection using standard shell notation such as `<`, `<<`, and `>`, pipelines with `|`, and background processes with `&`.

The example below creates a simple user interface for saving and re-invoking commonly used shell commands. Type the following script into a file named `redo` and invoke it:

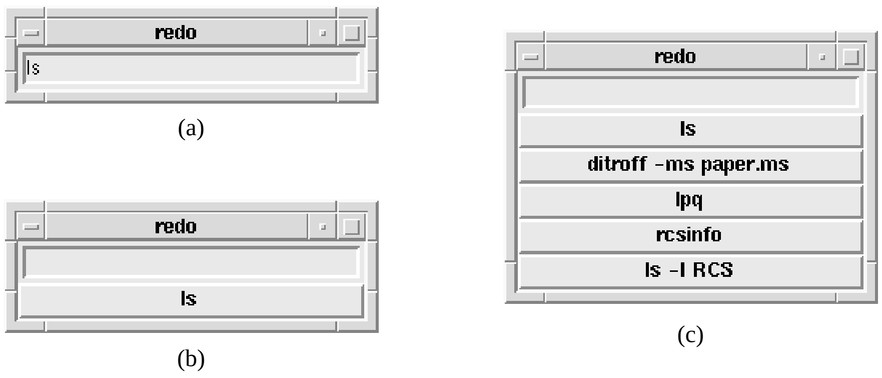


Figure 2.3. The `redo` application. The user can type a command in the entry window, as in (a). When the user types return the command is invoked as a subprocess using `exec` and a new button is created that can be used to re-invoke the command later, as in (b). Additional commands can be typed to create additional buttons, up to a limit of five buttons as in (c).

```
#!/usr/local/bin/wish -f
set id 0
entry .entry -width 30 -relief sunken -textvariable cmd
pack .entry -padx 1m -pady 1m
bind .entry <Return> {
    set id [expr $id + 1]
    if {$id > 5} {
        destroy .b[expr $id - 5]
    }
    button .b$id -command "exec <@stdin >@stdout $cmd" \
            -text $cmd
    pack .b$id -fill x
    .b$id invoke
    .entry delete 0 end
}
```

Initially the script creates an interface with a single entry widget. You can type a shell command such as `ls` into the entry, as shown in Figure 2.3(a). When you type return the command gets executed just as if you had typed it to the shell from which you invoked `redo`, and output from the command appears in the shell's window. Furthermore, the script creates a new button widget that displays the command (see Figure 2.3(b)) and you can re-invoke the command later by clicking on the button. As you type more and more commands, more and more buttons appear, up to a limit of five remembered commands as in Figure 2.3(c).

Note: This example suffers from several limitations. For example, you cannot specify wild-cards such as "`*`" in command lines, and the "`cd`" command doesn't behave properly. In Part I you'll read about Tcl facilities that you can use to eliminate these limitations.

The most interesting part of the `redo` script is in the `bind` command. The binding for `<Return>` must execute the command, which is stored in the `cmd` variable, and create a new button widget. First it creates the widget. The button widgets have names like `.b1`, `.b2`, and so on, where the number comes from the variable `id. Id` starts at zero and increments before each new button is created. The notation "`.b$id`" generates a widget name by "`.b`" and the value of `id`. Before creating a new widget the script checks to see if there are already five saved commands; if so then the oldest existing button is deleted. The notation "`.b[expr $id - 5]`" produces the name of the oldest button by subtracting five from the number of the new button and concatenating it with "`.b`". The `-command` option for the new button invokes `exec` and redirects standard input and standard output for the subprocess(es) to `wish`'s standard input and standard output, which are the same as those of the shell from which `wish` was invoked: this causes output from the subprocesses to appear in the shell's window instead of being returned to `wish`.

The command "`pack .b$id -fill x`" makes the new button appear at the bottom of the window. The option "`-fill x`" improves the appearance by stretching the button horizontally so that it fills the width of the window even it it doesn't really need that much space for its text. Try omitting the `-fill` option to see what happens without it.

The last two commands of the binding script are called *widget commands*. Whenever a new widget is created a new Tcl command is also created with the same name as the widget, and you can invoke this command to communicate with the widget. The first argument to a widget command selects one of several operations and additional arguments are used as parameters for that operation. In the `redo` script the first widget command causes the button widget to invoke its `-command` option just as if you had clicked the mouse button on it. The second widget command clears the entry widget in preparation for a new command to be typed.

Each class of widget supports a different set of operations in its widget commands, but many of the operations are similar from widget to widget. For example, every widget class supports a `configure` widget command that can be used to modify any of the configuration options for the widget. If you run the `redo` script interactively you could type the following command to change the background of the entry widget to yellow:

```
.entry configure -background yellow
```

Or, you could type

```
.b1 configure -foreground brown
.b1 flash
```

to change the color of the text in button `.b1` to brown and then cause the button to flash.

One of the most important things about Tcl and Tk is that they make every aspect of an application accessible and modifiable at run-time. For example, the `redo` script modifies its own interface on the fly. In addition, Tk provides commands that you can use to query the structure of the widget hierarchy, and you can use `configure` widget commands to query and modify the configuration options of individual widgets.

2.8 Additional features of Tcl and Tk

The examples in this chapter used every aspect of the Tcl language syntax and they illustrated many of the most important features of Tcl and Tk. However, Tcl and Tk contain many other facilities that are not used in this chapter; all of these will be described later in the book. Here is a sampler of some of the most useful features that haven't been mentioned yet:

Arrays and lists. Tcl provides associative arrays for storing key-value pairs efficiently and lists for managing aggregates of data.

More control structures. Tcl provides several additional commands for controlling the flow of execution, such as `eval`, `for`, `foreach`, and `switch`.

String manipulation. Tcl contains a number of commands for manipulating strings, such as measuring their length and performing regular expression pattern matching and substitution.

File access. You can read and write files from Tcl scripts and retrieve directory information and file attributes such as length and creation time.

More widgets. Tk contains many widget classes besides those shown here, such as menus, scrollbars, a drawing widget called a *canvas*, and a text widget that makes it easy to achieve hypertext effects.

Access to other X facilities. Tk provides commands for accessing all of the major facilities in the X Window System, such as a command for communicating with the window manager (to set the window's title, for example), a command for retrieving the selection, and a command to manage the input focus.

C interfaces. Tcl provides C library procedures that you can use to define your own new Tcl commands in C, and Tk provides a library that you can use to create your own widget classes and geometry managers in C.

2.9 Extensions and applications

Tcl and Tk have an active and rapidly-growing user community that now numbers in the tens of thousands. Many people have built applications based on Tcl and Tk and packages that extend the base functionality of Tcl and Tk. Several of these packages and applications are publically available and widely used in the Tcl/Tk community. There isn't space in this book to discuss all of the exciting Tcl/Tk software in detail but this section gives a quick overview of five of the most popular extensions and applications. See Appendix A for information on how you can obtain them and other contributed Tcl/Tk software.

2.9.1 Expect

`Expect` is one of the oldest Tcl applications and also one of the most popular. It is a program that “talks” to interactive programs. Following a script, `expect` knows what output can be expected from a program and what the correct responses should be. It can be used to automatically control programs like `ftp`, `telnet`, `rlogin`, `crypt`, `fsck`, `tip`, and others that cannot be automated from a shell script because they require interactive input. `Expect` also allows the user to take control and interact directly with the program when desired. For example, the following `expect` script logs into a remote machine using the `rlogin` program, sets the working directory to that of the originating machine, then turns control over to the user:

```
#!/usr/local/bin/expect
spawn rlogin [lindex $argv 1]
expect -re "(%|#) "
send "cd [pwd]\r"
interact
```

The `spawn`, `expect`, `send`, and `interact` commands are implemented by `expect`, and `lindex` and `pwd` are built-in Tcl commands. The `spawn` command starts up `rlogin`, using a command-line argument as the name of the remote machine. The `expect` command waits for `rlogin` to output a prompt (either “`%`” or “`#`”, followed by a space), then `send` outputs a command to change the working directory, just as if a user had typed the command interactively. Finally, `interact` causes `expect` to step out of the way so that the user who invoked the `expect` script can now talk directly to `rlogin`.

`Expect` can be used for many purposes, such as a scriptable front-end to debuggers, mailers, and other programs that don’t have scripting languages of their own. The programs require no changes to be driven by expect. `Expect` is also useful for regression testing of interactive programs. `Expect` can be combined with Tk or other Tcl extensions. For example, using Tk it is possible to make a graphical front end for an existing interactive application without changing the application.

`Expect` was created by Don Libes.

2.9.2 Extended Tcl

Extended Tcl (TclX) is a library package that augments the built-in Tcl commands with many additional commands and procedures oriented towards system programming tasks. It can be used with any Tcl application. Here are a few of the most popular features of TclX:

- Access to many additional POSIX system calls and functions.
- A file scanning facility with functionality much like that of the `awk` program.

- Keyed lists, which provide functionality similar to C structures.
- Commands for manipulating times and dates and converting them to and from ASCII.
- An on-line help facility.
- Facilities for debugging, profiling, and program development.

Many of the best features of TclX are no longer part of TclX: they turned out to be so widely useful that they were incorporated into the Tcl core. Among the Tcl features pioneered by TclX are file input and output, array variables, real arithmetic and transcendental functions, auto-loading, XPG-based internationalization, and the `upvar` command.

Extended Tcl was created by Karl Lehenbauer and Mark Diekhans.

2.9.3 XF

Tk makes it relatively easy to create graphical user interfaces by writing Tcl scripts, but XF makes it even easier. XF is an interactive interface builder: you design a user interface by manipulating objects on the screen, then XF creates a Tcl script that will generate the interface you have designed (see Figure 2.4). XF provides tools for creating and configuring widgets, arranging them with Tk's geometry managers, creating event bindings, and so on. XF manipulates a live application while it is running, so the full effect of each change in the interface can be seen and tested immediately.

XF supports all of Tk's built-in widget classes and allows you to add new widget classes by writing class-specific Tcl scripts for XF to use to handle the classes. You needn't use XF exclusively: you can design part of a user interface with XF and part by writing Tcl scripts. XF supports most of the currently available extensions to Tcl and Tk, and XF itself is written in Tcl.

XF was created by Sven Delmas. It is based on an earlier interface builder for Tk called BYO, which was developed at the Victoria University of Wellington, New Zealand.

2.9.4 Distributed programming

Tcl Distributed Programming (Tcl-DP) is a collection of Tcl commands that simplify the development of distributed programs. Tcl-DP's most important feature is a *remote procedure call* facility, which allows Tcl applications to communicate by exchanging Tcl scripts. For example, the following script uses Tcl-DP to implement a trivial "id server", which returns unique identifiers in response to `GetId` requests:

```
set myId 0
proc GetId {} {
    global myId;
    set myId [expr $myId+1]
    return $myId
}
MakeRPCServer 4545
```

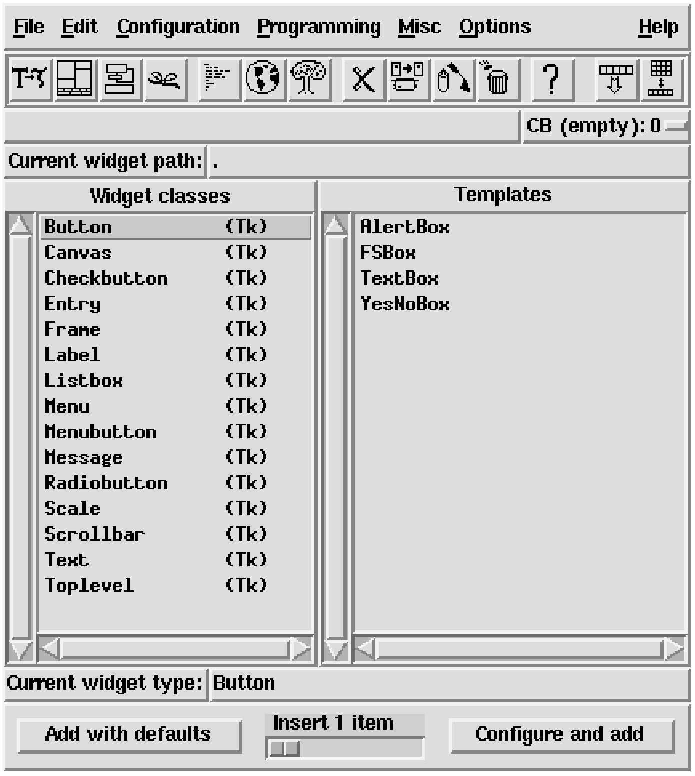


Figure 2.4. A screen dump showing the main window of XF, an interactive application builder for Tcl and Tk.

All of the code in this script except the last line is ordinary Tcl code that defines a global variable `myId` and a procedure `GetId` that increments the variable and returns its new value. The `MakeRPCServer` command is implemented by Tcl-DP; it causes the application to listen for requests on TCP socket 4545.

Other Tcl applications can communicate with this server using scripts that look like the following:

```
set server [MakeRPCClient server.company.com 4545]
RPC $server GetId
```

The first command opens a connection with the server and saves an identifier for that connection. The arguments to `MakeRPCClient` identify the server's host and the socket on which the server is listening. The `RPC` command performs a remote procedure call. Its arguments are a connection identifier and an arbitrary Tcl script. `RPC` forwards the script to the server; the server executes the script and returns its result (a new identifier in this case), which becomes the result of the `RPC` command. Any script whatosever could be substituted in place of the `GetId` command.

Tcl-DP also includes several other features, including asynchronous remote procedure calls, where the client need not wait for the call to complete, a distributed object system in which objects can be replicated in several applications and updates are automatically propagated to all copies, and a simple name service. Tcl-DP has been used for applications such as a video playback system, groupware, and games. Tcl-DP is more flexible than most remote procedure call systems because it is not based on compiled interfaces between clients and servers: it is easy in Tcl-DP to connect an existing client to a new server without recompiling or restarting the client.

Tcl-DP was created by Lawrence A. Rowe, Brian Smith, and Steve Yen.

2.9.5 Ak

Ak is an audio extension for Tcl. It is built on top of AudioFile, a network-transparent, device independent audio system that runs on a variety of platforms. Ak provides Tcl commands for file playback, recording, telephone control, and synchronization. The basic abstractions in Ak are connections to AudioFile servers, device contexts (which encapsulate the state for a particular audio device), and requests such as file playback. For example, here is a script that plays back an audio file on a remote machine:

```
audioserver remote "server.company.com:0"
remote context room -device 1
room create play "announcement-file.au"
```

The first command opens a connection to the audio server on the machine `server.company.com` and gives this connection the name `remote`. It also creates a command named `remote`, which is used to issue commands over the connection. The second command creates a context named `room`, which is associated with audio device 1 on the server, and also creates a command named `room` for communicating with the context. The last command initiates a playback of a particular audio file.

Ak implements a unique model of time that allows clients to specify precisely when audio samples are going to emerge. It also provides a mechanism to execute arbitrary Tcl scripts at specified audio times; this can be used to achieve a variety of hypermedia effects, such as displaying images or video in sync with an audio playback. When combined with Tk, Ak provides a powerful and flexible scripting system for developing multimedia applications such as tutorials and telephone inquiry systems.

Ak was created by Andrew C. Payne.

Part I:

The Tcl Language

Chapter 3
Tcl Language Syntax

In order to write Tcl scripts you must learn two things. First, you must learn the Tcl syntax, which consists of about a half-dozen rules that determine how commands are parsed. The Tcl syntax is the same for every command. Second, you must learn about the individual commands that you use in your scripts. Tcl provides about 60 built-in commands, Tk adds several dozen more, and any application based on Tcl or Tk will add a few more of its own. You'll need to know all of the syntax rules right away, but you can learn about the commands more gradually as you need them.

This chapter describes the Tcl language syntax. The remaining chapters in Part I describe the built-in Tcl commands, and Part II describes Tk's commands.

3.1 Scripts, commands, and words

A Tcl *script* consists of one or more *commands*. Commands are separated by newlines and semi-colons. For example,

```
set a 24
set b 15
```

is a script with two commands separated by a newline character. The same script could be written on a single line using a semi-colon separator:

```
set a 24; set b 15
```

Each command consists of one or more *words*, where the first word is the name of a command and additional words are arguments to that command. Words are separated by spaces and tabs. Each of the commands in the above examples has three words. There may

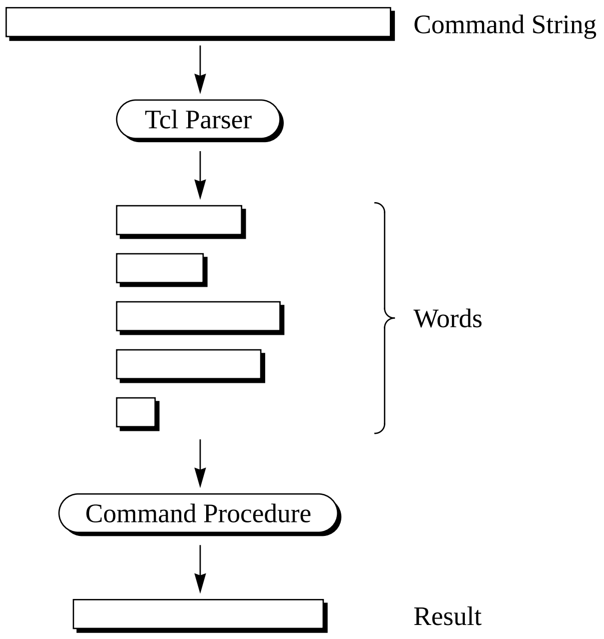


Figure 3.1. Tcl commands are evaluated in two steps. First the Tcl interpreter parses the command string into words, performing substitutions along the way. Then a command procedure processes the words to produce a result string. Each command has a separate command procedure.

be any number of words in a command, and each word may have an arbitrary string value. The white space that separates words is not part of the words, nor are the newlines and semi-colons that terminate commands

3.2 Evaluating a command

Tcl evaluates a command in two steps as shown in Figure 3.1: *parsing* and *execution*. In the parsing step the Tcl interpreter applies the rules described in this chapter to divide the command up into words and perform substitutions. Parsing is done in exactly the same way for every command. During the parsing step the Tcl interpreter does not apply any meaning to the values of the words. Tcl just performs a set of simple string operations such as replacing the characters “`$a`” with the string stored in variable `a`; Tcl does not know or care whether `a` or the resulting word is a number or the name of a widget or anything else.

In the execution step meaning is applied to the words of the command. Tcl treats the first word as a command name, checking to see if the command is defined and locating a *command procedure* to carry out its function. If the command is defined then the Tcl interpreter invokes its command procedure, passing all of the words of the command to the command procedure. The command procedure is free to interpret the words in any way that it pleases, and different commands apply very different meanings to their arguments

Note: I use the terms "word" and "argument" interchangeably to refer to the values passed to command procedures. The only difference between these two terms is that the first argument is the second word.

The following commands illustrate some of meanings that are commonly applied to arguments:

```
set a 122
```

In many cases, such as the `set` command, arguments may take any form whatsoever. The `set` command simply treats the first argument as a variable name and the second argument as a value for the variable. The command "`set 122 a`" is valid too: it creates a variable whose name is "`122`" and whose value is "`a`".

```
expr 24/3.2
```

The argument to `expr` must be an arithmetic expression that follows the rules described in Chapter 5. Several other commands also take expressions as arguments.

```
eval {set a 122}
```

The argument to `eval` is a Tcl script. `Eval` passes it to the Tcl interpreter where another round of parsing and execution occurs for the argument. Other control-flow commands such as `if` and `while` also take scripts as arguments.

```
lindex {red green blue purple} 2
```

The first argument to `lindex` is a *list* consisting of four values separated by spaces. This command will extract element 2 ("`blue`") from the list and return it. Tcl's commands for manipulating lists are described in Chapter 6.

```
string length abracadabra
```

Some commands, like `string` and the Tk widget commands, are actually several commands rolled into one. The first argument of the command selects one of several operations to perform and determines the meaning of the remaining arguments. For example "`string length`" requires one additional argument and computes its length, whereas "`string compare`" requires two additional arguments.

```
button .b -text Hello -fg red
```

The arguments starting with `-text` are option-value pairs that allow you to specify the options you care about and use default values for the others.

In writing Tcl scripts one of the most important things to remember is that the Tcl parser doesn't apply any meaning to the words of a command while it parses them. All of the above meanings are applied by individual command procedures, not by the Tcl parser. Another way of saying this is that arguments are quoted by default; if you want evaluation you must request it explicitly. This approach is similar to that of most shell languages but different than most programming languages. For example, consider the following C program:

```
x = 4;
y = x+10;
```

In the first statement C stores the integer value 4 in variable `x`. In the second statement C evaluates the expression "`x+10`", fetching the the value of variable `x` and adding 10, and stores the result in variable `y`. At the end of execution `y` has the integer value 14. If you want to use a literal string in C without evaluation you must enclose it in quotes. Now consider a similar-looking program written in Tcl:

```
set x 4
set y x+10
```

The first command assigns the *string* "`4`" to variable `x`. The value of the variable need not have any particular form. The second command simply takes the string "`x+10`" and stores it as the new value for `y`. At the end of the script y has the string value "`x+10`", not the integer value 14. In Tcl if you want evaluation you must ask for it explicitly:

```
set x 4
set y [expr $x+10]
```

Evaluation is requested twice in this example. First, the second word of the second command is enclosed in brackets, which tells the Tcl parser to evaluate the characters between the brackets as a Tcl script and use the result as the value of the word. Second, a dollar-sign has been placed before `x`. When Tcl parses the `expr` command it substitutes the value of variable `x` for the `$x`. If the dollar-sign were omitted then `expr`'s argument would contain the string "`x`", resulting in a syntax error. At the end of the script `y` has the string value "`14`", which is almost the same as in the C example.

3.3 Variable substitution

Tcl provides three forms of *substitution:* variable substitution, command substitution, and backslash substitution. Each substitution causes some of the original characters of a word to be replaced with some other value. Substitutions may occur in any word of a command, including the command name, and there may be any number of substitutions within a single word.

The first form of substitution is *variable substitution*. It is triggered by a dollar-sign character and it causes the value of a Tcl variable to be inserted into a word. For example, consider the following commands:

```
    set kgrams 20
    expr $kgrams*2.2046
⇒   44.092
```

The first command sets the value of variable `kgrams` to `20`. The second command computes the corresponding weight in pounds by multiplying the value of `kgrams` by 2.2046. It does this using variable substitution: the string `$kgrams` is replaced with the value of variable `kgrams`, so that the actual argument received by the `expr` command procedure is “`20*2.2046`”.

Variable substitution can occur anywhere within a word and any number of times as in the following command:

```
    expr $result*$base
```

The variable name consists of all of the numbers, letters, and underscores following the dollar-sign. Thus the first variable name (`result`) extends up to the `*` and the second variable name (`base`) extends to the end of the word.

The examples above show only the simplest form of variable substitution. There are two other forms of variable substitution, which are used for associative array references and to provide more explicit control over the extent of a variable name (e.g. so that there can be a letter immediately following the variable name). These other forms are discussed in Chapter 4.

3.4 Command substitution

The second form of substitution provided by Tcl is *command substitution*. Command substitution causes part or all of a command word to be replaced with the result of another Tcl command. Command substitution is invoked by enclosing a nested command in brackets:

```
    set kgrams 20
    set lbs [expr $kgrams*2.2046]
⇒   44.092
```

The characters between the brackets must constitute a valid Tcl script. The script may contain any number of commands separated by newlines or semi-colons in the usual fashion. The brackets and all of the characters in between are replaced with the result of the script. Thus in the example above the `expr` command is executed while parsing the words for `set`; its result, the string “`44.092`”, becomes the second argument to `set`. As with variable substitution, command substitution can occur anywhere in a word and there may be more than one command substitution within a single word.

3.5 Backslash substitution

The final form of substitution in Tcl is *backslash substitution*. It is used to insert special characters such as newlines into words and also to insert characters like `[` and `$` without them being treated specially by the Tcl parser. For example, consider the following command:

```
    set msg Eggs:\ \$2.18/dozen\nGasoline:\ \$1.49/gallon
⇒   Eggs: $2.18/dozen
    Gasoline: $1.49/gallon
```

There are two sequences of backslash followed by space; each of these sequences is replaced in the word by a single space and the space characters are not treated as word separators. There are also two sequences of backslash followed by dollar-sign; each of these is replaced in the word with a single dollar-sign, and the dollar signs are treated like ordinary characters (they do not trigger variable substitution). The backslash followed by `n` is replaced with a newline character

Table 3.1 lists all of the backslash sequences supported by Tcl. These include all of the sequences defined for ANSI C, such as `\t` to insert a tab character and `\xd4` to insert the character whose hexadecimal value is 0xd4. If a backslash is followed by any character not listed in the table, as in `\$` or `\[`, then the backslash is dropped from the word and the following character is included in the word as an ordinary character. This allows you to include any of the Tcl special characters in a word without the character being treated specially by the Tcl parser. The sequence `\\` will insert a single backslash into a word.

The sequence backslash-newline can be used to spread a long command across multiple lines, as in the following example:

```
pack .base .label1 .power .label2 .result \
        -side left -padx 1m -pady 2m
```

The backslash and newline, plus any leading space on the next line, are replaced by a single space character in the word. Thus the two lines together form a single command.

Note: *Backslash-newline sequences are unusual in that they are replaced in a separate preprocessing step before the Tcl interpreter parses the command. This means, for example, that the space character that replaces backslash-newline will be treated as a word separator unless it is between double-quotes or braces.*

3.6 Quoting with double-quotes

Tcl provides several ways for you to prevent the parser from giving special interpretation to characters such as `$` and semi-colon. These techniques are called *quoting*. You have already seen one form of quoting in backslash subsitution; for example, `\$` causes a dollar-sign to be inserted into a word without triggering variable substitution. In addition to backslash substitution Tcl provides two other forms of quoting: double-quotes and braces.

Backslash Sequence	Replaced By
`\a`	Audible alert (0x7)
`\b`	Backspace (0x8)
`\f`	Form feed (0xc)
`\n`	Newline (0xa)
`\r`	Carriage return (0xd)
`\t`	Tab (0x9)
`\v`	Vertical tab (0xb)
`\`*`ddd`*	Octal value given by *ddd* (one, two, or three *d*'s)
`\x`*`hh`*	Hex value given by *hh* (any number of *h*'s)
`\`*`newline space`*	A single space character.

Table 3.1. Backslash substitutions supported by Tcl. Each of the sequences in the first column is replaced by the corresponding character from the second column. If a backslash is followed by a character other than those in the first column, then the two characters are replaced by the second character.

Double-quotes disable word and command separators, while braces disable almost all special characters.

If a word is enclosed in double-quotes then spaces, tabs, newlines, and semi-colons are treated as ordinary characters within the word. The example from page 30 can be rewritten more cleanly with double-quotes as follows:

```
set msg "Eggs: \$2.18/dozen\nGasoline: \$1.49/gallon"
⇒ Eggs: $2.18/dozen
  Gasoline: $1.49/gallon
```

Note that the quotes themselves are not part of the word. The `\n` in the example could also be replaced with an actual newline character, as in

```
set msg "Eggs: \$2.18/dozen
Gasoline: \$1.49/gallon"
```

but I think the script is more readable with `\n`.

Variable substitutions, command substitutions, and backslash substitutions all occur as usual inside double-quotes. For example, the following script sets `msg` to a string containing the name of a variable, its value, and the square of its value:

```
set a 2.1
set msg "a is $a; the square of a is [expr $a*$a]"
```
⇒ *a is 2.1; the square of a is 4.41*

If you would like to include a double-quote in a word enclosed in double-quotes, then use backlash substitution:

```
set name a.out
set msg "Couldn’t open file \"$name\""
```
⇒ *Couldn’t open file "a.out"*

3.7 Quoting with braces

Braces provide a more radical form of quoting where all the special charaters lose their meaning. If a word is enclosed in braces then the characters between the braces are the value of the word, verbatim. No substitutions are performed on the word and spaces, tabs, newlines, and semi-colons are treated as ordinary characters. The example on page 30 can be rewritten with braces as follows:

```
set msg {Eggs: $2.18/dozen
Gasoline: $1.49/gallon}
```

The dollar-signs in the word do not trigger variable substitution and the newline does not act as a command separator. In this case `\n` cannot be used to insert a newline into the wod as on page 31, because the `\n` will be included in the argument as-is without triggering backslash substitution:

```
set msg {Eggs: $2.18/dozen\nGasoline: $1.49/gallon}
```
⇒ *Eggs: $2.18/dozen\nGasoline: $1.49/gallon*

One of the most important uses for braces is to *defer evaluation*. Deferred evaluation means that special characters aren’t processed immediately by the Tcl parser. Instead they will be passed to the command procedure as part of its argument and the command procedure will process the special characters itself. Braces are almost always used when passing scripts to Tcl commands, as in the following example that computes the factorial of five:

```
set result 1
set i 5
while {$i > 0} {
    set result [expr $result*$i]
    set i [expr $i-1]
}
```

The body of the `while` loop is enclosed in braces to defer substitutions. `While` passes the script back into Tcl for evaluation during each iteration of the loop and the subsitutions will be performed at that time. In this case it is important to defer the substitutions so that they are done afresh each time that `while` evaluates the loop body, rather than once-and-for-all while parsing the `while` command.

Braces nest, as in the following example:

```
proc power {base p} {
    set result 1
    while {$p > 0} {
        set result [expr $result*base]
        set p [expr $p-1]
    }
    return $result
}
```

In this case the third argument to `proc` contains two pairs of nested braces (the outermost braces are removed by the Tcl parser). The command substitution requested with "`[expr $p-1]`" will not be performed when the `proc` command is parsed, or even when the `while` command is parsed as part of executing the procedure's body, but only when `while` evaluates its second argument to execute the loop.

Note: If a brace is backslashed then it does not count in finding the matching close brace for a word enclosed in braces. The backslash will not be removed when the word is parsed.

Note: The only form of substitution that occurs between braces is for backslash-newline. As discussed in Section 3.5, backslash-newline sequences are actually removed in a pre-processing step before the command is parsed.

3.8 Comments

If the first non-blank character of a command is # then the # and all the characters following it up through the next newline are treated as a comment and discarded. Note that the hash-mark must occur in a position where Tcl is expecting the first character of a command. If a hash-mark occurs anywhere else then it is treated as an ordinary character that forms part of a command word:

```
  # This is a comment
  set a 100            # Not a comment
∅ wrong # args: should be "set varName ?newValue?"
  set b 101;           # This is a comment
⇒ 101
```

The # on the second line is not treated as a comment character because it occurs in the middle of a command. As a result the first `set` command receives 6 arguments and generates an error. The last # is treated as a comment character, since it occurs just after the command was terminated with a semi-colon.

3.9 Normal and exceptional returns

A Tcl command can terminate in several different ways. A *normal return* is the most common case; it means that the command completed successfully and the return includes a string result. Tcl also supports *exceptional returns* from commands. The most frequent form of exceptional return is an error. When an error return occurs, it means that the command could not complete its intended function. The command is aborted and any commands that follow it in the script are skipped. An error return includes a string identifying what went wrong; the string is normally displayed by the application. For example, the following `set` command generates an error because it has too many arguments:

```
   set state West Virginia
∅  wrong # args: should be "set varName ?newValue?"
```

Different commands generate errors under different conditions. For example, `expr` accepts any number of arguments but requires the arguments to have a particular syntax; it generates an error if, for example, parentheses aren't matched:

```
   expr 3 * (20+4
∅  unmatched parentheses in expression "3 * (20+4"
```

The complete exceptional return mechanism for Tcl is discussed in Chapter 9. It supports a number of exceptional returns other than errors, provides additional information about errors besides the error message mentioned above, and allows errors to be "caught" so that effects of the error can be contained within a piece of Tcl code. For now, though, all you need to know is that commands normally return string results but they sometimes return errors that cause Tcl command interpretation to be aborted.

Note: *You may also find the `errorInfo` variable useful. After an error Tcl sets `errorInfo` to hold a stack trace indicating exactly where the error occurred. You can print out this variable with the command "`set errorInfo`".*

3.10 More on substitutions

The most common difficulty for new Tcl users is understanding when substitutions do and do not occur. A typical scenario is for a user to be surprised at the behavior of a script because a substitution didn't occur when the user expected it to happen, or a substitution occurred when it wasn't expected. However, I think that you'll find Tcl's substitution mechanism to be simple and predictable if you just remember two related rules:

1. Tcl parses a command and makes substitutions in a single pass from left to right. Each character is scanned exactly once.
2. At most a single layer of substitution occurs for each character; the result of one substitution is not scanned for further substitutions.

Tcl's substitutions are simpler and more regular than you may be used to if you've programmed with UNIX shells (particularly `csh`). When new users run into problems with Tcl substitutions it is often because they have assumed a more complex model than actually exists.

For example, consider the following command:

```
    set x [format {Earnings for July: $%.2f} $earnings]
⇒   Earnings for July: $1400.26
```

The characters between the brackets are scanned exactly once, during command substitution, and the value of the `earnings` variable is substituted at that time. It is *not* the case that Tcl first scans the whole `set` command to substitute variables, then makes another pass to perform command substitution; everything happens in a single scan. The result of the `format` command is passed verbatim to `set` as its second argument without any additional scanning (for example, the dollar-sign in `format`'s result does not trigger variable substitution).

One consequence of the substitution rules is that all the word boundaries within a command are immediately evident and are not affected by substitutions. For example, consider the following script:

```
    set city "Los Angeles"
    set bigCity $city
```

The second `set` command is guaranteed to have exactly three words regardless of the value of variable `city`. In this case `city` contains a space character but the space is *not* treated as a word separator.

In some situations the single-layer-of-substitutions rule can be a hindrance rather than a help. For example, the following script is an erroneous attempt to delete all files with names ending in "`.o`":

```
    exec rm [glob *.o]
∅   rm: a.o b.o c.o nonexistent
```

The `glob` command returns a list of all file names that match the pattern "`*.o`", such as "`a.o b.o c.o`". The `exec` command then attempts to invoke the `rm` program to delete all of these files. However, the entire list of files is passed to `rm` as a single argument; `rm` reports an error because it cannot find a file named "`a.o b.o c.o`". For `rm` to work correctly the result of `glob` must be split up into multiple words.

Fortunately, it is easy to add additional layers of parsing if you want them. Remember that Tcl commands are evaluated in two phases: parsing and execution. The substitution rules apply only to the parsing phase. Once Tcl passes the words of a command to a command procedure for execution, the command procedure can do anything it likes with them. Some commands will reparse their words, for example by passing them back to the Tcl interpreter again. `Eval` is an example of such a command, and it can be used to solve the problems with `rm` above:

```
    eval exec rm [glob *.o]
```

`Eval` concatenates all of its arguments with spaces in-between and then evaluates the result as a Tcl script, at which point another round of parsing and evaluation occurs. In this example `eval` receives three arguments: "`exec`", "`rm`", and "`a.o b.o c.o`". It concatenates them to form the string "`exec rm a.o b.o c.o`". When this string is parsed as a Tcl script it yields five words; each of the file names is passed to `exec` and then to the `rm` program as a separate argument, so the files are all removed successfully. See Section 7.5 for more details on this.

One final note. It is possible to use substitutions in very complex ways but I urge you not to do so. Substitutions work best when used in very simple ways such as "`set a $b`". If you use a great many substitutions in a single command, and particularly if you use lots of backslashes, your code is unlikely to be unreadable and it's also unlikely to work reliably. In situations like these I suggest breaking up the offending command into several commands that build up the arguments in simple stages. Tcl provides several commands, such as `format` and `list`, that should make this easy to do.

Chapter 4
Variables

Tcl supports two kinds of variables: simple variables and associative arrays. This chapter describes the basic Tcl commands for manipulating variables and arrays, and it also provides a more complete description of variable substitution. See Table 4.1 for a summary of the commands discussed in this chapter.

4.1 Simple variables and the set command

A simple Tcl variable consists of two things: a name and a value. Both the name and the value may be arbitrary strings of characters. For example, it is possible to have a variable named “`xyz !# 22`” or “`March earnings: $100,472`”. In practice variable names usually start with a letter and consist of a combination of letters, digits, and underscores, since that makes it easier to use variable substitution.

Variables may be created, read, and modified with the `set` command, which takes either one or two arguments. The first argument is the name of a variable and the second, if present, is a new value for the variable:

```
   set a {Eggs: $2.18/dozen}
⇒  Eggs: $2.18/dozen
   set a
⇒  Eggs: $2.18/dozen
   set a 44
⇒  44
```

`append` *`varName value`* ?*`value`* ...?	Appends each of the *`value`* arguments to variable *`varName`*, in order. If *`varName`* doesn't exist then it is created with an empty value before appending. The return value is the new value of *`varName`*.
`incr` *`varName`* ?*`increment`*?	Adds *`increment`* to the value of variable *`varName`*. *`Increment`* and the old value of *`varName`* must both be integer strings (decimal, hexadecimal, or octal). If *`increment`* is omitted then it defaults to `1`. The new value is stored in *`varName`* as a decimal string and returned as the result of the command.
`set varName` ?*`value`*?	If *`value`* is specified, sets the value of variable *`varName`* to *`value`*. In any case the command returns the (new) value of the variable.
`unset` *`varName`* ?*`varName varName`* ...?	Deletes the variables given by the *`varName`* arguments. Returns an empty string.

Table 4.1. A summary of the basic commands for manipulating variables. Optional arguments are indicated by enclosing them in question-marks.

The first command above creates a new variable `a` if it doesn't already exist and sets its value to the character sequence "`Eggs: $2.18/dozen`". The result of the command is the new value of the variable. The second `set` command has only one argument: `a`. In this form it simply returns the current value of the variable. The third `set` command changes the value of `a` to `44` and returns that new value.

Although the final value of `a` looks like a decimal integer, it is stored as a character string. Tcl variables can be used to represent many things, such as integers, floating-point numbers, names, lists, and Tcl scripts, but they are always stored as strings. This use of a single representation for all values allows different values to be manipulated in the same way and communicated easily.

Tcl variables are created automatically when they are assigned values. Variables don't have types so there is no need for declarations.

4.2 Arrays

In addition to simple variables Tcl also provides *arrays*. An array is a collection of *elements*, each of which is a variable with its own name and value. The name of an array element has two parts: the name of the array and the name of the element within that array. Both array names and element names may be arbitrary strings. For this reason Tcl arrays are sometimes called *associative arrays* to distinguish them from arrays in other languages where the element names must be integers.

Array elements are referenced using notation like `earnings(January)` where the array name (`earnings` in this case) is followed by the element name in parentheses (`January` in this case). Arrays may be used anywhere that simple variables may be used, such as in the `set` command:

```
   set earnings(January) 87966
⇒ 87966
   set earnings(February) 95400
⇒ 95400
   set earnings(January)
⇒ 87966
```

The first command creates an array named `earnings`, if it doesn't already exist. Then it creates an element `January` within the array, if it doesn't already exist, and assigns it the value `87966`. The second command assigns a value to the `February` element of the array, and the third command returns the value of the `January` element.

4.3 Variable substitution

Chapter 3 introduced the use of `$`-notation for substituting variable values into Tcl commands. This section describes the mechanism in more detail.

Variable substitution is triggered by the presence of an unquoted `$` character in a Tcl command. The characters following the `$` are treated as a variable name, and the `$` and name are replaced in the word by the value of the variable. Tcl provides three forms of variable substitution. So far you have seen only the simplest form, which is used like this:

```
expr $a+2
```

In this form the `$` is followed by a variable name consisting of letters, digits, and underscores. The first character that is not a letter or digit or underscore ("`+`" in the example) terminates the name.

The second form of variable substitution allows array elements to be substituted. This form is like the first one except that the variable name is followed immediately by an element name enclosed in parentheses. Variable, command, and backslash substitutions are performed on the element name in the same way as a command word in double-quotes, and spaces in the element name are treated as part of the name rather than as word separators. For example, consider the following script:

```
set yearTotal 0
foreach month {Jan Feb Mar Apr May Jun Jul Aug Sep \
        Oct Nov Dec} {
    set yearTotal [expr $yearTotal+$earnings($month)]
}
```

In the `expr` command "`$earnings($month)`" is replaced with the value of an element of the array `earnings`. The element's name is given by the value of the `month` variable, which varies from iteration to iteration.

The last form of substitution is used for simple variables in places where the variable name is followed by a letter or number or underscore. For example, suppose that you wish to pass a value like "`1.5m`" to a command as an argument but the number is in a variable `size` (in Tk you might do this to specify a size in millimeters). If you try to substitute the variable value with a form like "`$sizem`" then Tcl will treat the `m` as part of the variable name. To get around this problem you can enclose the variable name in braces as in the following command:

```
.canvas configure -width ${size}m
```

You can also use braces to specify variable names containing characters other than letters or numbers or underscores.

Note: *Braces can only be used to delimit simple variables. However, they shouldn't be needed for arrays since the parentheses already indicate where the variable name ends.*

Tcl's variable substitution mechanism is only intended to handle the most common situations; there exist scenarios where none of the above forms of substitution achieves the desired effect. More complicated situations can be handled with a sequence of commands. For example, the `format` command can be used to generate a variable name of almost any imaginable form, `set` can be used to read or write the variable with that name, and command substitution can be used to substitute the value of the variable into other commands.

4.4 Removing variables: unset

The `unset` command destroys variables. It takes any number of arguments, each of which is a variable name, and removes all of the variables. Future attempts to read the variables will result in errors just as if the variables had never been set in the first place. The arguments to `unset` may be either simple variables, elements of arrays, or whole arrays, as in the following example:

```
unset a earnings(January) b
```

In this case the variables `a` and `b` are removed entirely and the `January` element of the `earnings` array is removed. The `earnings` array continues to exist after the `unset` command. If `a` or `b` is an array then all of the elements of that array are removed along with the array itself.

4.5 Multi-dimensional arrays

Tcl only implements one-dimensional arrays, but multi-dimensional arrays can be simulated by concatenating multiple indices into a single element name. The program below simulates a two-dimensional array indexed with integers:

```
set matrix(1,1) 140
set matrix(1,2) 218
set matrix(1,3) 84
set i 1
set j 2
set cell $matrix($i,$j)
```

⇒ *218*

`Matrix` is an array with three elements whose names are “`1,1`” and “`1,2`” and “`1,3`”. However, the array behaves just as if it were a two-dimensional array; in particular, variable substitution occurs while scanning the element name in the `expr` command, so that the values of `i` and `j` get combined into an appropriate element name.

4.6 The incr and append commands

`Incr` and `append` provide simple ways to change the value of a variable. `Incr` takes two arguments, which are the name of a variable and an integer; it adds the integer to the variable’s value, stores the result back into the variable as a decimal string, and returns the variable’s new value as result:

```
set x 43
incr x 12
```

⇒ *55*

The number can have either a positive or negative value. It can also be omitted, in which case it defaults to `1`:

```
set x 43
incr x
```

⇒ *44*

Both the variable’s original value and the increment must be integer strings, either in decimal, octal (indicated by a leading `0`), or hexadecimal (indicated by a leading `0x`).

The `append` command adds text to the end of a variable. It takes two arguments, which are the name of the variable and the new text to add. It appends the new text to the variable and returns the variable’s new value. The following example uses `append` to compute a table of squares:

```
set msg ""
foreach i {1 2 3 4 5} {
    append msg "$i squared is [expr $i*$i]\n"
}
set msg
```

```
⇒ 1 squared is 1
  2 squared is 4
  3 squared is 9
  4 squared is 16
  5 squared is 25
```

Neither `incr` nor `append` adds any new functionality to Tcl, since the effects of both of these commands can be achieved in other ways. However, they provide simple ways to do common operations. In addition, `append` is implemented in a fashion that avoids character copying. If you need to construct a very large string incrementally from pieces it will be much more efficient to use a command like

```
append x $piece
```

instead of a command like

```
set x "$x$piece"
```

4.7 Preview of other variable facilities

Tcl provides a number of other commands for manipulating variables. These commands will be introduced in full after you've learned more about the Tcl language, but this section contains a short preview of some of the facilities.

The `trace` command can be used to monitor a variable so that a Tcl script gets invoked whenever the variable is set or read or unset. Variable tracing is sometimes useful during debugging, and it allows you to create read-only variables. You can also use traces for *propagation* so that, for example, a database or screen display gets updated whenever a variable changes value. Variable tracing is discussed in Section 13.4.

The `array` command can be used to find out the names of all the elements in an array and to step through them one at a time (see Section 13.1). It's possible to find out what variables exist using the `info` command (see Section 13.2).

The `global` and `upvar` commands can be used by a procedure to access variables other than its own local variables. These commands are discussed in Chapter 8.

Chapter 5
Expressions

Expressions combine values (or *operands*) with *operators* to produce new values. For example, the expression “`4+2`” contains two operands, “`4`” and “`2`”, and one operator, “`+`”; it evaluates to `6`. Many Tcl commands expect one or more of their arguments to be expressions. The simplest such command is `expr`, which just evaluates its arguments as an expression and returns the result as a string:

```
   expr (8+4) * 6.2
⇒  74.4
```

Another example is `if`, which evaluates its first argument as an expression and uses the result to determine whether or not to evaluate its second argument as a Tcl script:

```
   if $x<2 then {set x 2}
```

This chapter uses the `expr` command for all of its examples, but the same syntax, substitution, and evaluation rules apply to all other uses of expressions too. See Table 5.1 for a summary of the `expr` command.

5.1 Numeric operands

Expression operands are normally integers or real numbers. Integers are usually specified in decimal, but if the first character is 0 (zero) then the number is read in octal (base 8) and if the first two characters are `0x` then the number is read in hexadecimal (base 16). For example, `335` is a decimal number, `0517` is an octal number with the same value, and `0x14f` is a hexadecimal number with the same value. `092` is not a valid integer: the leading `0` causes the number to be read in octal but `9` is not a valid octal digit. Real operands

`expr` *`arg`* ?*`arg arg`* …?	Concatenates all the *`arg`* values together (with spaces in between), evaluates the result as an expression, and returns a string corresponding to the expression's value.

Table 5.1. A summary of the `expr` command.

may be specified using most of the forms defined for ANSI C, including the following examples:

```
2.1
7.91e+16
6E4
3.
```

Note: These same forms are allowable not just in expressions but anywhere in Tcl that an integer or real value is required.

Expression operands can also be non-numeric strings. String operands are discussed in Section 5.5.

5.2 Operators and precedence

Table 5.2 lists all of the operators supported in Tcl expressions; they are similar to the operators for expressions in ANSI C. Horizontal lines separate groups of operators with the same precedence, and operators with higher precedence appear in the table above operators with lower precedence. For example, `4*2<7` evaluates to `0` because the `*` operator has higher precedence than `<`. Except in the simplest and most obvious cases you should use parentheses to indicate the way operators should be grouped; this will prevent errors by you or by others who modify your programs.

Operators with the same precedence group from left to right. For example, `10-4-3` is the same as `(10-4)-3`; it evaluates to `3`.

5.2.1 Arithmetic operators

Tcl expressions support the arithmetic operators `+`, `-`, `*`, `/`, and `%`. The `-` operator may be used either as a binary operator for subtraction, as in `4-2`, or as a unary operator for negation, as in `-(6*$i)`. The `/` operator truncates its result to an integer value if both operands are integers. `%` is the modulus operator: its result is the remainder when its first operand is divided by the second. Both of the operands for `%` must be integers.

Note: The / and % operators have a more consistent behavior in Tcl than in ANSI C. In Tcl the remainder is always positive and has an absolute value less than the absolute value of the

Syntax	Result	Operand Types
`-a`	Negative of *a*	int, float
`!a`	Logical NOT: 1 if *a* is zero, 0 otherwise	int, float
`~a`	Bit-wise complement of *a*	int
`a*b`	Multiply *a* and *b*	int, float
`a/b`	Divide *a* by *b*	int, float
`a%b`	Remainder after dividing *a* by *b*	int
`a+b`	Add *a* and *b*	int, float
`a-b`	Subtract *b* from *a*	int, float
`a<<b`	Left-shift *a* by *b* bits	int
`a>>b`	Arithmetic right-shift *a* by *b* bits	int
`a<b`	1 if *a* is less than *b*, 0 otherwise	int, float, string
`a>b`	1 if *a* is greater than *b*, 0 otherwise	int, float, string
`a<=b`	1 if *a* is less than or equal to *b*, 0 otherwise	int, float, string
`a>=b`	1 if *a* is greater than or equal to *b*, 0 otherwise	int, float, string
`a==b`	1 if *a* is equal to *b*, 0 otherwise	int, float, string
`a!=b`	1 if *a* is not equal to *b*, 0 otherwise	int, float, string
`a&b`	Bit-wise AND of *a* and *b*	int
`a^b`	Bit-wise exclusive OR of *a* and *b*	int
`a|b`	Bit-wise OR of *a* and *b*	int
`a&&b`	Logical AND: 1 if both *a* and *b* are non-zero, 0 otherwise	int, float
`a||b`	Logical OR: 1 if either *a* is non-zero or *b* is non-zero, 0 otherwise	int, float
`a?b:c`	Choice: if *a* is non-zero then *b*, else *c*	*a*: int, float

Table 5.2. Summary of the operators allowed in Tcl expressions. These operators have the same behavior as in ANSI C except that some of the operators allow string operands. Groups of operands between horizontal lines have the same precedence; higher groups have higher precedence.

divisor. ANSI C guarantees only the second property: In both ANSI C and Tcl the quotient will always have the property that `(x/y)*y + x%y` *is* `x`*., for all* `x` *and* `y`*.*

5.2.2 Relational operators

The operators < (less than), <= (less than or equal), >=(greater than or equal), > (greater than), == (equal), and != (not equal) are used for comparing two values. Each operator produces a result of 1 (true) if its operands meet the condition and 0 (false) if they don't.

5.2.3 Logical operators

The logical operators &&, ||, and ! are typically used for combining the results of relational operators, as in the expression

```
($x > 4) && ($x < 10)
```

Each operator produces a 0 or 1 result. && (logical "and") produces a 1 result if both its operands are non-zero, || (logical "or") produces a 1 result if either of its operands is non-zero, and ! ("not") produces a 1 result if its single operand is zero.

In Tcl, as in ANSI C, a zero value is treated as false and anything other than zero is treated as true. Whenever Tcl generates a true/false value it uses 1 for true and 0 for false.

5.2.4 Bitwise operators

Tcl provides six operators that manipulate the individual bits of integers: &, |, ^, <<, >>, and ~. These operators require their operands to be integers. The &, |, and ^ operators perform bitwise and, or, and exclusive or: each bit of the result is generated by applying the given operation to the corresponding bits of the left and right operands. Note that & and | do not always produce the same result as && and ||:

```
   expr 8&&2
⇒  1
   expr 8&2
⇒  0
```

The operators << and >> use the right operand as a shift count and produce a result consisting of the left operand shifted left or right by that number of bits. During left shifts zeros are shifted into the low-order bits. Right shifting is always "arithmetic right shift", meaning that it shifts in zeroes for positive numbers and ones for negative numbers. This behavior is different from right-shifting in ANSI C, which is machine-dependent.

The ~ operand ("ones complement") takes only a single operand and produces a result whose bits are the opposite of those in the operand: zeroes replace ones and vice versa.

5.2.5 Choice operator

The ternary operator ?: may be used to select one of two results:

```
expr {($a < $b) ? $a : $b}
```

This expression returns the smaller of `$a` and `$b`. The choice operator checks the value of its first operand for truth or falsehood. If it is true (non-zero) then the argument following the `?` is evaluated and becomes the result; if the first operand is false (zero) then the third operand is evaluated and becomes the result. Only one of the second and third arguments is evaluated.

5.3 Math functions

Tcl expressions support a number of mathematical functions such as `sin` and `exp`. Math functions are invoked using standard functional notation:

```
expr 2*sin($x)
expr hypot($x, $y) + $z
```

The arguments to math functions may be arbitrary expressions, and multiple arguments are separated by commas. See Table 5.3 for a list of all the built-in functions.

5.4 Substitutions

Substitutions can occur in two ways for expression operands. The first way is through the normal Tcl parser mechanisms, as in the following command:

```
expr 2*sin($x)
```

In this case the Tcl parser substitutes the value of variable `x` before executing the command, so the first argument to `expr` will have a value such as "`2*sin(0.8)`". The second way is through the expression evaluator, which performs an additional round of variable and command substitution on the expression while evaluating it. For example, consider the command:

```
expr {2*sin($x)}
```

In this case the braces prevent the Tcl parser from substituting the value of `x`, so the argument to `expr` is "`2*sin($x)`". When the expression evaluator encounters the dollar-sign it performs variable substitution itself, using the value of variable `x` as the argument to `sin`.

Having two layers of substitution doesn't usually make any difference for the `expr` command, but it is vitally important for other commands like `while` that evaluate an expression repeatedly and expect to get different results each time. For example, consider the following script that raises a base to a power:

```
set result 1
while {$power>0} {
    set result [expr $result*$base]
    incr power -1
}
```

Function	Result
`abs(`*x*`)`	Absolute value of *x*.
`acos(`*x*`)`	Arc cosine of *x*, in the range 0 to π.
`asin(`*x*`)`	Arc sine of *x*, in the range -π/2 to π/2.
`atan(`*x*`)`	Arc tangent of *x*, in the range -π/2 to π/2.
`atan2(`*x*`,`*y*`)`	Arc tangent of *x*/*y*, in the range -π/2 to π/2.
`ceil(`*x*`)`	Smallest integer not less than *x*.
`cos(`*x*`)`	Cosine of *x* (*x* in radians).
`cosh(`*x*`)`	Hyperbolic cosine of *x*.
`double(`*i*`)`	Real value equal to integer *i*.
`exp(`*x*`)`	*e* raised to the power *x*.
`floor(`*x*`)`	Largest integer not greater than *x*.
`fmod(`*x*`,`*y*`)`	Floating-point remainder of *x* divided by *y*.
`hypot(`*x*`,`*y*`)`	Square root of ($x^2 + y^2$).
`int(`*x*`)`	Integer value produced by truncating *x*.
`log(`*x*`)`	Natural logarithm of *x*.
`log10(`*x*`)`	Base 10 logarithm of *x*.
`pow(`*x*`,`*y*`)`	*x* raised to the power *y*.
`round(`*x*`)`	Integer value produced by rounding *x*.
`sin(`*x*`)`	Sine of *x* (*x* in radians).
`sinh(`*x*`)`	Hyperbolic sine of *x*.
`sqrt(`*x*`)`	Square root of *x*.
`tan(`*x*`)`	Tangent of *x* (*x* in radians).
`tanh(`*x*`)`	Hyperbolic tangent of *x*.

Table 5.3. The mathematical functions supported in Tcl expressions. In most cases the functions have the same behavior as the ANSI C library procedures with the same names.

The expression “`$power>0`” gets evaluated by `while` at the beginning of each iteration to decide whether or not to terminate the loop. It is essential that the expression evaluator use a new value of `power` each time. If the variable substitution were performed while parsing the `while` command, for example “`while $power>0` ...”, then `while`’s argument would be a constant expression such as “`5>0`”; either the loop would never execute or it would execute forever.

Note: When the expression evaluator performs variable or command substitution the value substituted must be an integer or real number (or a string, as described below). It cannot be an arbitrary expression.

5.5 String manipulation

Unlike expressions in ANSI C, Tcl expressions allow som simple string operations, as in the following command:

```
if {$x == "New York"} {
...
}
```

In this example the expression evaluator compares the value of variable `x` to the string "`New York`" using string comparison; the body of the `if` will be executed if they are identical. In order to specify a string operand you must either enclose it in quotes or braces or use variable or command substitution. It is important that the expression in the above example is enclosed in braces so that the expression evaluator substitutes the value of `x`; if the braces are left out then the argument to `if` will be a string like

```
Los Angeles == "New York"
```

The expression parser will not be able to parse "`Los`" (it isn't a number, it doesn't make sense as a function name, and it can't be interpreted as a string because it isn't delimited) so a syntax error will occur.

If a string is enclosed in quotes then the expression evaluator performs command, variable, and backslash substitution on the characters between the quotes. If a string is enclosed in braces then no substitutions are performed. Braces nest for strings in expressions in the same way that they nest for words of a command.

The only operators that allow string operands are <, >, <=, >=, ==, and !=. For all other operators the operands must be numeric. For operators like < the strings are compared lexicographically using the system's `strcmp` library function; the sorting order may vary from system to system.

5.6 Types and conversions

Tcl evaluates expressions numerically whenever possible. String operations are only performed for the relational operators and only if one or both of the operands doesn't make sense as a number. Most operators permit either integer or real operands but a few, such as << and &, allow only integers.

If the operands for an operator have different types then Tcl automatically converts one of them to the type of the other. If one operand is an integer and the other is a real then the integer operand is converted to real. If one operand is a non-numeric string and the other is an integer or real then the integer or real operand is converted to a string. The result of an operation always has the same type as the operands except for relational operators like `<`, which always produce 0/1 integer results. You can use the math function `double` to explicitly promote an integer to a real, and `int` and `round` to convert a real value back to integer by truncation or rounding.

5.7 Precision

During expression evaluation Tcl represents integers internally with the C type `int`, which provides at least 32 bits of precision on most machines. Real numbers are represented with with the C type `double`, which is usually represented with 64-bit values (about 15 decimal digits of precision) using the IEEE Floating Point Standard.

Numbers are kept in internal form throughout the evaluation of an expression and are only converted back to strings when necessary, such as when `expr` returns its result. Integers are converted to signed decimal strings without any loss of precision. When a real value is converted to a string only six significant digits are retained by default:

```
expr 1.11111111 + 1.11111111
⇒ 2.22222
```

If you would like more significant digits to be retained when real values are converted to strings you can set the `tcl_precision` global variable with the desired number of significant digits:

```
set tcl_precision 12
expr 1.11111111 + 1.11111111
⇒ 2.22222222
```

The `tcl_precision` variable is used not just for the `expr` command but anywhere that a Tcl application converts a real number to a sting.

Note: *If you set `tcl_precision` to 17 on a machine that uses IEEE floating point, you will guarantee that string conversions do not lose information: if an expression result is converted to a string and then later used in a different expression, the internal form after conversion back from the string will be identical to the internal form before converting to the string.*

Chapter 6
Lists

Lists are used in Tcl to deal with collections of things, such as all the users in a group or all the files in a directory or all the options for a widget. Lists allow you to collect together any number of values in one place, pass around the collection as a single entity, and later get the component values back again. A list is an ordered collection of *elements* where each element can have any string value, such as a number, a person’s name, the name of a window, or a word of a Tcl command. Lists are represented as strings with a particular structure; this means that you can store lists in variables, type them to commands, and nest them as elements of other lists.

This chapter describes the structure of lists and presents a dozen basic commands for manipulating lists. The commands perform operations like creating lists, inserting and extracting elements, and searching for particular elements (see Table 6.1 for a summary). There are other Tcl commands besides those described in this chapter that take lists as arguments or return them as results; these other commands will be described in later chapters.

6.1 Basic list structure and the lindex command

In its simplest form a list is a string containing any number of elements separated by spaces or tabs. For example, the string

```
John Anne Mary Jim
```

`concat` *`list`* ?*`list`* ...?	Joins multiple lists into a single list (each element of each *`list`* becomes an element of the result list) and returns the new list.
`join` *`list`* ?*`joinString`*?	Concatenates list elements together with *`joinString`* as separator and returns the result.
`lappend` *`varName value`* ?*`value`* ...?	Appends each *`value`* to variable *`varName`* as a list element and returns the new value of the variable. Creates the variable if it doesn't already exist.
`lindex` *`list index`*	Returns the *`index`*'th element from *`list`*.
`linsert` *`list index value`* ?*`value`* ...?	Returns a new list formed by inserting all of the *`value`* arguments as list elements before *`index`*'th element of *`list`*.
`list` *`value`* ?*`value`* ...?	Returns a list whose elements are the *`value`* arguments.
`llength` *`list`*	Returns the number of elements in *`list`*.
`lrange` *`list first last`*	Returns a list consisting of elements *`first`* through *`last`* of *`list`*. If *`last`* is `end` then it selects all elements up to the end of the list.
`lreplace` *`list first last`* ?*`value value`* ...?	Returns a new list formed by replacing elements *`first`* through *`last`* of *`list`* with zero or more new elements, each formed from one *`value`* argument.
`lsearch` ?`-exact`? ?`-glob`? ?`-regexp`? *`list pattern`*	Returns the index of the first element in *`list`* that matches *`pattern`* or `-1` if none. The optional switch selects a pattern-matching technique (default: `-glob`).
`lsort` ?`-ascii`? ?`-integer`? ?`-real`? ?`-command` *`command`*? `\` ?`-increasing`? ?`-decreasing`? *`list`*	Returns a new list formed by sorting the elements of *`list`*. The switches determine the comparison function and sorted order (default: `-ascii -increasing`).
`split` *`string`* ?*`splitChars`*?	Returns a list formed by splitting *`string`* at instances of *`splitChars`* and turning the characters between these instances into list elements.

Table 6.1. A summary of the list-related commands in Tcl.

is a list with four elements. There can be any number of elements in a list, and each element can be an arbitrary string. In the simple form above, elements cannot contain spaces, but there is additional list syntax that allows spaces within elements (see below).

The `lindex` command extracts an element from a list:

```
  lindex {John Anne Mary Jim} 1
⇒ Anne
```

`Lindex` takes two arguments, a list and an index, and returns the selected element of the list. An index of `0` corresponds to the first element of the list, `1` corresponds to the second element, and so on. If the index is outside the range of the list then an empty string is returned.

When a list is entered in a Tcl command the list is usually enclosed in braces, as in the above example. The braces are not part of the list; they are needed on the command line to pass the entire list to the command as a single word. When lists are stored in variables or printed out, there are no braces around them:

```
  set x {John Anne Mary Jim}
⇒ John Anne Mary Jim
```

Curly braces and backslashes within list elements are handled by the list commands in the same way that the Tcl command parser treats them in words. This means that you can enclose a list element in braces if it contains spaces, and you can use backslash substitution to get special characters such as braces into list elements. Braces are often used to nest lists within lists, as in the following example:

```
  lindex {a b {c d e} f} 2
⇒ c d e
```

In this case element 2 of the list is itself a list with three elements. There is no limit on how deeply lists may be nested.

6.2 Creating lists: concat, list, and llength

Tcl provides two commands that combine strings together to produce lists: `concat` and `list`. Each of these commands accepts an arbitrary number of arguments, and each produces a list as a result. However, they differ in the way they combine their arguments. The `concat` command takes one or more lists as arguments and joins all of the elements of the argument lists together into a single large list:

```
  concat {a b c} {d e} f {g h i}
⇒ a b c d e f g h i
```

`Concat` expects its arguments to have proper list structure; if the arguments are not well-formed lists then the result may not be a well-formed list either. In fact, all that `concat` does is to concatenate its argument strings into one large string with space characters between the arguments. The same effect as `concat` can be achieved using double-quotes:

```
   set x {a b c}
   set y {d e}
   set z [concat $x $y]
⇒ a b c d e
   set z "$x $y"
⇒ a b c d e
```

The `list` command joins its arguments together so that each argument becomes a distinct element of the resulting list:

```
   list {a b c} {d e} f {g h i}
⇒ {a b c} {d e} f {g h i}
```

In this case, the result list contains only four elements. The `list` command will always produce a list with proper structure, regardless of the structure of its arguments (it adds braces or backslashes as needed), and the `lindex` command can always be used to extract the original elements of a list created with `list`. The arguments to `list` need not themselves be well-formed lists.

The `llength` command returns the number of elements in a list:

```
   llength {{a b c} {d e} f {g h i}}
⇒ 4
   llength a
⇒ 1
   llength {}
⇒ 0
```

As you can see from the examples, a simple string like “a” is a proper list with one element and an empty string is a proper list with zero elements.

6.3 Modifying lists: linsert, lreplace, lrange, and lappend

The `linsert` command forms a new list by adding one or more elements to an existing list:

```
   set x {a b {c d} e}
⇒ a b {c d} e
   linsert $x 2 X Y Z
⇒ a b X Y Z {c d} e
   linsert $x 0 {X Y} Z
⇒ {X Y} Z a b {c d} e
```

`Linsert` takes three or more arguments. The first is a list, the second is the index of an element within that list, and the third and additional arguments are new elements to insert into the list. The return value from `linsert` is a list formed by inserting the new elements just before the element indicated by the index. If the index is zero then the new elements go at the beginning of the list; if it is one then the new elements go after the first element in the old list; and so on. If the index is greater than or equal to the number of elements in the original list then the new elements are inserted at the end of the list.

The `lreplace` command deletes elements from a list and optionally adds new elements in their place. It takes three or more arguments. The first argument is a list and the second and third arguments give the indices of the first and last elements to be deleted. If only three arguments are specified then the result is a new list produced by deleting the given range of elements from the original list:

```
    lreplace {a b {c d} e} 3 3
 ⇒  a b {c d}
```

If additional arguments are specified to `lreplace` as in the example below, then they are inserted into the list in place of the elements that were deleted.

```
    lreplace {a b {c d} e} 1 2 {W X} Y Z
 ⇒  a {W X} Y Z e
```

The `lrange` command extracts a range of elements from a list. It takes as arguments a list and two indices and it returns a new list consisting of the range of elements that lie between the two indices (inclusive):

```
    set x {a b {c d} e}
 ⇒  a b {c d} e
    lrange $x 1 3
 ⇒  b {c d} e
    lrange $x 0 1
 ⇒  a b
```

The `lappend` command provides an efficient way to append new elements to a list stored in a variable. It takes as arguments the name of a variable and any number of additional arguments. Each of the additional arguments is appended to the variable's value as a new list element and `lappend` returns the variable's new value:

```
    set x {a b {c d} e}
 ⇒  a b {c d} e
    lappend x XX {YY ZZ}
 ⇒  a b {c d} e XX {YY ZZ}
    set x
 ⇒  a b {c d} e XX {YY ZZ}
```

`Lappend` is similar to `append` except that it enforces proper list structure. As with append, it isn't strictly necessary. For example, the command

```
    lappend x $a $b $c
```

could be written instead as

```
    set x "$x [list $a $b $c]"
```

However, as with `append`, `lappend` is implemented in a way that avoids string copies. For large lists this can make a big difference in performance.

6.4 Searching lists: lsearch

The `lsearch` command searches a list for an element with a particular value. It takes two arguments, the first of which is a list and second of which is a pattern:

```
   set x {John Anne Mary Jim}
   lsearch $x Mary
⇒  2
   lsearch $x Phil
⇒  -1
```

`Lsearch` returns the index of the first element in the list that matches the pattern, or `-1` if there was no matching element.

One of three different pattern matching techniques can be selected by specifying one of the switches `-exact`, `-glob`, and `-regexp` before the list argument:

```
   lsearch -glob $x A*
⇒  1
```

The `-glob` switch causes matching to occur with the rules of the `string match` command described in Section 10.1. A `-regexp` switch causes matching to occur with regular expression rules as described in Section 10.2, and `-exact` insists on an exact match only. If no switch is specified then `-glob` is assumed by default.

6.5 Sorting lists: lsort

The `lsort` command takes a list as argument and returns a new list with the same elements, but sorted in increasing lexicographic order:

```
   lsort {John Anne Mary Jim}
⇒  Anne Jim John Mary
```

You can precede the list with any of several switches to control the sort. For example, `-decreasing` specifies that the result should have the “largest” element first and `-integer` specifies that the elements should be treated as integers and sorted according to integer value:

```
   lsort -decreasing {John Anne Mary Jim}
⇒  Mary John Jim Anne
   lsort {10 1 2}
⇒  1 10 2
```

```
    lsort -integer {10 1 2}
⇒  1 2 10
```

You can use the `-command` option to specify your own sorting function (see the reference documentation for details).

6.6 Converting between strings and lists: split and join

The `split` command breaks up a string into component pieces so that you can process the pieces independently. It creates a list whose elements are the pieces, so that you can use any of the list commands to process the pieces. For example, suppose a variable contains a UNIX file name with components separated by slashes, and you want to convert it to a list with one element for each component:

```
    set x a/b/c
    set y /usr/include/sys/types.h
    split $x /
⇒  a b c
    split $y /
⇒  {} usr include sys types.h
```

The first argument to `split` is the string to be split up and the second argument contains one or more *split characters*. `Split` locates all instances of any of the split characters in the string. It then creates a list whose elements consist of the substrings between the split characters. The ends of the string are also treated as split characters. If there are consecutive split characters or if the string starts or ends with a split character as in the second example, then empty elements are generated in the result list. The split characters themselves are discarded. Several split characters can be specified, as in the following example:

```
    split xbaybz ab
⇒  x {} y z
```

If an empty string is specified for the split characters then each character of the string is made into a separate list element:

```
    split {a b c} {}
⇒  a { } b { } c
```

The `join` command is approximately the inverse of `split`. It concatenates list elements together with a given separator string between them:

```
    join {{} usr include sys types.h} /
⇒  /usr/include/sys/types.h
    set x {24 112 5}
    expr [join $x +]
⇒  141
```

`Join` takes two arguments: a list and a separator string. It extracts all of the elements from the list and concatenates them together with the separator string between each pair of elements. The separator string can contain any number of characters, including zero. In the first example above a file name is generated by joining the list elements with “`/`”. In the second example a Tcl expression is generated by joining the list elements with “`+`”.

One of the most common uses for `split` and `join` is for dealing with file names as shown above. Another common use is for splitting up text into lines by using newline as the split character.

6.7 Lists and commands

There is a very important relationship between lists and commands in Tcl. Any proper list is also a well-formed Tcl command. If a list is evaluated as a Tcl script then it will consist of a single command whose words are the list elements. In other words, the Tcl parser will perform no substitutions whatsoever: it will simply extract the list elements with each element becoming one word of the command. This property is very important because it allows you to generate Tcl commands that are guaranteed to parse in a particular fashion even if some of the command’s words contain special characters like spaces or `$`.

For example, suppose you are creating a button widget in Tk, and when the user clicks on the widget you would like to reset a variable to a particular value. You might create such a widget with a command like this:

```
button .b -text "Reset" -command {set x 0}
```

The Tcl script “`set x 0`” will be evaluated whenever the user clicks on the button. Now suppose that the value to be stored in the variable is not constant, but instead is computed just before the `button` command and must be taken from a variable `initValue`. Furthermore, suppose that `initValue` could contain any string whatsoever. You might rewrite the command as

```
button .b -text "Reset" -command {set x $initValue}
```

The script “`set x $initValue`” will be evaluated when the user clicks on the button. However, this will use the value of `initValue` at the time the user clicks on the button, which may not be the same as the value when the button was created. For example, the same variable might be used to create several buttons, each with a different intended reset value.

To solve this problem you must generate a Tcl command that contains the *value* of the `initValue` variable, not its name, and use this as part of the `-command` option for the `button` command. Unfortunately, a simple approach like

```
button .b -text "Reset" -command "set x $initValue"
```

will not work in general. If the value of `initValue` is something simple like `47` then this will work fine: the resulting command will be “`set x 47`”, which will produce the desired result. However, what if `initValue` contains “`New York`”? In this case the resulting command will be “`set x New York`”, which has four words; `set` will generate an error because there are too many arguments. Even worse, what if `initValue` contains special characters like “`$`” or “`[`”? These characters could cause unwanted substitutions to occur when the command is evaluated.

The only solution that is guaranteed to work for any value of `initValue` is to use list commands to generate the command, as in the following example:

```
button .b -text "Reset" -command [list set x $initValue]
```

The result of the `list` command is a Tcl command whose first word will be `set`, whose second word will be `x`, and whose third word will be the value of `initValue`. The command will always produce the desired result: whatever value is stored in `initValue` at the time `button` is invoked will be stored in `x` when the widget is invoked. For example, suppose that the value of `initValue` is “`New York`”. The command generated by `list` will be “`set x {New York}`”, which will parse and execute correctly. Any of the Tcl special characters will also be handled correctly by `list`:

```
   set initValue {Earnings: $1410.13}
   list set x $initValue
⇒ set x {Earnings: $1410.13}
   set initValue "{ \\"
   list set x $initValue
⇒ set x \{\ \\
```

Chapter 7 Control Flow

This chapter describes the Tcl commands for controlling the flow of execution in a script. Tcl's control flow commands are similar to the control flow statements in the C programming language and `csh`, including `if`, `while`, `for`, `foreach`, `switch`, and `eval`. Table 7.1 summarizes these commands.

7.1 The if command

The `if` command evaluates an expression, tests its result, and conditionally executes a script based on the result. For example, consider the following command, which sets variable `x` to zero if it was previously negative:

```
if {$x < 0} {
    set x 0
}
```

In this case `if` receives two arguments. The first is an expression and the second is a Tcl script. The expression can have any of the forms for expressions described in Chapter 5. The `if` command evaluates the expression and tests the result; if it is non-zero then `if` evaluates the Tcl script. If the value is zero then `if` returns without taking any further action.

`If` commands can also include one or more `elseif` clauses with additional tests and scripts, plus a final `else` clause with a script to evaluate if no test succeeds:

break	Terminates the innermost nested looping command.
continue	Terminates the current iteration of the innermost looping command and goes on to the next iteration of that command.
eval *arg* ?*arg arg* ...?	Concatenates all of the *arg*'s with separator spaces, then evaluates the result as a Tcl script and returns its result.
for *init test reinit body*	Executes *init* as a Tcl script. Then evaluates *test* as an expression. If it evaluates to non-zero then executes *body* as a Tcl script, executes *reinit* as a Tcl script, and re-evaluates *test* as an expression. Repeats until *test* evaluates to zero. Returns an empty string.
foreach *varName list body*	For each element of *list*, in order, set variable *varName* to that value and execute *body* as a Tcl script. Returns an empty string. *List* must be a valid Tcl list.
if *test1* ?then? *body1* ?elseif *test2* ?then? *body2* elseif ...? \ ?else? ?*bodyn*?	Evaluates *test* as an expression. If its value is non-zero then executes *body1* as a Tcl script and returns its value . Otherwise evaluates *test2* as an expression; if its value is non-zero then executes *body2* as a script and returns its value. If no test succeeds then executes *bodyn* as a Tcl script and returns its result.
source *fileName*	Reads the file whose name is *fileName* and evaluates its contents as a Tcl script. Returns the result of the script.
switch ?*options*? *string pattern body* ?*pattern body* ...? switch ?*options*? *string* {*pattern body* ?*pattern body* ...?}	Matches *string* against each *pattern* in order until a match is found, then executes the *body* corresponding to the matching *pattern*. If the last `pattern` is `default` then it matches anything. Returns the result of the *body* executed, or an empty string if no pattern matches. *Options* may be any of `-exact`, `-glob`, `-regexp`, or `--`.
while *test body*	Evaluates *test* as an expression. If its value is non-zero then executes *body* as a Tcl script and re-evaluates *test*. Repeats until *test* evaluates to zero. Returns an empty string.

Table 7.1. A summary of the Tcl commands for controlling the flow of execution.

```
if {$x < 0} {
    ...
} elseif {$x == 0} {
    ...
} elseif {$x == 1} {
    ...
} else {
    ...
}
```

This command will execute one of the four scripts indicated by "..." depending on the value of `x`. The result of the command will be the result of whichever script is executed. If an `if` command has no `else` clause and none of its tests succeeds then it returns an empty string.

The argument `else` is an optional "noise word". It is also legal to have `then` noise words after any of the expressions to test. The `elseif` words are not optional: they are needed to distinguish `elseif` clauses from `else` clauses.

Remember that the expressions and scripts for `if` and other control flow commands are parsed using the same approach as all arguments to all Tcl commands. It is almost always a good idea to enclose the expressions and scripts in braces so that substitutions are deferred until the the command is executed. Furthermore, each open brace must be on the same line as the preceding word or else the newline will be treated as a command separator. The following script is parsed as two commands, which probably isn't the desired result:

```
if {$x < 0}
{
    set x 0
}
```

7.2 Looping commands: while, for, and foreach

Tcl provides three commands for looping: `while`, `for`, and `foreach`. `While` and `for` are similar to the corresponding C statements and `foreach` is similar to the corresponding feature of the `csh` shell. Each of these commands executes a nested script over and over again; they differ in the kinds of setup they do before each iteration and in the ways they decide to terminate the loop.

The `while` command takes two arguments: an expression and a Tcl script. It evaluates the expression and if the result is non-zero then it executes the Tcl script. This process repeats over and over until the expression evaluates to zero, at which point the `while` command terminates and returns an empty string. For example, the script below copies a list from variable `b` to variable `a`, reversing the order of the elements along the way:

```
set b ""
set i [expr [llength $a] -1]
while {$i >= 0} {
    lappend b [lindex $a $i]
    incr i -1
}
```

The `for` command is similar to `while` except that it provides more explicit loop control. The program to reverse the elements of a list can be rewritten using `for` as follows:

```
set b ""
for {set i [expr [llength $a]-1]} {$i >= 0} {incr i -1} {
    lappend b [lindex $a $i]
}
```

The first argument to `for` is an initialization script, the second is an expression that determines when to terminate the loop, the third is a reinitialization script, which is evaluated after each execution of the loop body before evaluating the test again, and the fourth argument is a script that forms the body of the loop. `For` executes its first argument (the initialization script) as a Tcl command, then evaluates the expression. If the expression evaluates to non-zero, then `for` executes the body followed by the reinitialization script and re-evaluates the expression. It repeats this sequence over and over again until the expression evaluates to zero. If the expression evaluates to zero on the first test then neither the body script nor the reinitialization script is ever executed. Like `while`, `for` returns an empty string as result.

`For` and `while` are equivalent in that anything you can write using one command you can also write using the other command. However, `for` has the advantage of placing all of the loop control information in one place where it is easy to see. Typically the initialization, test, and re-initialization arguments are used to select a set of elements to operate on (integer indices in the above example) and the body of the loop carries out the operations on the chosen elements. This clean separation between element selection and action makes `for` loops easier to understand and debug. Of course, there are some situations where a clean separation between selection and action is not possible, and in these cases a `while` loop may make more sense.

The `foreach` command iterates over all of the elements of a list. For example, the following script provides yet another implementation of list reversal:

```
set b "";
foreach i $a {
    set b [linsert $b 0 $i]
}
```

`Foreach` takes three arguments. The first is the name of a variable, the second is a list, and the third is a Tcl script that forms the body of the loop. `Foreach` will execute the body script once for each element of the list, in order. Before executing the body in each iteration, `foreach` sets the variable to hold the next element of the list. Thus if variable `a` has the value “`first second third`” in the above example, the body will be executed three times. In the first iteration `i` will have the value `first`, in the second iteration it will have the value `second`, and in the third iteration it will have the value `third`. At the end of the loop, b will have the value “`third second first`” and `i` will have the value “`third`”. As with the other looping commands, `foreach` always returns an empty string.

7.3 Loop control: break and continue

Tcl provides two commands that can be used to abort part or all of a looping command: `break` and `continue`. These commands have the same behavior as the corresponding statements in C. Neither takes any arguments. The `break` command causes the innermost enclosing looping command to terminate immediately. For example, suppose that in the list reversal example above it is desired to stop as soon as an element equal to `ZZZ` is found in the source list. In other words, the result list should consist of a reversal of only those source elements up to (but not including) a `ZZZ` element. This can be accomplished with `break` as follows:

```
set b "";
foreach i $a {
    if {$i == "ZZZ"} break
    set b [linsert $b 0 $i]
}
```

The `continue` command causes only the current iteration of the innermost loop to be terminated; the loop continues with its next iteration. In the case of `while`, this means skipping out of the body and re-evaluating the expression that determines when the loop terminates; in `for` loops, the re-initialization script is executed before re-evaluating the termination condition. For example, the following program is another variant of the list reversal example, where `ZZZ` elements are simply skipped without copying them to the result list:

```
set b "";
foreach i $a {
    if {$i == "ZZZ"} continue
    set b [linsert $b 0 $i]
}
```

7.4 The switch command

The `switch` command tests a value against a number of patterns and executes one of several Tcl scripts depending on which pattern matched. The same effect as `switch` can be achieved with an `if` command that has lots of `elseif` clauses, but `switch` provides a more compact encoding. Tcl’s `switch` command has two forms; here is an example of the first form:

```
switch $x {a {incr t1} b {incr t2} c {incr t3}}
```

The first argument to `switch` is the value to be tested (the contents of variable `x` in the example). The second argument is a list containing one or more pairs of elements. The first argument in each pair is a pattern to compare against the value, and the second is a script to execute if the pattern matches. The `switch` command steps through these pairs in order, comparing the pattern against the value. As soon as it finds a match it executes the corresponding script and returns the value of that script as its value. If no pattern matches then no script is executed and `switch` returns an empty string. This particular command increments variable `t1` if `x` has the value a, `t2` if `x` has the value `b`, `t3` if `x` has the value `c`, and does nothing otherwise.

The second form spreads the patterns and scripts out into separate arguments rather than combining them all into one list:

```
switch $x a {incr t1} b {incr t2} c {incr t3}
```

This form has the advantage that you can invoke substitutions on the pattern arguments more easily, but most people prefer the first form because you can easily spread the patterns and scripts across multiple lines like this:

```
switch $x {
    a {incr t1}
    b {incr t2}
    c {incr t3}
}
```

The outer braces keep the newlines from being treated as command separators. With the second form you would have to use backslash-newlines like this:

```
switch $x \
    a {incr t1} \
    b {incr t2} \
    c {incr t3} \
}
```

The `switch` command supports three forms of pattern matching. You can precede the value to test with a switch that selects the form you want: `-exact` selects exact comparison, `-glob` selects pattern matching as in the `string match` command (see Section 10.1 for details) and `-regexp` selects regular-expression matching as described in Section 10.2. The default is `-glob`.

If the last pattern in a `switch` command is `default` then it matches any value. Its script will thus be executed if no other patterns match. For example, the script below will examine a list and produce three counters. The first, `t1`, counts the number of elements in the list that contain an `a`. The second, `t2`, counts the number of elements that are unsigned decimal integers. The third, `t3`, counts all of the other elements:

```
set t1 0
set t2 0
set t3 0
foreach i $x {
    switch -regexp $i in {
        a           {incr t1}
        ^[0-9]*$    {incr t2}
        default     {incr t3}
    }
}
```

If a script in a `switch` command is “`-`” then `switch` uses the script for the next pattern instead. This makes it easy to have several patterns that all execute the same script, as in the following example:

```
switch $x {
    a -
    b -
    c {incr t1}
    d {incr t2}
}
```

This script increments variable `t1` if `x` is `a`, `b`, or `c` and it increments `t2` if `x` is `d`.

7.5 Eval

`Eval` is a general-purpose building block for creating and executing Tcl scripts. It accepts any number of arguments, concatenates them together with separator spaces, and then executes the result as a Tcl script. One use of `eval` is for generating commands, saving them in variables, and then later evaluating the variables as Tcl scripts. For example, the script

```
set cmd "set a 0"
...
eval $cmd
```

clears variable `a` to `0` when the `eval` command is invoked.

Perhaps the most important use for `eval` is to force another level of parsing. The Tcl parser performs only level of parsing and substitution when parsing a command; the results of one substitution are not reparsed for other substitutions. However, there are occasionally times when another level of parsing is desirable, and `eval` provides the mechanism to achieve this. For example, suppose that a variable `vars` contains a list of variables and that you wish to unset each of these variables. One solution is to use the following script:

```
foreach i $vars {
    unset $i
}
```

This script will work just fine, but the `unset` command takes any number of arguments so it should be possible to unset all of the variables with a single command. Unfortunately the following script will not work:

```
unset $vars
```

The problem with this script is that all of the variable names are passed to `unset` as a single argument, rather than using a separate argument for each name. The solution is to use `eval`, as with the following command:

```
eval unset $vars
```

`Eval` generates a string consisting of "`unset `" followed by the list of variable names and then passes the string to Tcl for evaluation. The string gets re-parsed so each variable name ends up in a different argument to `unset`.

Note: This approach works even if some of the variable names contain spaces or special characters such as `$`*. As described in Section 6.7, the only safe way to generate Tcl commands is using list operations such as* `list` *and* `concat`*. The command "*`eval unset $vars`*" is identical to the command "*`eval [concat unset $vars]`*"; in either case the script evaluated by* `eval` *is a proper list whose first element is "*`unset`*" and whose other elements are the elements of* `vars`*.*

7.6 Executing from files: source

The `source` command is similar to the command by the same name in the `csh` shell: it reads a file and executes the contents of the file as a Tcl script. It takes a single argument that contains the name of the file. For example, the command

```
source init.tcl
```

will execute the contents of the file `init.tcl`. The return value from `source` will be the value returned when the file contents are executed, which is the return value from the last command in the file. In addition, `source` allows the `return` command to be used in the file's script to terminate the processing of the file. See Section 8.1 for more information on `return`.

Chapter 8
Procedures

A Tcl procedure is a command that is implemented with a Tcl script rather than C code. You can define new procedures at any time with the `proc` command described in this chapter. Procedures make it easy for you to package up solutions to problems so that they can be re-used easily. Procedures also provide a simple way for you to prototype new features in an application: once you've tested the procedures, you can reimplement them in C for higher performance; the C implementations will appear just like the original procedures so none of the scripts that invoke them will have to change.

Tcl provides special commands for dealing with variable scopes. Among other things, these commands allow you to pass arguments by reference instead of by value and to implement new Tcl control structures as procedures. Table 8.1 summarizes the Tcl commands related to procedures.

8.1 Procedure basics: proc and return

Procedures are created with the `proc` command, as in the following example:

```
proc plus {a b} {expr $a+$b}
```

The first argument to `proc` is the name of the procedure to be created, `plus` in this case. The second argument is a list of names of arguments to the procedure (`a` and `b` in the example). The third argument to `proc` is a Tcl script that forms the body of the new procedure. `Proc` creates a new command and arranges that whenever the command is invoked the procedure's body will be evaluated. In this case the new command will have the name `plus`; whenever `plus` is invoked it must receive two arguments. While the

`global` *`name1`* ?*`name2`* ...?	Binds variable names *`name1`*, *`name2`*, etc. to global variables. References to these names will refer to global variables instead of local variables for the duration of the current procedure. Returns an empty string.
`proc` *`name argList body`*	Defines a procedure whose name is *`name`*, replacing any existing command by that name. *`ArgList`* is a list with one element for each of the procedure's arguments, and *`body`* contains a Tcl script that is the procedure's body. Returns an empty string.
`return` ?*`options`*? ?*`value`*?	Returns from the innermost nested procedure or `source` command with *`value`* as the result of the procedure. *`Value`* defaults to an empty string. Additional options may be used to trigger an exceptional return (see Section 9.4).
`uplevel` ?*`level`*? *`arg`* ?*`arg arg`* ...?	Concatenates all of the *`arg`*'s with spaces as separators, then executes the resulting Tcl script in the variable context of stack level *`level`*. *`Level`* consists of a number or a number preceded by #, and defaults to `-1`. Returns the result of the script.
`upvar` ?*`level`*? *`otherVar1 myVar1`* ?*`otherVar2 myVar2`* ...?	Binds the local variable name *`myVar1`* to the variable at stack level *`level`* whose name is *`otherVar1`*. For the duration of the current procedure, variable references to *`myVar1`* will be directed to *`otherVar1`* instead. Additional bindings may be specified with *`otherVar2`* and *`myVar2`*, etc. *`Level`* has the same syntax and meaning as for `uplevel` and defaults to `-1`. Returns an empty string.

Table 8.1. A summary of the Tcl commands related to procedures and variable scoping.

body of `plus` is executing the variables `a` and `b` will contain the values of the arguments. The return value from the `plus` command is the value returned by the last command in `plus`'s body. Here are some correct and incorrect invocations of `plus`:

```
   plus 3 4
⇒ 7
   plus 3 -1
⇒ 2
   plus 1
∅ no value given for parameter "b" to "plus"
```

If you wish for a procedure to return early without executing its entire script, you can invoke the `return` command: it causes the enclosing procedure to return immediately and the argument to `return` will be the result of the procedure. Here is an implementation of factorial that uses `return`:

```
proc fac x {
    if {$x <= 1} {
        return 1
    }
    expr $x * [fac [expr $x-1]]
}
fac 4
```
⇒ *24*
```
fac 0
```
⇒ *1*

If the argument to `fac` is less than or equal to one then `fac` invokes `return` to return immediately. Otherwise it executes the `expr` command. The `expr` command is the last one in the procedure's body, so its result is returned as the result of the procedure.

8.2 Local and global variables

When the body of a Tcl procedure is evaluated it uses a different set of variables from its caller. These variables are called *local variables*, since they are only accessible within the procedure and are deleted when the procedure returns. Variables referenced outside any procedure are called *global variables*. It is possible to have a local variable with the same name as a global variable or a local variable in another active procedure, but these will be different variables: changes to one will not affect any of the others. If a procedure is invoked recursively then each recursive invocation will have a distinct set of local variables.

The arguments to a procedure are just local variables whose values are set from the words of the command that invoked the procedure. When execution begins in a procedure, the only local variables with values are those corresponding to arguments. Other local variables are created automatically when they are set.

A procedure can reference global variables with the `global` command. For example, the following command makes the global variables `x` and `y` accessible inside a procedure:

```
global x y
```

The `global` command treats each of its arguments as the name of a global variable and sets up bindings so that references to those names within the procedure will be directed to global variables instead of local ones. `Global` can be invoked at any time during a procedure; once it has been invoked, the bindings will remain in effect until the procedure returns.

Note: Tcl does not provide a form of variable equivalent to “static” variables in C, which are limited in scope to a given procedure but have values that persist across calls to the procedure. In Tcl you must use global variables for purposes like this. To avoid name conflicts with other such variables you should include the name of the procedure or the name of its enclosing package in the variable name, for example “`Hypertext_numLinks`”.

8.3 Defaults and variable numbers of arguments

In the examples so far, the second argument to `proc` (which describes the arguments to the procedure) has taken a simple form consisting of the names of the arguments. Three additional features are available for specifying arguments. First, the argument list may be specified as an empty string. In this case the procedure takes no arguments. For example, the following command defines a procedure that prints out two global variables:

```
proc printVars {} {
    global a b
    puts "a is $a, b is $b"
}
```

The second additional feature is that defaults may be specified for some or all of the arguments. The argument list is actually a list of lists, with each sublist corresponding to a single argument. If a sublist has only a single element (which has been the case up until now) that element is the name of the argument. If a sublist has two arguments, the first is the argument’s name and the second is a default value for it. For example, here is a procedure that increments a given value by a given amount, with the amount defaulting to 1:

```
proc inc {value {increment 1}} {
    expr $value+$increment
}
```

The first element in the argument list, `value`, specifies a name with no default value. The second element specifies an argument with name `increment` and a default value of `1`. This means that `inc` can be invoked with either one or two arguments:

```
   inc 42 3
⇒  45
   inc 42
⇒  43
```

If a default isn’t specified for an argument in the `proc` command then that argument must be supplied whenever the procedure is invoked. The defaulted arguments, if any, must be the last arguments for the procedure: if a particular argument is defaulted then all the arguments after it must also be defaulted.

The third special feature in argument lists is support for variable numbers of arguments. If the last argument in the argument list is the special value `args`, then the procedure may be called with varying numbers of arguments. Arguments before `args` in the argument list are handled as before, but any number of additional arguments may be specified. The procedure's local variable `args` will be set to a list whose elements are all of the extra arguments. If there are no extra arguments then `args` will be set to an empty string. For example, the following procedure takes any number of arguments and returns their sum:

```
     proc sum args {
         set s 0
         foreach i $args {
             incr s $i
         }
         return $s
     }
     sum 1 2 3 4 5
  ⇒  15
     sum
  ⇒  0
```

If a procedure's argument list contains additional arguments before `args` then they may be defaulted as described above. Of course, if this happens there will be no extra arguments so `args` will be set to an empty string. No default value may be specified for `args`: the empty string is its default.

8.4 Call by reference: upvar

The `upvar` command provides a general mechanism for accessing variables outside the context of a procedure. It can be used to access either global variables or local variables in some other active procedure. Most often it is used to implement call-by-reference argument passing. Here is a simple example of `upvar` in a procedure that prints out the contents of an array:

```
     proc parray name {
         upvar $name a
         foreach el [lsort [array names a]] {
             puts "$el = $a($el)"
         }
     }
     set info(age) 37
     set info(position) "Vice President"
     parray info
  ⇒  age = 37
     position = "Vice President"
```

When `parray` is invoked it is given the name of an array as argument. The `upvar` command then makes this array accessible through a local variable in the procedure. The first argument to `upvar` is the name of a variable accessible to the procedure's caller. This may be either a global variable, as in the example, or a local variable in a calling procedure. The second argument is the name of a local variable. `Upvar` arranges things so that accesses to local variable `a` will actually refer to the variable in the caller whose name is given by variable `name`. In the example this means that when `parray` reads elements of `a` it is actually reading elements of the `info` global variable. If `parray` were to write `a` it would modify `info`. `Parray` uses the “`array names`” command to retrieve a list of all the elements in the array, sorts them with `lsort`, then prints out each the elements in order.

Note: In the example it appears as if the output is returned as the procedure’s result; in fact it is printed directly to standard output and the result of the procedure is an empty string.

The first variable name in an `upvar` command normally refers to the context of the current procedure’s caller. However, it is also possible to access variables from any level on the call stack, including global level. For example,

```
upvar #0 other x
```

makes global variable `other` accessible via local variable `x` (the `#0` argument specifies that `other` should be interpreted as a global variable, regardless of how many nested procedure calls are active), and

```
upvar -2 other x
```

makes variable `other` in the caller of the caller of the current procedure accessible as local variable `x` (`-2` specifies that the context of `other` is 2 levels up the call stack). See the reference documentation for more information on specifying a level in `upvar`.

8.5 Creating new control structures: uplevel

The `uplevel` command is a cross between `eval` and `upvar`. It evaluates its argument(s) as a script, just like `eval`, but the script is evaluated in the variable context of a different stack level, like `upvar`. With `uplevel` you can define new control structures as Tcl procedures. For example, here is a new control flow command called `do`:

```
proc do {varName first last body} {
    upvar $varName v
    for {set v $first} {$v <= $last} {incr v} {
        uplevel $body
    }
}
```

The first argument to `do` is the name of a variable. `Do` sets that variable to consecutive integer values in the range between its second and third arguments, and executes the fourth argument as a Tcl command once for each setting. Given this definition of `do`, the following script creates a list of squares of the first five integers:

```
    set a {}
    do i 1 5 {
        lappend a [expr $i*$i]
    }
    set a
⇒   1 4 9 16 25
```

The `do` procedure uses `upvar` to access the loop variable (`i` in the example) as local variable `v`. Then it uses the `for` command to increment the loop variable through the desired range. For each value it invokes `uplevel` to execute the loop body in the variable context of the caller; this causes references to variables `a` and `i` in the body of the loop to refer to variables in `do`'s caller. If `eval` were used instead of `uplevel` then `a` and `i` would be treated as local variables in `do`, which would not produce the desired effect.

Note: This implementation of `do` does not handle exceptional conditions properly. For example, if the body of the loop contains a `return` command it will only cause the `do` procedure to return, which is more like the behavior of `break`. If a `return` occurs in the body of a built-in control-flow command like `for` or `while` then it causes the procedure that invoked the command to return. In Chapter 9 you will see how to implement this behavior for `do`.

As with `upvar`, `uplevel` takes an optional initial argument that specifies an explicit stack level. See the reference documentation for details.

Chapter 9
Errors and Exceptions

As you have seen in previous chapters, there are many things that can result in errors in Tcl commands. Errors can occur because a command doesn't exist, or because it doesn't receive the right number of arguments, or because the arguments have the wrong form, or because some other problem occurs in executing the command, such as an error in a system call for file I/O. In most cases errors represent severe problems that make it impossible for the application to complete the script it is processing. Tcl's error facilities are intended to make it easy for the application to unwind the work in progress and display an error message to the user that indicates what went wrong. Presumably the user will fix the problem and retry the operation.

Errors are just one example of a more general phenomenon called *exceptions*. Exceptions are events that cause scripts to be aborted; they include the `break`, `continue`, and `return` commands as well as errors. Tcl allows exceptions to be "caught" by scripts so that only part of the work in progress is unwound. After catching an exception the script can ignore it or take steps to recover from it. If the script can't recover then it can reissue the exception. Table 9.1 summarizes the Tcl commands related to exceptions.

9.1 What happens after an error?

When a Tcl error occurs the current command is aborted. If that command is part of a larger script then the script is also aborted. If the error occurs while executing a Tcl procedure, then the procedure is aborted, along with the procedure that called it, and so on until all the active procedures have aborted. After all Tcl activity has been unwound in this way, control eventually returns to C code in the application, along with an indication that an

Command	Description
`catch` *`command`* ?*`varName`*?	Evaluates *`command`* as a Tcl script and returns an integer code that identifies the completion status of the command. If *`varName`* is specified then it gives the name of a variable, which will be modified to hold the return value or error message generated by *`command`*.
`error` *`message`* ?*`info`*? ?*`code`*?	Generates an error with *`message`* as the error message. If *`info`* is specified and is not an empty string then it is used to initialize the `errorInfo` variable. If *`code`* is specified then it is stored in the `errorCode` variable.
`return -code` *`code`* ?`-errorinfo` *`info`*? ?`-errorcode` *`code`*? ?*`string`*?	Causes the current procedure to return an exceptional condition. *`Code`* specifies the condition and must be `ok`, `error`, `return`, `break`, `continue`, or an integer. The `-errorinfo` option may be used to specify a starting value for the `errorInfo` variable, and `-errorcode` may be used to specify a value for the `errorCode` variable. *`String`* gives the return value or error message associated with the return; it defaults to an empty string.

Table 9.1. A summary of the Tcl commands related to exceptions.

error occurred and a message describing the error. It is up to the application to decide how to handle this situation, but most interactive applications will display the error message for the user and continue processing user input. In a batch-oriented application where the user can't see the error message and adjust future actions accordingly, the application might print the error message into a log and abort.

For example, consider the following script, which is intended to sum the elements of a list:

```
set list {44 16 123 98 57}
set sum 0
foreach el $list {
    set sum [expr $sum+$element]
}
∅ can't read "element": no such variable
```

This script is incorrect because there is no variable `element`: the variable name `element` in the `expr` command should have been `el` to match the loop variable for the `foreach` command. When the script is executed an error will occur as Tcl parses the `expr` command: Tcl will attempt to substitute the value of variable `element` but will not be able to find a variable by that name, so it will signal an error. This error indication will be returned to the `foreach` command, which had invoked the Tcl interpreter to evaluate the loop body. When `foreach` sees that an error has occurred, it will abort its loop and return the same error indication as its own result. This in turn will cause the overall script to be aborted. The error message "`can't read "element": no such variable`" will be returned along with the error, and will probably be displayed for the user.

In many cases the error message will provide enough information for you to pinpoint where and why the error occurred so you can avoid the problem in the future. However, if the error occurred in a deeply nested set of procedure calls the message alone may not provide enough information to figure out where the error occurred. To help pinpoint the location of the error, Tcl creates a stack trace as it unwinds the commands that were in progress, and it stores the stack trace in the global variable `errorInfo`. The stack trace describes each of the nested calls to the Tcl interpreter. For example, after the above error `errorInfo` will have the following value:

```
can't read "element": no such variable
    while executing
"expr $sum+$element"
    invoked from within
"set sum [expr $sum+$element]..."
    ("foreach" body line 2)
    invoked from within
"foreach el $list {
    set sum [expr $sum+$element]
}"
```

Tcl provides one other piece of information after errors, in the global variable `errorCode`. `ErrorCode` has a format that is easy to process with Tcl scripts; it is most commonly used in Tcl scripts that attempt to recover from errors using the `catch` command described below. The `errorCode` variable consists of a list with one or more elements. The first element identifies a general class of errors and the remaining elements provide more information in a class-dependent fashion. For example, if the first element of `errorCode` is `POSIX` then it means that an error occurred in a POSIX system call. `ErrorCode` will contain two additional elements giving the POSIX name for the error, such as `ENOENT`, and a human-readable message describing the error. See the reference documentation for a complete description of all the forms `errorCode` can take, or refer to the descriptions of individual commands that set `errorCode`, such as those in Chapter 11 and Chapter 12.

The `errorCode` variable is a late-comer to Tcl and is only filled in by a few commands, mostly dealing with file access and child processes. If a command generates an error without setting `errorCode` then Tcl fills it in with the value `NONE`.

9.2 Generating errors from Tcl scripts

Most Tcl errors are generated by the C code that implements the Tcl interpreter and the built-in commands. However, it is also possible to generate an error by executing the `error` Tcl command as in the following example:

```
if {($x < 0} || ($x > 100)} {
    error "x is out of range ($x)"
}
```

The `error` command generates an error and uses its argument as the error message.

As a matter of programming style, you should only use the `error` command in situations where the correct action is to abort the script being executed. If you think that an error is likely to be recovered from without aborting the entire script, then it is probably better to use the normal return value mechanism to indicate success or failure (e.g. return one value from a command if it succeeded and another if it failed, or set variables to indicate success or failure). Although it is possible to recover from errors (you'll see how in Section 9.3 below) the recovery mechanism is more complicated than the normal return value mechanism. Thus it's best to generate errors only in situations where you won't usually want to recover.

9.3 Trapping errors with catch

Errors generally cause all active Tcl commands to be aborted, but there are some situations where it is useful to continue executing a script after an error has occurred. For example, suppose that you want to unset variable `x` if it exists, but it may not exist at the time of the `unset` command. If you invoke `unset` on a variable that doesn't exist then it generates an error:

```
  unset x
∅ can't unset "x": no such variable
```

You can use the `catch` command to ignore the error in this situation:

```
  catch {unset x}
⇒ 1
```

The argument to `catch` is a Tcl script, which `catch` evaluates. If the script completes normally then `catch` returns 0. If an error occurs in the script then `catch` traps the error (so that the `catch` command itself is not aborted by the error) and returns 1 to indicate that an error occurred. The example above ignores any errors in `unset` so `x` is unset if it existed and the script has no effect if `x` didn't previously exist.

The `catch` command can also take a second argument. If the argument is provided then it is the name of a variable and `catch` modifies the variable to hold either the script's return value (if it returns normally) or the error message (if the script generates an error):

```
  catch {unset x} msg
⇒ 1
  set msg
⇒ can't unset "x": no such variable
```

In this case the `unset` command generates an error so `msg` is set to contain the error message. If variable `x` had existed then `unset` would have returned successfully, so the return value from `catch` would have been `0` and `msg` would have contained the return value from the `unset` command, which is an empty string. This longer form of `catch` is useful if you need access to the return value when the script completes successfully. It's also useful if you need to do something with the error message after an error, such as logging it to a file.

9.4 Exceptions in general

Errors are not the only things in Tcl that cause work in progress to be aborted. Errors are just one example of a set of events called *`exceptions`*. In addition to errors there are three other kinds of exceptions in Tcl, which are generated by the `break`, `continue`, and `return` commands. All exceptions cause active scripts to be aborted in the same way, except for two differences. First, the `errorInfo` and `errorCode` variables are only set during error exceptions. Second, the exceptions other than errors are almost always caught by an enclosing command, whereas errors usually unwind all the work in progress. For example, `break` and `continue` commands are normally invoked inside a looping command such as `foreach`; `foreach` will catch break and continue exceptions and terminate the loop or skip to the next iteration. Similarly, `return` is normally only invoked inside a procedure or a file being `source`'d. Both the procedure implementation and the `source` command catch return exceptions.

Note: If a `break` or `continue` command is invoked outside any loop then active scripts unwind until the outermost script for a procedure is reached or all scripts in progress have been unwound. At this point Tcl turns the break or continue exception into an error with an appropriate message.

All exceptions are accompanied by a string value. In the case of an error, the string is the error message. In the case of `return`, the string is the return value for the procedure or script. In the case of `break` and `continue` the string is always empty.

The `catch` command actually catches all exceptions, not just errors. The return value from `catch` indicates what kind of exception occurred and the variable specified in `catch`'s second argument is set to hold the string associated with the exception (see Table 9.2). For example:

```
  catch {return "all done"} string
⇒ 2
  set string
⇒ all done
```

Whereas `catch` provides a general mechanism for catching exception of all types, `return` provides a general mechanism for generating exceptions of all types. If its first argument consists of the keyword `-code`, as in

Return value from `catch`	Description	Caught by
0	Normal return. String gives return value.	Not applicable
1	Error. String gives message describing the problem.	`Catch`
2	The `return` command was invoked. String gives return value for procedure or `source` command.	`Catch`, `source`, procedures
3	The `break` command was invoked. String is empty.	`Catch`, `for`, `foreach`, `while`, procedures
4	The `continue` command was invoked. String is empty.	`Catch`, `for`, `foreach`, `while`, procedures
anything else	Defined by user or application.	`Catch`

Table 9.2. A summary of Tcl exceptions. The first column indicates the value returned by `catch` in each instance. The second column describes when the exception occurs and the meaning of the string associated with the exception. The last column lists the commands that catch exceptions of that type ("procedures" means that the exception is caught by a Tcl procedure when its entire body has been aborted). The top row refers to normal returns where there is no exception.

```
return -code return 42
```

then its second argument is the name of an exception (`return` in this case) and the third argument is the string associated with the exception. The enclosing procedure will return immediately, but instead of a normal return it will return with the exception described by the `return` command's arguments. In the example above the procedure will generate a return exception, which will then cause the calling procedure to return as well.

In Section 8.5 you saw how a new looping command `do` could be implemented as a Tcl procedure using `upvar` and `uplevel`. However, the example in Section 8.5 did not properly handle exceptions within the loop body. Here is a new implementation of `do` that uses `catch` and `return` to deal with exceptions properly:

```
proc do {varName first last body} {
    global errorInfo errorCode
    upvar $varName v
    for {set v $first} {$v <= $last} {incr v} {
        switch [catch {uplevel $body} string] {
            1 {return -code error -errorinfo $errorInfo \
                    -errorCode $errorcode $string}
            2 {return -code return $string}
            3 return
        }
    }
}
```

This new implemenation evaluates the loop body inside a `catch` command and then checks to see how the body terminates. If no exception occurs (return value 0 from `catch`) or if the exception is a continue (return value 4) then `do` just goes on to the next iteration. If an error or return occurs (return value 1 or 2 from `catch`) then `do` uses the `return` command to reflect the exception upward to the caller. If a break exception occurs (return value 3 from `catch`) then `do` returns to its caller normally, ending the loop.

When `do` reflects an error upwards it uses the `-errorinfo` option to `return` to make sure that a proper stack trace is available after the error. If that option were omitted then a fresh stack trace would be generated starting with `do`'s error return; the stack trace would not indicate where in `body` the error occurred. The context within `body` is available in the `errorInfo` variable at the time `catch` returns, and the `-errorinfo` option causes this value to be used as the initial contents of the stack trace when `do` returns an error. As additional unwinding occurs more information gets added to the initial value, so that the final stack trace includes both the context within `body` and the context of the call to `do`. The `-errorcode` option serves a similar purpose for the `errorCode` variable, retaining the `errorCode` value from the original error as the `errorCode` value when `do` propagates the error. Without the `-errorcode` option the `errorCode` variable will always end up with the value `NONE`.

Chapter 10
String Manipulation

This chapter describes Tcl's facilities for manipulating strings. The string manipulation commands provide pattern matching in two different forms, one that mimics the rules used by shells for file name expansion and another that uses regular expressions as patterns. Tcl also has commands for formatted input and output in a style similar to the C procedures `scanf` and `printf`. Finally, there are several utility commands with functions such as computing the length of a string, extracting characters from a string, and case conversion. Tables10.1 and 10.2 summarize the Tcl commands for string processing.

10.1 Glob-style pattern matching

The simplest of Tcl's two forms of pattern matching is called "glob" style. It is named after the mechanism used in the `csh` shell for file name expansion, which is called "globbing". Glob-style matching is easier to learn and use than the regular expressions described in the next two sections, but it only works well for simple cases. For more complex pattern matching you will probably need to use regular expressions.

The command `string match` implements glob-style pattern matching. For example, the following script extracts all of the elements of a list that begin with "`Tcl`":

```
set new {}
foreach el $list {
    if [string match Tcl* $el] {
        lappend new $el
    }
}
```

format *formatString* ?*value value* ...?	Returns a result equal to *formatString* except that the *value* arguments have been substituted in place of % sequences in *formatString*.
regexp ?-indices? ?-nocase? ?--? *exp string* ?*matchVar*? \ ?*subVar subVar* ...?	Determines whether the regular expression *exp* matches part or all of *string* and returns 1 if it does, 0 if it doesn't. If there is a match, information about matching range(s) is placed in the variables named by *matchVar* and the *subVar*'s, if they are specified.
regsub ?-*all*? ?-*nocase*? ?--? *exp string subSpec varName*	Matches *exp* against *string* as for regexp and returns 1 if there is a match, 0 if there is none. Also copies *string* to the variable named by *varName*, making substitutions for the matching portion(s) as specified by *subSpec*.
scan *string format varName* ?*varName varName* ...?	Parses fields from *string* as specified by *format* and places the values that match % sequences into variables named by the *varName* arguments.
string compare *string1 string2*	Returns -1, 0, or 1 if *string1* is lexicographically less than, equal to, or greater than *string2*.
string first *string1 string2*	Returns the index in *string2* of the first character in the leftmost substring that exactly matches the characters in *string1*, or -1 if there is no such match.
string index *string charIndex*	Returns the *charIndex*'th character of *string*, or an empty string if there is no such character. The first character in *string* has index 0.
string last *string1 string2*	Returns the index in *string2* of the first character in the rightmost substring of *string2* that exactly matches *string1*. If there is no matching substring then -1 is returned.
string length *string*	Returns the number of characters in *string*.
string match *pattern string*	Returns 1 if *pattern* matches *string* using glob-style matching rules (*, ?, [], and \) and 0 if it doesn't.
string range *string first last*	Returns the substring of *string* that lies between the indices given by *first* and *last*, inclusive. An index of 0 refers to the first character in the string, and *last* may be end to refer to the last character of the string.

Table 10.1. A summary of the Tcl commands for string manipulation (continued in Table 10.2).

`string tolower` *`string`*	Returns a value identical to *`string`* except that all upper case characters have been converted to lower case.
`string toupper` *`string`*	Returns a value identical to *`string`* except that all lower case characters have been converted to upper case.
`string trim` *`string`* ?*`chars`*?	Returns a value identical to *`string`* except that any leading or trailing characters that appear in *`chars`* are removed. *`Chars`* defaults to the white space characters (space, tab, newline, and carriage return).
`string trimleft` *`string`* ?*`chars`*?	Same as `string trim` except that only leading characters are removed.
`string trimright` *`string`* ?*`chars`*?	Same as `string trim` except that only trailing characters are removed.

Table 10.2. A summary of the Tcl commands for string manipulation, cont'd.

The `string` command is actually about a dozen string-manipulation commands rolled into one. If the first argument is `match` then the command performs glob-style pattern matching and there must be two additional arguments, a pattern and a string. The command returns `1` if the pattern matches the string, `0` if it doesn't. For the pattern to match the string, each character of the pattern must be the same as the corresponding character of the string, except that a few pattern characters are interpreted specially. For example, a `*` in the pattern matches a substring of any length, so "`Tcl*`" matches any string whose first three characters are "`Tcl`". Here is a list of all the special characters supported in glob-style matching:

`*`	Matches any sequence of zero or more characters.
`?`	Matches any single character.
`[`*`chars`*`]`	Matches any single character in *`chars`*. If *`chars`* contains a sequence of the form *`a-b`* then any character between *`a`* and *`b`*, inclusive, will match.
`\`*`x`*	Matches the single character *`x`*. This provides a way to avoid special interpretation for any of the characters `*?[]\` in the pattern.

Many simple things can be done easily with glob-style patterns. For example, "`*.[ch]`" matches all strings that end with either "`.c`" or "`.h`". However, many interesting forms of pattern matching cannot be expressed at all with glob-style patterns. For example, there is no way to use a glob-style pattern to test whether a string consists entirely of digits: the pattern "`[0-9]`" tests for a single digit, but there is no way to specify that there may be more than one digit.

Character(s)	Meaning
`.`	Matches any single character.
`^`	Matches the null string at the start of the input string.
`$`	Matches the null string at the end of the input string.
`\`*`x`*	Matches the character *`x`*.
`[`*`chars`*`]`	Matches any single character from *`chars`*. If the first character of *`chars`* is `^` then it matches any single character not in the remainder of *`chars`*. A sequence of the form *`a`*`-`*`b`* in *`chars`* is treated as shorthand for all of the ASCII characters between *`a`* and *`b`*, inclusive. If the first character in *`chars`* (possibly following a `^`) is `]` then it is treated literally (as part of *`chars`* instead of a terminator). If a `-` appears first or last in *`chars`* then it is treated literally.
`(`*`regexp`*`)`	Matches anything that matches the regular expression *`regexp`*. Used for grouping and for identifying pieces of the matching substring.
`*`	Matches a sequence of 0 or more matches of the preceding atom.
`+`	Matches a sequence of 1 or more matches of the preceding atom.
`?`	Matches either a null string or a match of the preceding atom.
`regexp1``|`*`regexp2`*	Matches anything that matches either *`regexp1`* or *`regexp2`*.

Table 10.3. The special characters permitted in regular expression patterns.

10.2 Pattern matching with regular expressions

Tcl's second form of pattern matching uses regular expressions like those for the `egrep` program. Regular expressions are more complex than glob-style patterns but more powerful. Tcl's regular expressions are based on Henry Spencer's publicly available implementation, and parts of the description below are copied from Spencer's documentation.

A regular expression pattern can have several layers of structure. The basic building blocks are called *atoms*, and the simplest form of regular expression consists of one or more atoms. For a regular expression to match an input string, there must be a substring of the input where each of the regular expression's atoms (or other components, as you'll see below) matches the corresponding part of the substring. In most cases atoms are single characters, each of which matches itself. Thus the regular expression `abc` matches any string containing `abc`, such as `abcdef` or `xabcy`.

A number of characters have special meanings in regular expressions; they are summarized in Table 10.3. The characters `^` and `$` are atoms that match the beginning and end of the input string respectively; thus `^abc` matches any string that starts with `abc`, `abc$` matches any string that ends in `abc`, and `^abc$` matches `abc` and nothing else. The atom

"`.`" matches any single character, and the atom `\x`, where `x` is any single character, matches `x`. For example, the regular expression "`.\$`" matches any string that contains a dollar-sign, as long as the dollar-sign isn't the first character.

Besides the atoms already described, there are two other forms for atoms in regular expressions. The first form consists of any regular expression enclosed in parentheses, such as "`(a.b)`". Parentheses are used for grouping. They allow operators such as `*` to be applied to entire regular expressions as well as atoms. They are also used to identify pieces of the matching substring for special processing. Both of these uses are described in more detail below.

The final form for an atom is a *range*, which is a collection of characters between square brackets. A range matches any single character that is one of the ones between the brackets. Furthermore, if there is a sequence of the form *`a-b`* among the characters, then all of the ASCII characters between *`a`* and *`b`* are treated as acceptable. Thus the regular expression `[0-9a-fA-F]` matches any string that contains a hexadecimal digit. If the character after the `[` is a `^` then the sense of the range is reversed: it only matches characters `not` among those specified between the `^` and the `]`.

The three operators `*`, `+`, and `?` may follow an atom to specify repetition. If an atom is followed by `*` then it matches a sequence of zero or more matches of that atom. If an atom is followed by `+` then it matches a sequence of one or more matches of the atom. If an atom is followed by `?` then it matches either an empty string or a match of the atom. For example, "`^(0x)?[0-9a-fA-F]+$`" matches strings that are proper hexadecimal numbers, i.e. those consisting of an optional `0x` followed by one or more hexadecimal digits.

Finally, regular expressions may be joined together with the `|` operator. The resulting regular expression matches anything that matches either of the regular expresssions that surround the `|`. For example, the following pattern matches any string that is either a hexadecimal number or a decimal number:

```
^((0x)?[0-9a-fA-F]+|[0-9]+)$
```

Note that the information between parentheses may be any regular expression, including additional regular expressions in parentheses, so it is possible to build up quite complex structures.

The `regexp` command invokes regular expression matching. In its simplest form it takes two arguments: the regular expression pattern and an input string. It returns `0` or `1` to indicate whether or not the pattern matched the input string:

```
   regexp {^[0-9]+$} 510
⇒  1
   regexp {^[0-9]+$} -510
⇒  0
```

Note: *The pattern must be enclosed in braces so that the characters `$`, `[`, and `]` are passed through to the `regexp` command instead of triggering variable and command* *substitution. In almost always a good idea to enclose regular expression patterns in braces.*

If `regexp` is invoked with additional arguments after the input string then each additional argument is treated as the name of a variable. The first variable is filled in with the substring that matched the entire regular expression. The second variable is filled in with the portion of the substring that matched the leftmost parenthesized subexpression within the pattern; the third variable is filled in with the match for the next parenthesized subexpression, and so on. If there are more variable names than parenthesized subexpressions then the extra variables are set to empty strings. For example, after executing the command

```
regexp {([0-9]+) *([a-z]+)} "Walk 10 km" a b c
```

variable `a` will have the value “`10 km`”, `b` will have the value `10`, and `c` will have the value `km`. This ability to extract portions of the matching substring allows `regexp` to be used for parsing.

It is also possible to specify two extra switches to `regexp` before the regular expression argument. A `-nocase` switch specifies that alphabetic atoms should match either upper-case or lower-case letters. For example:

```
    regexp {[a-z]} A
⇒  0
    regexp -nocase {[a-z]} A
⇒  1
```

The `-indices` switch specifies that the additional variables should not be filled in with the values of matching substrings. Instead, each should be filled in with a list giving the first and last indices of the substring’s range within the input string. After the command

```
regexp -indices {([0-9]+) *([a-z]+)} "Walk 10 km" \
    a b c
```

variable `a` will have the value “`5 9`”, `b` will have the value “`5 6`”, and `c` will have the value “`8 9`”.

10.3 Using regular expressions for substitutions

Regular expressions can also be used to perform substitutions using the `regsub` command. Consider the following example:

```
    regsub there "They live there lives" their x
⇒  1
```

The first argument to `regsub` is a regular expression pattern and the second argument is an input string, just as for `regexp`. And, like `regexp`, `regsub` returns `1` if the pattern matches the string, `0` if it doesn’t. However, `regsub` does more than just check for a match: it creates a new string by substituting a replacement value for the matching substring. The replacement value is contained in the third argument to `regsub`, and the new string is stored in the variable named by the final argument to `regsub`. Thus, after the above command completes `x` will have the value "`They live their lives`". If the pattern had not matched the string then `0` would have been returned and `x` would have the value "`They live there lives`".

Two special switches may appear as arguments to `regsub` before the regular expression. The first is `-nocase`, which causes case differences between the pattern and the string to be ignored just as for `regexp`. The second possible switch is `-all`. Normally `regsub` makes only a single substitution, for the first match found in the input string. However, if `-all` is specified then `regsub` continues searching for additional matches and makes substitutions for all of the matches found. For example, after the command

```
regsub -all a ababa zz x
```

`x` will have the value `zzbzzbzz`. If `-all` had been omitted then `x` would have been set to `zzbaba`.

In the examples above the replacement string is a simple literal value. However, if the replacement string contains a "`&`" or "`\0`" then the "`&`" or "`\0`" is replaced in the substitution with the substring that matched the regular expression. If a sequence of the form `\`*n* appears in the replacement string, where *n* is a decimal number, then the substring that matched the *n*-th parenthesized subexpression is substituted instead of the `\`*n*. For example, the command

```
regsub -all a|b axaab && x
```

doubles all of the `a`'s and `b`'s in the input string. In this case it sets `x` to `aaxaaaabb`. Or, the command

```
regsub -all (a+)(ba*) aabaabxab {z\2} x
```

replaces sequences of `a`'s with a single `z` if they precede a `b` but don't also follow a `b`. In this case `x` is set to `zbaabxzb`. Backslashes may be used in the replacement string to allow "`&`", "`\0`", "`\`*n*", or backslash characters to be substituted verbatim without any special interpretation.

Note: It's usually a good idea to enclose complex replacement strings in braces as in the example above; otherwise the Tcl parser will process backslash sequences and the replacement string received by `regsub` *may not contain backslashes that are needed.*

10.4 Generating strings with format

Tcl's `format` command provides facilities like those of the `sprintf` procedure from the ANSI C library. For example, consider the following command:

```
    format "The square root of 10 is %.3f" [expr sqrt(10)]
⇒   The square root of 10 is 3.162
```

The first argument to `format` is a format string, which may contain any number of conversion specifiers such as “`%.3f`”. For each conversion specifier `format` generates a replacement string by reformatting the next argument according to the conversion specifier. The result of the `format` command consists of the format string with each conversion specifier replaced by the corresponding replacement string. In the above example “`%.3f`” specifies that the next argument is to be formatted as a real number with three digits after the decimal point. `Format` supports almost all of the conversion specifiers defined for ANSI C `sprintf`, such as “`%d`” for a decimal integer, “`%x`” for a hexadecimal integer, and “`%e`” for real numbers in mantissa-exponent form.

The `format` command plays a less significant role in Tcl than `printf` and `sprintf` play in C. Many of the uses of `printf` and `sprintf` are simply for conversion from binary to string format or for string substitution. Binary-to-string conversion isn’t needed in Tcl because values are already stored as strings, and substitution is already available through the Tcl parser. For example, the command

```
set msg [format "%s is %d years old" $name $age]
```

can be written more simply as

```
set msg "$name is $age years old"
```

The `%d` conversion specifier in the `format` command could be written just as well as `%s`; with `%d` `format` converts the value of age to a binary integer, then converts the integer back to a string again.

`Format` is typically used in Tcl to reformat a value to improve its appearance, or to convert from one representation to another (e.g. from decimal to hexadecimal). As an example of reformatting, here is a that script prints the first ten powers of *e* in a table:

```
puts "Number  Exponential"
for {set i 1} {i <= 10} {incr i} {
    puts [format "%4d %12.3f" $i [expr exp($i)]]
}
```

This script generates the following output on standard output:

```
Number  Exponential
   1        2.718
   2        7.389
   3       20.085
   4       54.598
   5      148.413
   6      403.429
   7     1096.630
   8     2980.960
   9     8103.080
  10    22026.500
```

The conversion specifier “`%4d`” causes the integers in the first column of the table to be printed right-justifed in a field four digits wide, so that they line up under their column header. The conversion specifier “`%12.3f`” causes each of the real values to be printed right-justified in a field 12 digits wide, so that the values line up; it also sets the precision at 3 digits to the right of the decimal point.

The second main use for `format`, changing the reprensentation of a value, is illustrated by the script below, which prints a table showing the ASCII characters that correspond to particular integer values:

```
puts "Integer  ASCII"
for {set i 95} {$i <= 101} {incr i} {
    puts [format "%4d       %c" $i $i]
}
```

This script generates the following output on standard output:

```
Integer  ASCII
  95       _
  96       `
  97       a
  98       b
  99       c
 100       d
 101       e
```

The value of `i` is used twice in the format command, once with `%4d` and once with `%c`. The `%c` specifier takes an integer argument and generates a replacement string consisting of the ASCII character whose represented by the integer.

10.5 Parsing strings with scan

The `scan` command provides almost exactly the same facilities as the `sscanf` procedure from the ANSI C library. `Scan` is roughly the inverse of `format`. It starts with a formatted string, parses the string under the control of a format string, extracts fields corresponding to `%` conversion specifiers in the format string, and places the extracted values in Tcl variables. For example, after the following command is executed variable `a` will have the value `16` and variable `b` will have the value `24.2`:

```
scan "16 units, 24.2% margin" "%d units, %f" a b
⇒ 2
```

The first argument to `scan` is the string to parse, the second is a format string that controls the parsing, and any additional arguments are names of variables to fill in with converted values. The return value of 2 indicates that two conversions were completed successfully.

`Scan` operates by scanning the string and the format together. Each character in the format must match the corresponding character in the string, except for blanks and tabs, which are ignored, and `%` characters. When a `%` is encountered in the format, it indicates the start of a conversion specifier: `scan` converts the next input characters according to the conversion specifier and stores the result in the variable given by the next argument to `scan`. White space in the string is skipped except in the case of a few conversion specifiers such as `%c`.

One common use for scan is for simple string parsing, as in the example above. Another common use is for converting ASCII characters to their integer values, which is done with the `%c` specifier. The procedure below uses this feature to return the character that follows a given character in lexicographic ordering:

```
    proc next c {
        scan $c %c i
        format %c [expr $i+1]
    }
    next a
⇒   b
    next 9
⇒   :
```

The `scan` command converts the value of the `c` argument from an ASCII character to the integer used to represent that character, then the integer is incremented and converted back to an ASCII character again with the `format` command.

10.6 Extracting characters: string index and string range

The remaining string manipulation commands are all implemented as options of the `string` command. For example, `string index` extracts a character from a string:

```
    string index "Sample string" 3
⇒   p
```

The argument after `index` is a string and the last argument gives the index of the desired character in the string. An index of `0` selects the first character.

The `string range` command is similar to `string index` except that it takes two indices and returns all the characters from the first index to the second, inclusive:

```
    string range "Sample string" 3 7
⇒   ple s
```

The second index may have the value `end` to select all the characters up to the end of the string:

```
    string range "Sample string" 3 end
⇒   ple string
```

10.7 Searching and comparison

The command `string first` takes two additional string arguments as in the following example:

```
    string first th "There is the tub where I bathed today"
⇒   3
```

It searches the second string to see if there is a substring that is identical to the first string. If so then it returns the index of the first character in the leftmost matching substring; if not then it returns `-1`. The command `string last` is similar except it returns the starting index of the rightmost matching substring:

```
    string last th "There is the tub where I bathed today"
⇒   21
```

The command `string compare` takes two additional arguments and compares them in their entirety. It returns `0` if the strings are identical, `-1` if the first string sorts before the second, and `1` if the first string is after the second in sorting order:

```
    string compare Michigan Minnesota
⇒   -1
    string compare Michigan Michigan
⇒   0
```

10.8 Length, case conversion, and trimming

The `string length` command counts the number of characters in a string and returns that number:

```
    string length "sample string"
⇒   13
```

The `string toupper` command converts all lower-case characters in a string to upper case, and the `string tolower` command converts all upper-case characters in its argument to lower-case:

```
    string toupper "Watch out!"
⇒   WATCH OUT!
    string tolower "15 Charing Cross Road"
⇒   15 charing cross road
```

The `string` command provides three options for trimming: `trim`, `trimleft`, and `trimright`. Each option takes two additional arguments: a string to trim and an optional set of trim characters. The `string trim` command removes all instances of the trim characters from both the beginning and end of its argument string, returning the trimmed string as result:

```
    string trim aaxxxbab abc
⇒   xxx
```

The `trimleft` and `trimright` options work in the same way except that they only remove the trim characters from the beginning or end of the string, respectively. The trim commands are most commonly used to remove excess white space; if no trim characters are specified then they default to the white space characters (space, tab, newline, and carriage return).

Chapter 11
Accessing Files

This chapter describes Tcl's commands for dealing with files. The commands allow you to read and write files sequentially or in a random-access fashion. They also allow you to retrieve information kept by the system about files, such as the time of last access. Lastly, they can be used to manipulate file names; for example, you can remove the extension from a file name or find the names of all files that match a particular pattern. See Table 11.1 for a summary of the file-related commands.

Note: *The commands described in this chapter are only available on systems that support the kernel calls defined in the POSIX standard, such as most UNIX workstations. If you are using Tcl on another system, such as a Macintosh or a PC, then the file commands may not be present and there may be other commands that provide similar functionality for your system.*

11.1 File names

File names are specified to Tcl using the normal UNIX syntax. For example, the file name `x/y/z` refers to a file named `z` that is located in a directory named `y`, which in turn is located in a directory named `x`, which must be in the current working directory. The file name `/top` refers to a file `top` in the root directory. You can also use tilde notation to specify a file name relative to a particular user's home directory. For example, the name `~ouster/mbox` refers to a file named `mbox` in the home directory of user `ouster`, and `~/mbox` refers to a file named `mbox` in the home directory of the user running the Tcl script. These conventions (and the availability of tilde notation in particular) apply to all Tcl commands that take file names as arguments.

`cd` ?*`dirName`*?	Changes the current working directory to *`dirName`*, or to the home directory (as given by the `HOME` environment variable) if *`dirName`* isn't given. Returns an empty string.
`close` ?*`fileId`*?	Closes the file given by *`fileId`*. Returns an empty string.
`eof` *`fileId`*	Returns `1` if an end-of-file condition has occurred on *`fileId`*, `0` otherwise.
`file` *`option name`* ?*`arg arg`* ...?	Performs one of several operations on the filename given by *`name`* or on the file that it refers to, depending on *`option`*. See Table 11.3 for details.
`flush` *`fileId`*	Writes out any buffered output that has been generated for *`fileId`*. Returns an empty string.
`gets` *`fileId`* ?*`varName`*?	Reads the next line from *`fileId`* and discards its terminating newline. If *`varName`* is specified, places the line in that variable and returns a count of characters in the line (or `-1` for end of file). If *`varName`* isn't specified, returns line as result (or an empty string for end of file).
`glob` ?`-nocomplain`? ?`--`? *`pattern`* ?*`pattern`* ...?	Returns a list of the names of all files that match any of the *`pattern`* arguments (special characters `?`, `*`, `[]`, {}, and `\`). If `-nocomplain` isn't specified then an error occurs if the return list would be empty.
`open` *`name`* ?*`access`*?	Opens file *`name`* in the mode given by *`access`*. Access may be `r`, `r+`, `w`, `w+`, `a`, or `a+` or a list of flags such as `RDONLY`; it defaults to `r`. Returns a file identifier for use in other commands like `gets` and `close`. If the first character of *`name`* is "`|`" then a command pipeline is invoked instead of opening a file (see Section 12.2 for more information).
`puts` ?`-nonewline`? ?*`fileId`*? *`string`*	Writes *`string`* to *`fileId`*, appending a newline character unless `-nonewline` is specified. *`FileId`* defaults to `stdout`. Returns an empty string.
`pwd`	Returns the full path name of the current working directory.

Table 11.1. A summary of the Tcl commands for manipulating files (continued in Table 11.2).

`read ?-nonewline? fileId`	Reads and returns all of the bytes remaining in *`fileId`*. If `-nonewline` is specified then the final newline, if any, is dropped.
`read fileId numBytes`	Reads and returns the next *`numBytes`* bytes from *`fileId`* (or up to the end of the file, if fewer than *`numBytes`* bytes are left).
`seek fileId offset ?origin?`	Position *`fileId`* so that the next access starts at *`offset`* bytes from *`origin`*. *`Origin`* may be `start`, `current`, or `end`, and defaults to `start`. Returns an empty string.
`tell fileId`	Returns the current access position for *`fileId`*.

Table 11.2. A summary of the Tcl commands for manipulating files, cont'd.

11.2 Basic file I/O

The Tcl commands for file I/O are similar to the procedures in the C standard I/O library, both in their names and in their behavior. Here is a script called `tgrep` that illustrates most of the basic features of file I/O:

```
#!/usr/local/bin/tclsh
if {$argc != 2} {
    error "Usage: tgrep pattern fileName"
}
set f [open [lindex $argv 1] r]
set pat [lindex $argv 0]
while {[gets $f line] >= 0} {
    if [regexp $pat $line] {
        puts stdout $line
    }
}
close $f
```

This script behaves much like the UNIX `grep` program: you can invoke it from your shell with two arguments, a regular expression pattern and a file name, and it will print out all of the lines in the file that match the pattern.

When `tclsh` processes evaluates the script it makes the command-line arguments available as a list in variable `argv`, with the length of that list in variable `argc`. After making sure that it received enough arguments, the script invokes the `open` command on the file to search, which is the second argument. `Open` takes two arguments, the name of a file and an access mode. The access mode provides information such as whether you'll be reading the file or writing it, and whether you want to append to the file or access it from the beginning. The access mode may have one of the following values:

`r`	Open for reading only. The file must already exist. This is the default if the access mode isn't specified.
`r+`	Open for reading and writing; the file must already exist.
`w`	Open for writing only. Truncate the file if it already exists, otherwise create a new empty file.
`w+`	Open for reading and writing. Truncate the file if it already exists, otherwise create a new empty file.
`a`	Open for writing only and set the initial access position to the end of the file. If the file doesn't exist then create a new empty file.
`a+`	Open the file for reading and writing and set the initial access position to the end of the file. If the file doesn't exist then create a new empty file.

The access mode may also be specified as a list of POSIX flags like `RDONLY`, `CREAT`, and `TRUNC`. See the reference documentation for more information about these flags.

The `open` command returns a string such as `file3` that identifies the open file. This *file identifier* is used when invoking other commands to manipulate the open file, such as `gets`, `puts`, and `close`. Normally you will save the file identifier in a variable when you open a file and then use that variable to refer to the open file. You should not expect the identifiers returned by `open` to have any particular format.

Three file identifiers have well-defined names and are always available to you, even if you haven't explicitly opened any files. These are `stdin`, `stdout`, and `stderr`; they refer to the standard input, output, and error channels for the process in which the Tcl script is executing.

After opening the file to search, the `tgrep` script reads the file one line at a time with the `gets` command. `Gets` normally takes two arguments: a file identifier and the name of a variable. It reads the next line from the open file, discards the terminating newline character, stores the line in the named variable, and returns a count of the number of characters stored into the variable. If the end of the file is reached before reading any characters then `gets` stores an empty string in the variable and returns `-1`.

Note: Tcl also provides a second form of `gets` where the line is returned as the result of the command, and a command `read` for non-line-oriented input.

For each line in the file the `tgrep` script matches the line against the pattern and prints it using `puts` if it matches. The `puts` command takes two arguments, which are a file identifier and a string to print. `Puts` adds a newline character to the string and outputs the line on the given file. The script uses `stdout` as the file identifier so the line is printed on standard output.

When `tgrep` reaches the end of the file `gets` will return `-1`, which ends the `while` loop. The script then closes the file with the `close` command; this releases the resources associated with the open file. In most systems there is a limit on how many files may be open at one time in an application, so it is important to close files as soon as you are finished reading or writing them. In this example the close is unnecessary, since the file will be closed automatically when the application exits.

11.3 Output buffering

The `puts` command uses the buffering scheme of the C standard I/O library. This means that information passed to `puts` may not appear immediately in the target file. In many cases (particularly if the file isn't a terminal device) output will be saved in the application's memory until a large amount of data has accumulated for the file, at which point all of the data will be written out in a single operation. If you need for data to appear in a file immediately then you should invoke the `flush` command:

```
flush $f
```

The `flush` command takes a file identifier as its argument and forces any buffered output data for that file to be written to the file. `Flush` doesn't return until the data has been written. Buffered data is also flushed when a file is closed.

11.4 Random access to files

File I/O is sequential by default: each `gets` or `read` command returns the next bytes after the previous `gets` or `read` command, and each `puts` command writes its data immediately following the data written by the previous `puts` command. However, you can use the `seek`, `tell`, and `eof` commands to access files non-sequentially.

Each open file has an *access position*, which is the location in the file where the next read or write will occur. When a file is opened the access position is set to the beginning or end of the file, depending on the access mode you specified to `open`. After each read or write operation the access position increments by the number of bytes transferred. The `seek` command may be used to change the current access position. In its simplest form `seek` takes two arguments, which are a file identifier and an integer offset within the file. For example, the command

```
seek $f 2000
```

changes the access position for the file so that the next read or write will start at byte number 2000 in the file.

`Seek` can also take a third argument that specifies an origin for the offset. The third argument must be either `start`, `current`, or `end`. `Start` produces the same effect as if the argument is omitted: the offset is measured relative to the start of the file. `Current` means that the offset is measured relative to the file's current access position, and `end` means that the offset is measured relative to the end of the file. For example, the following command sets the access position to 100 bytes before the end of the file:

```
seek $f -100 end
```

If the origin is `current` or `end` then the offset may be either positive or negative; for `start` the offset must be positive.

Note: It is possible to seek past the current end of the file, in which case the file may contain a hole. Check the documentation for your operating system for more information on what this means.

The `tell` command returns the current access position for a particular file identifier:

```
tell $f
⇒ 186
```

This allows you to record a position and return to that position later on.

The `eof` command takes a file identifier as argument and returns `0` or `1` to indicate whether the most recent `gets` or `read` command for the file attempted to read past the end of the file:

```
eof $f
⇒ 0
```

11.5 The current working directory

Tcl provides two commands that help to manage the current working directory: `pwd` and `cd`. `Pwd` takes no arguments and returns the full path name of the current working directory. `Cd` takes a single argument and changes the current working directory to the value of that argument. If `cd` is invoked with no arguments then it changes the current working directory to the home directory of the user running the Tcl script (`cd` uses the value of the `HOME` environment variable as the path name of the home directory).

11.6 Manipulating file names: glob and file

Tcl has two commands for manipulating file *names* as opposed to file contents: `glob` and `file`. The `glob` command takes one or more patterns as arguments and returns a list of all the file names that match the pattern(s):

```
glob *.c *.h
⇒ main.c hash.c hash.h
```

`Glob` uses the matching rules of the `string match` command (see Section 10.1). In the above example `glob` returns the names of all files in the current directory that end in `.c` or `.h`. `Glob` also allows patterns to contain comma-separated lists of alternatives between braces, as in the following example:

```
glob {{src,backup}/*.[ch]}
⇒ src/main.c src/hash.c src/hash.h backup/hash.c
```

`Glob` treats this pattern as if it were actually multiple patterns, one containing each of the strings, as in the following example:

```
glob {src/*.[ch]} {backup/*.[ch]}
```

Note: The extra braces around the patterns in these examples are needed to keep the brackets inside the patterns from triggering command substitution. They are removed by the Tcl parser in the usual fashion before invoking the command procedure for `glob`.

If a `glob` pattern ends in a slash then it only matches the names of directories. For example, the command

```
glob */
```

will return a list of all the subdirectories of the current directory.

If the list of file names to be returned by `glob` is empty then it normally generates an error. However, if the first argument to `glob`, before any patterns, is `-nocomplain` then `glob` will not generate an error if its result is an empty list.

The second command for manipulaing file names is `file`. `File` is a general-purpose command with many options that can be used both to manipulate file names and also to retrieve information about files. See Tables 11.3 and 11.4 for a summary of the options to `file`. This section discusses the name-related options and Section 11.7 describes the other options.The commands in this section operate purely on file names. They make no system calls and do not check to see if the names actually correspond to files.

`File dirname` returns the name of the directory containing a particular file:

```
  file dirname /a/b/c
⇒ /a/b
  file dirname main.c
⇒ .
```

`File extension` returns the extension for a file name (all the characters starting with the last `.` in the name), or an empty string if the name contains no extension:

```
  file extension src/main.c
⇒ .c
```

`File rootname` returns everything in a file name except the extension:

```
  file rootname src/main.c
⇒ src/main
  file rootname foo
⇒ foo
```

Lastly, `file tail` returns the last element in a file's path name (i.e. the name of the file within its directory):

```
  file tail /a/b/c
⇒ c
  file tail foo
⇒ foo
```

`file atime` *`name`*	Returns a decimal string giving the time at which file *`name`* was last accessed, measured in seconds from 12:00 A.M. on January 1, 1970.
`file dirname` *`name`*	Returns all of the characters in *`name`* up to but not including the last `/` character. Returns `.` if *`name`* contains no slashes, `/` if the last slash in *`name`* is its first character.
`file executable` *`name`*	Returns `1` if *`name`* is executable by the current user, `0` otherwise.
`file exists` *`name`*	Returns `1` if *`name`* exists and the current user has search privilege for the directories leading to it, `0` otherwise.
`file extension` *`name`*	Returns all of the characters in *`name`* after and including the last dot. Returns an empty string if there is no dot in *`name`* or no dot after the last slash in *`name`*.
`file isdirectory` *`name`*	Returns `1` if *`name`* is a directory, `0` otherwise.
`file isfile` *`name`*	Returns `1` if *`name`* is an ordinary file, `0` otherwise.
`file lstat` *`name arrayName`*	Invokes the `lstat` system call on *`name`* and sets elements of *`arrayName`* to hold information returned by `lstat`. This option is identical to the `stat` option unless *`name`* refers to a symbolic link, in which case this command returns information about the link instead of the file it points to.
`file mtime` *`name`*	Returns a decimal string giving the time at which file *`name`* was last modified, measured in seconds from 12:00 A.M. on January 1, 1970.
`file owned` *`name`*	Returns `1` if *`name`* is owned by the current user, `0` otherwise.
`file readable` *`name`*	Returns `1` if *`name`* is readable by the current user, `0` otherwise.
`file readlink` *`name`*	Returns the value of the symbolic link given by *`name`* (the name of the file it points to).

Table 11.3. A summary of the options for the `file` command (continued in Table 11.4).

`file rootname` *`name`*	Returns all of the characters in *`name`* up to but not including the last `.` character. Returns *`name`* if it doesn't contain any dots or if it doesn't contain any dots after the last slash.
`file size` *`name`*	Returns a decimal string giving the size of file `name` in bytes.
`file stat` *`name arrayName`*	Invokes `stat` system call on *`name`* and sets elements of *`arrayName`* to hold information returned by `stat`. The following elements are set, each as a decimal string: `atime`, `ctime`, `dev`, `gid`, `ino`, `mode`, `mtime`, `nlink`, `size`, and `uid`.
`file tail` *`name`*	Returns all of the characters in *`name`* after the last `/` character. Returns *`name`* if it contains no slashes.
`file type` *`name`*	Returns a string giving the type of file *`name`*. The return value will be one of `file`, `directory`, `characterSpecial`, `blockSpecial`, `fifo`, `link`, or `socket`.
`file writable` *`name`*	Returns `1` if *`name`* is writable by the current user, `0` otherwise.

Table 11.4. A summary of the options for the `file` command, cont'd.

11.7 File information commands

In addition to the options already discussed in Section 11.6 above, the `file` command provides many other options that can be used to retrieve information about files. Each of these options except `stat` and `lstat` has the form

```
file option name
```

where *`option`* specifies the information desired, such as `exists` or `readable` or `size`, and *`name`* is the name of the file. Table 11.3 summarizes all of the options for the `file` command.

The `exists`, `isfile`, `isdirectory`, and `type` options return information about the nature of a file. `File exists` returns `1` if there exists a file by the given name and `0` if there is no such file or the current user doesn't have search permission for the directories leading to it. `File isfile` returns `1` if the file is an ordinary disk file and `0` if it is something else, such as a directory or device file. `File isdirectory` returns `1` if the file is a directory and `0` otherwise. `File type` returns a string such as `file`, `direc-tory`, or `socket` that identifies the file type.

The `readable`, `writable`, and `executable` options return `0` or `1` to indicate whether the current user is permitted to carry out the indicated action on the file. The `owned` option returns `1` if the current user is the file's owner and `0` otherwise.

The `size` option returns a decimal string giving the size of the file in bytes. `File mtime` returns the time when the file was last modified. The time value is returned in the standard POSIX form for times, namely an integer that counts the number of seconds since 12:00 A.M. on January 1, 1970. The `atime` option is similar to `mtime` except that it returns the time when the file was last accessed.

The `stat` option provides a simple way to get many pieces of information about a file at one time. This can be significantly faster than invoking `file` many times to get the pieces of information individually. `File stat` also provides additional information that isn't accessible with any other file options. It takes two additional arguments, which are the name of a file and the name of a variable, as in the following example:

```
file stat main.c info
```

In this case the name of the file is `main.c` and the variable name is `info`. The variable will be treated as an array and the following elements will be set, each as a decimal string:

`atime`	Time of last access.
`ctime`	Time of last status change.
`dev`	Identifier for device containing file.
`gid`	Identifier for the file's group.
`ino`	Serial number for the file within its device.
`mode`	Mode bits for file.
`mtime`	Time of last modification.
`nlink`	Number of links to file.
`size`	Size of file, in bytes.
`uid`	Identifier for the user that owns the file.

The `atime`, `mtime`, and `size` elements have the same values as produced by the corresponding `file` options discussed above. For more information on the other elements, refer to your system documentation for the `stat` system call; each of the elements is taken directly from the corresponding field of the structure returned by `stat`.

The `lstat` and `readlink` options are useful when dealing with symbolic links, and they can only be used on systems that support symbolic links. `File lstat` is identical to `file stat` for ordinary files, but when it is applied to a symbolic link it returns information about the symbolic link itself, whereas `file stat` will return information about the file the link points to. `File readlink` returns the contents of a symbolic link, i.e. the name of the file that it refers to; it may only be used on symbolic links. For all of the other `file` commands, if the name refers to a symbolic link then the command operates on the target of the link, not the link itself.

11.8 Errors in system calls

Most of the commands described in this chapter invoke calls on the operating system, and in many cases the system calls can return errors. This can happen, for example, if you invoke `open` or `file stat` on a file that doesn't exist, or if an I/O error occurs in reading a file. The Tcl commands detect these system call errors and in most cases the Tcl commands will return errors themselves. The error message will identify the error that occurred:

```
   open bogus
∅  couldn't open "bogus": no such file or directory
```

When an error occurs in a system call Tcl also sets the `errorCode` variable to provide more precise information. You may find this information useful as part of error recovery so that, for example, you can determine exactly why the the file wasn't accessible (Was there no such file? Was it protected to prevent access? ...). If a system call error has occurred then `errorCode` will consist of a list with three elements:

```
   set errorCode
⇒  POSIX ENOENT {no such file or directory}
```

The first element is always `POSIX` to indicate that the error occurred in a POSIX system call. The second element is the official name for the error (`ENOENT` in the above example). Refer to your system documentation or to the include file `errno.h` for a complete list of the error names for your system. These names adhere to the POSIX standard as much as possible. The third element is the error message that corresponds to the error. This string usually appears in the error message returned by the Tcl command. Tcl uses the standard list of error messages provided by your system, if there is one, and adheres to the POSIX standard as much as possible.

Chapter 12
Processes

Tcl provides several commands for dealing with processes. You can create new processes with the `exec` command, or you can create new processes with `open` and then use file I/O commands to communicate with them. You can access process identifiers with the `pid` command. You can read and write environment variables using the `env` variable and you can terminate the current process with the `exit` command. Like the file commands in Chapter 11, these commands are only available on systems that support POSIX kernel calls. Table 12.1 summarizes the commands related to process management.

12.1 Invoking subprocesses with exec

The `exec` command creates one or more subprocesses and waits until they complete before returning. For example,

```
exec rm main.o
```

executes `rm` as a subprocess, passes it the argument `main.o`, and returns after `rm` completes. The arguments to `exec` are similar to what you would type as a command line to a shell program such as `sh` or `csh`. The first argument to `exec` is the name of a program to execute and each additional argument forms one argument to that subprocess.

To execute a subprocess, `exec` looks for an executable file with a name equal to `exec`'s first argument. If the name contains a `/` or starts with `~` then `exec` checks the single file indicated by the name. Otherwise `exec` checks each of the directories in the `PATH` environment variable to see if the command name refers to an executable file in that directory. `Exec` uses the first executable that it finds.

`exec ?-keepnewline? ?--? arg ?arg ...?`	Executes command pipeline specified by *`arg`*'s using one or more subprocesses and returns the pipeline's standard output or an empty string if output is redirected (the trailing newline, if any, is dropped unless `-keepnewline` is specified). I/O redirection may be specified with `<`, `<<`, and `>` and several other forms and pipes may be specified with `|`. If the last *`arg`* is `&` then the pipeline is executed in background and the return value is a list of its process ids.
`exit ?code?`	Terminates process, returning *`code`* to parent as exit status. *`Code`* must be an integer. *`Code`* defaults to 0.
`open |command ?access?`	Treats *`command`* as a list with the same structure as arguments to `exec` and creates subprocess(es) to execute command(s). Depending on *`access`*, creates pipes for writing input to pipeline and reading output from it.
`pid ?fileId?`	If *`fileId`* is omitted, returns the process identifier for the current process. Otherwise returns a list of all the process ids in the pipeline associated with *`fileId`* (which must have been opened using |).

Table 12.1. A summary of Tcl commands for manipulating processes.

`Exec` collects all of the information written to standard output by the subprocess and returns that information as its result, as in the following example:

```
     exec echo wc tcl.h
⇒        618    2641   21825 tcl.h
```

If the last character of output is a newline then `exec` removes the newline. This behavior may seem strange but it makes `exec` consistent with other Tcl commands,which don't normally terminate the last line of the result; you can retain the newline by specifying `-keepnewline` as the first argument to `exec`.

`Exec` supports I/O redirection in a fashion similar to the UNIX shells. For example, if one of the arguments to `exec` is "`>foo`" (or if there is a "`>`" argument followed by a "`foo`" argument), then output from the process is placed in file `foo` instead of returning to Tcl as `exec`'s result. In this case `exec`'s result will be an empty string. `Exec` also supports several other forms of output redirection, such as `>>` to append to a file, `>&` to redirect both standard output and standard error, and `2>` to redirect standard error independently from standard output.

Standard input may be redirected using either `<` or `<<`. The `<` form causes input to be taken from a file. In the `<<` form the following argument is not a file name, but rather an immediate value to be passed to the subprocess as its standard input. The following command uses `<<` to write data to a file:

```
exec cat << "test data" > foo
```

The string "`test input`" is passed to `cat` as its standard input; `cat` copies the string to its standard ouput, which has been redirected to file `foo`. If no input redirection is specified then the subprocess inherits the standard input channel from the Tcl application.

You can also invoke a pipeline of processes instead of a single process using `|`, as in the following example:

```
    exec grep #include tclInt.h | wc
⇒          8      25     212
```

The `grep` program extracts all the lines containing the string "`#include`" from the file `tclInt.h`. These lines are then piped to the `wc` program, which computes the number of lines, words, and characters in the `grep` output and prints this information on its standard output. The `wc` output is returned as the result of `exec`.

If the last argument to `exec` is `&` then the subprocess(es) will be executed in background. `Exec` will return immediately, without waiting for the subprocesses to complete. Its return value will be a list containing the process identifiers for all of the processes in the pipeline; standard output from the subprocesses will go to the standard output of Tcl application unless redirected. No errors will be reported for abnormal exits or standard error output, and standard error for the subprocesses will be directed to the standard error channel of the Tcl application.

If a subprocess is suspended or exits abnormally (i.e., it is killed or returns a non-zero exit status), or if it generates output on its standard error channel and standard error was not redirected, then `exec` returns an error. The error message will consist of the output generated by the last subprocess (unless it was redirected with `>`), followed by an error message for each process that exited abnormally, followed by the information generated on standard error by the processes, if any. In addition, `exec` will set the `errorCode` variable to hold information about the last process that terminated abnormally, if any (see the reference documentation for details).

Note: *Many UNIX programs are careless about the exit status that they return. If you invoke such a program with `exec` and it accidentally returns a non-zero status then the `exec` command will generate a false error. To prevent these errors from aborting your scripts, invoke `exec` inside a `catch` command.*

Although `exec`'s features are similar to those of the UNIX shells there is one important difference: `exec` does not perform any file name expansion. For example, suppose you invoke the following command with the goal of removing all `.o` files in the current directory:

```
    exec rm *.o
∅   rm: *.o nonexistent
```

`Rm` receives "`*.o`" as its argument and exits with an error when it cannot find a file by this name. If you want file name expansion to occur you can use the `glob` command to get it, but not in the obvious way. For example, the following command will not work:

```
   exec rm [glob *.o]
∅  rm: a.o b.o nonexistent
```

This fails because the list of file names that `glob` returns is passed to `rm` as a single argument. If, for example, there exist two `.o` files, `a.o` and `b.o`, then rm's argument will be "`a.o b.o`"; since there is no file by that name `rm` will return an error. The solution to this problem is the one described in Section 7.5: use `eval` to reparse the `glob` output so that it gets divided into multiple words. For example, the following command will do the trick:

```
eval exec rm [glob *.o]
```

In this case `eval` concatenates its arguments to produce the string

```
exec rm a.o b.o
```

which it then evaluates as a Tcl script. The names `a.o` and `b.o` are passed to `rm` as separate arguments and the files are deleted as expected.

12.2 I/O to and from a command pipeline

You can also create subprocesses using the `open` command; once you've done this you can then use commands like `gets` and `puts` to interact with the pipeline. Here are two simple examples:

```
set f1 [open {|tbl | ditroff -ms} w]
set f2 [open |prog r+}
```

If the first character of the "file name" passed to `open` is the pipe symbol `|` then the argument isn't really a file name at all. Instead, it specifies a command pipeline. The remainder of the argument after the `|` is treated as a list whose elements have exactly the same meaning as the arguments to the `exec` command. `Open` will create a pipeline of subprocesses just as for `exec` and it will return an identifier that you can use to transfer data to and from the pipeline. In the first example the pipeline is opened for writing, so a pipe is used for standard input to the `tbl` process and you can invoke `puts` to write data on that pipe; the output from `tbl` goes to `ditroff`, and the output from `ditroff` goes to the standard output of the Tcl application. The second example opens a pipeline for both reading and writing so separate pipes are created for `prog`'s standard input and standard output. Commands like `puts` can be used to write data to `prog` and commands like `gets` can be used to read the output from `prog`.

Note: *When writing data to a pipeline, don't forget that output is buffered: it probably will not actually be sent to the child process until you invoke the `flush` command to force the buffered data to be written.*

When you close a file identifier that corresponds to a command pipeline, the `close` command flushes any buffered output to the pipeline, closes the pipes leading to and from the pipeline, if any, and waits for all of the processes in the pipeline to exit. If any of the processes exit abnormally then `close` returns an error in the same way as `exec`.

12.3 Process ids

Tcl provides three ways that you can access process identifiers. First, if you invoke a pipeline in background using `exec` then `exec` returns a list containing the process identifiers for all of the subprocesses in the pipeline. You can use these identifers, for example, if you wish to kill the processes. Second, you can invoke the `pid` command with no arguments and it will return the process identifier for the current process. Third, you can invoke `pid` with a file identifier as argument, as in the following example:

```
set f [open {| tbl | ditroff -ms} w]
pid $f
⇒ 7189 7190
```

If there is a pipeline corresponding to the open file, as in the example, then the `pid` command will return a list of identifiers for the processes in the pipeline.

12.4 Environment variables

Environment variables can be read and written using the standard Tcl variable mechanism. The array variable `env` contains all of the environment variables as elements, with the name of the element in `env` corresponding to the name of the environment variable. If you modify the `env` array, the changes will be reflected in the process's environment variables and the new values will also be passed to any child process created with `exec` or `open`.

12.5 Terminating the Tcl process with exit

If you invoke the `exit` command then it will terminate the process in which the command was executed. `Exit` takes an optional integer argument. If this argument is provided then it is used as the exit status to return to the parent process. `0` indicates a normal exit and non-zero values correspond to abnormal exits; values other than `0` and `1` are rare. If no argument is given to `exit` then it exits with a status of `0`. Since `exit` terminates the process, it doesn't have any return value.

Chapter 13
Managing Tcl Internals

This chapter describes a collection of commands that allow you to query and manipulate the internal state of the Tcl interpreter. For example, you can use these commands to see if a variable exists, to find out what entries are defined in an array, to monitor all accesses to a variable, to rename or delete a command, or to handle references to undefined commands. Tables 13.1 and 13.2 summarize the commands.

13.1 Querying the elements of an array

The `array` command provides information about the elements currently defined for an array variable. It provides this information in several different ways, depending on the first argument passed to it. The command `array size` returns a decimal string indicating how many elements are defined for a given array variable and the command `array names` returns a list whose entries are the names of the elements of a given array variable:

```
    set currency(France) franc
    set "currency(Great Britain)" pound
    set currency(Germany) mark
    array size currency
⇒  3
    array names currency
⇒  {Great Britain} France Germany
```

For each of these commands the final argument must be the name of an array variable. The list returned by `array names` does not have any particular order.

`array anymore` *`name searchId`*	Returns `1` if there are any more elements to process in search *`searchId`* of array *`name`*, `0` if all elements have already been returned.
`array donesearch` *`name searchId`*	Terminates search *`searchId`* of array *`name`* and discard any state associated with the search. Returns an empty string.
`array names` *`name`*	Returns a list containing the names of all the elements of array *`name`*.
`array nextelement` *`name searchId`*	Returns the name of the next element in search *`searchId`* of array *`name`*, or an empty string if all elements have already been returned in this search.
`array size` *`name`*	Returns a decimal string giving the number of elements in array *`name`*.
`array startsearch` *`name`*	Initializes a search through all of the elements of array *`name`*. Returns a search identifier that may be passed to `array nextelement`, `array anymore`, or `array donesearch.`
`auto_mkindex` *`dir pattern`*	Scans all of the files in diretory *`dir`* whose names match *`pattern`* (using the glob-style rules of `string match`) and generates a file `tclIndex` in *`dir`* that allows the files to be auto-loaded.
`info` *`option`* ?*`arg arg`* ...?	Returns information about the state of the Tcl interpreter. See Table 13.3.
`rename` *`old new`*	Renames command *`old`* to *`new`*, or deletes *`old`* if *`new`* is an empty string. Returns an empty string.
`time` *`script`* ?*`count`*?	Executes *`script count`* times and returns a string giving the average elapsed time per execution. *`Count`* defaults to 1.

Table 13.1. A summary of commands for manipulating Tcl's internal state (continued in Table 13.2).

The `array names` command can be used in conjunction with `foreach` to iterate through the elements of an array. For example, the code below deletes all elements of an array with values that are `0` or empty:

```
foreach i [array names a] {
    if {($a($i) == "") || ($a($i) == 0))} {
        unset a($i)
    }
}
```

`trace variable` *`name ops command`*	Establishes a trace on variable *`name`* such that *`command`* is invoked whenever one of the operations given by *`ops`* is performd on *`name`*. *`Ops`* must consist of one or more of the characters `r`, `w`, or `u`. Returns an empty string.
`trace vdelete` *`name ops command`*	If there exists a trace for variable *`name`* that has the operations and command given by *`ops`* and *`command`*, removes that trace so that its command will not be executed anymore. Returns an empty string.
`trace vinfo` *`name`*	Returns a list with one element for each trace currently set on variable *`name`*. Each element is a sub-list with two elements, which are the *`ops`* and *`command`* associated with that trace.
`unknown` *`cmd`* ?*`arg arg`* ...?	This command is invoked by the Tcl interpreter whenever an unknown command name is encountered. *`Cmd`* will be the unknown command name and the *`arg`*'s will be the fully-substituted arguments to the command. The result returned by `unknown` will be returned as the result of the unknown command.

Table 13.2. Commands for manipulating Tcl's internal state, cont'd.

Note: *The `array` command also provides a second way to search through the elements of an array, using the `startsearch`, `anymore`, `nextelement`, and `donesearch` options. This approach is more general than the `foreach` approach given above, and in some cases it is more efficient, but it is more verbose than the `foreach` approach and isn't needed very often. See the reference documentation for details.*

13.2 The info command

The `info` command provides information about the state of the interpreter. It has more than a dozen options, which are summarized in Tables 13.3 and 13.4.

13.2.1 Information about variables

Several of the `info` options provide information about variables. `Info exists` returns a `0` or `1` value indicating whether or not there exists a variable with a given name:

```
   set x 24
   info exists x
⇒  1
```

`info args` *`procName`*	Returns a list whose elements are the names of the arguments to procedure *`procName`*, in order.
`info body` *`procName`*	Returns the body of procedure *`procName`*.
`info cmdcount`	Returns a count of the total number of Tcl commands that have been executed in this interpreter.
`info commands` ?*`pattern`*?	Returns a list of all the commands defined for this interpreter, including built-in commands, application-defined commands, and procedures. If *`pattern`* is specified then only the command names matching *`pattern`* are returned (`string match`'s rules are used for matching).
`info default` *`procName argName varName`*	Checks to see if argument *`argName`* to procedure *`procName`* has a default value. If so, stores the default value in variable *`varName`* and returns `1`. Otherwise, returns `0` without modifying *`varName`*.
`info exists` *`varName`*	Returns `1` if there exists a variable named *`varName`* in the current context, `0` if no such variable is currently accessible.
`info globals` ?*`pattern`*?	Returns a list of all the global variables currently defined. If *`pattern`* is specified, then only the global variable names matching *`pattern`* are returned (`string match`'s rules are used for matching).
`info level` ?*`number`*?	If *`number`* isn't specified, returns a number giving the current stack level (`0` corresponds to top-level, `1` to the first level of procedure call, and so on). If *`number`* is specified, returns a list whose elements are the name and arguments for the procedure call at level *`number`*.
`info library`	Returns the full path name of the library directory in which standard Tcl scripts are stored.
`info locals` ?*`pattern`*?	Returns a list of all the local variables defined for the current procedure, or an empty string if no procedure is active. If *`pattern`* is specified then only the local variable names matching *`pattern`* are returned (`string match`'s rules are used for matching).

Table 13.3. A summary of the options for the `info` command (continued in Table 13.4).

`info procs ?`*`pattern`*`?`	Returns a list of the names of all procedures currently defined. If *`pattern`* is specified then only the procedure names matching *`pattern`* are returned (`string match`'s rules are used for matching).
`info script`	If a script file is currently being evaluated then this command returns the name of that file. Otherwise it returns an empty string.
`info tclversion`	Returns the version number for the Tcl interpreter in the form *`major.minor`*, where *`major`* and *`minor`* are each decimal integers. Increments in *`minor`* correspond to bug fixes, new features, and backwards-compatible changes. *`Major`* increments only when incompatible changes occur.
`info vars ?`*`pattern`*`?`	Returns a list of all the names of all variables that are currently accessible. If *`pattern`* is specified then only the variable names matching *`pattern`* are returned (`string match`'s rules are used for matching).

Table 13.4. A summary of the options for the `info` command, cont'd.

```
    unset x
    info exists x
⇒  0
```

The options `vars`, `globals`, and `locals` return lists of variable names that meet certain criteria. `Info vars` returns the names of all variables accessible at the current level of procedure call; `info globals` returns the names of all global variables, regardless of whether or not they are accessible; and `info locals` returns the names of local variables, including arguments to the current procedure, if any, but not global variables. In each of these commands an additional pattern argument may be supplied. If the pattern is supplied then only variable names matching that pattern (using the rules of `string match`) will be returned.

For example, suppose that global variables `global1` and `global2` have been defined and that the following procedure is being executed:

```
proc test {arg1 arg2} {
    global global1
    set local1 1
    set local2 2
    ...
}
```

Then the following commands might be executed in the procedure:

```
   info vars
⇒  global1 arg1 arg2 local2 local1
   info globals
⇒  global2 global1
   info locals
⇒  arg1 arg2 local2 local1
   info vars *al*
⇒  global1 local2 local1
```

13.2.2 Information about procedures

Another group of `info` options provides information about procedures. The command `info procs` returns a list of all the Tcl procedures that are currently defined. Like `info vars`, it takes an optional pattern argument that restricts the names returned to those that match a given pattern. `Info body`, `info args`, and `info default` return information about the definition of a procedure:

```
   proc maybePrint {a b {c 24}} {
       if {$a < $b}{
           puts stdout "c is $c"
       }
   }
   info body maybePrint
⇒
       if {$a < $b} {
           puts stdout "c is $c"
       }

   info args maybePrint
⇒  a b c
   info default maybePrint a x
⇒  0
   info default maybePrint c x
⇒  1
   set x
⇒  24
```

`Info body` returns the procedure's body exactly as it was specified to the `proc` command. `Info args` returns a list of the procedure's argument names, in the same order they were specified to `proc`. `Info default` returns information about an argument's default value. It takes three arguments: the name of a procedure, the name of an argument to that procedure, and the name of a variable. If the given argument has no default value (e.g. `a` in the above example), `info default` returns `0`. If the argument has a default value (`c` in the above example) then `info default` returns `1` and sets the variable to hold the default value for the argument.

As an example of how you might use the commands from the previous paragraph, here is a Tcl procedure that writes a Tcl script file. The script will contain Tcl code in the form of `proc` commands that recreate all of the procedures in the interpreter. The file can then be `source`'d in some other interpreter to duplicate the procedure state of the original interpreter. The procedure takes a single argument, which is the name of the file to write:

```
proc printProcs file {
    set f [open $file w]
    foreach proc [info procs] {
        set argList {}
        foreach arg [info args $proc] {
            if [info default $proc $arg default] {
                lappend argList [list $arg $default]
            } else {
                lappend argList $arg
            }
        }
        puts $f [list proc $proc $argList \
                [info body $proc]]
    }
    close $f
}
```

`Info` provides one other option related to procedures: `info level`. If `info level` is invoked with no additional arguments then it returns the current procedure invocation level: `0` if no procedure is currently active, `1` if the current procedure was called from top-level, and so on. If `info level` is given an additional argument, the argument indicates a procedure level and `info level` returns a list whose elements are the name and actual arguments for the procedure at that level. For example, the following procedure prints out the current call stack, showing the name and arguments for each active procedure:

```
proc printStack {} {
    set level [info level]
    for {set i 1} {$i < $level} {incr i} {
        puts "Level $i: [info level $i]"
    }
}
```

13.2.3 Information about commands

`Info commands` is similar to `info procs` except that it returns information about all existing commands, not just procedures. If invoked with no arguments, it returns a list of the names of all commands; if an argument is provided, then it is a pattern in the sense of `string match` and only command names matching that pattern will be returned.

The command `info cmdcount` returns a decimal string indicating how many commands have been executed in this Tcl interpreter. It may be useful during peformance tuning to see how many Tcl commands are being executed to carry out various functions.

The command `info script` indicates whether or not a script file is currently being processed. If so then the command returns the name of the innermost nested script file that is active. If there is no active script file then `info script` returns an empty string. This command is used for relatively obscure purposes such as disallowing command abbreviations in script files.

13.2.4 Tclversion and library

`Info tclversion` returns the version number for the Tcl interpreter in the form *`major.minor`*. Each of *`major`* and *`minor`* is a decimal string. If a new release of Tcl contains only backwards-compatible changes such as bug fixes and new features, then its minor version number increments and the major version number stays the same. If a new release contains changes that are not backwards-compatible, so that existing Tcl scripts or C code that invokes Tcl's library procedures will have to be modified, then the major version number increments and the minor version number resets to 0.

The command `info library` returns the full path name of the Tcl library directory. This directory is used to hold standard scripts used by Tcl, such as a default definition for the `unknown` procedure described in Section 13.6 below.

13.3 Timing command execution

The `time` command is used to measure the performance of Tcl scripts. It takes two arguments, a script and a repetition count:

```
    time {set a xyz} 10000
 ⇒  92 microseconds per iteration
```

`Time` will execute the given script the number of times given by the repetition count, divide the total elapsed time by the repetition count, and print out a message like the above one giving the average number of microseconds per iteration. The reason for the repetition count is that the clock resolution on most workstations is many milliseconds. Thus anything that takes less than tens or hundreds of milliseconds cannot be timed accurately. To make accurate timing measurements, I suggest experimenting with the repetition count until the total time for the `time` command is a few seconds.

13.4 Tracing operations on variables

The `trace` command allows you to monitor the usage of one or more Tcl variables. Such monitoring is called *tracing*. If a trace has been established on a variable then a Tcl command will be invoked whenever the variable is read or written or unset. Traces can be used for a variety of purposes:

- monitoring the variable’s usage (e.g. by printing a message for each read or write operation)
- propagating changes in the variable to other parts of the system (e.g. to ensure that a particular widget always displays the picture of a person named in a given variable)
- restricting usage of the variable by rejecting certain operations (e.g. generate an error on any attempt to change the variable’s value to anything other than a decimal string) or by overriding certain operations (e.g. recreate the variable whenever it is unset).

Here is a simple example that causes a message to be printed when either of two variables is modified:

```
trace variable color w pvar
trace variable a(length) w pvar
proc pvar {name element op} {
    if {$element != ""} {
        set name ${name}($element)
    }
    upvar $name x
    puts "Variable $name set to $x"
}
```

The first `trace` command arranges for procedure `pvar` to be invoked whenever variable `color` is written: `variable` specifies that a variable trace is being created, `color` gives the name of the variable, `w` specifies a set of operations to trace (any combination of `r` for read, `w` for write, and `u` for unset), and the last argument is a command to invoke. The second trace command sets up a trace for element `length` of array `a`.

Whenever `color` or `a(length)` is modified, Tcl will invoke `pvar` with three additional arguments, which are the variable’s name, the variable’s element name (if it is an array element, or an empty string otherwise), and an argument indicating what operation was actually invoked (`r` for read, `w` for write, or `u` for unset). For example, if the command “`set color purple`” is executed, Tcl will evaluate the command “`pvar color {} purple`” because of the trace. If “`set a(length) 108`” is invoked, the trace command “`pvar a length w`” will be evaluated.

The `pvar` procedure does three things. First, if the traced variable is an array element then `pvar` generates a complete name for the variable by combining the array name and the element name. Second, the procedure uses `upvar` to make the variable’s value accessible inside the procedure as local variable `x`. Finally, it prints out the variable’s name and value on standard output. For the two accesses in the previous paragraph the following messages will be printed:

```
Variable color set to purple
Variable a(length) set to 108
```

The example above set traces on individual variables. It’s also possible to set a trace on an entire array, as with the command

```
trace variable a w pvar
```

where `a` is the name of an array variable. In this case `pvar` will be invoked whenever any element of `a` is modified.

Write traces are invoked after the variable’s value has been modified but before returning the new value as the result of the write. The trace command can write a new value into the variable to override the value specified in the original write, and this value will be returned as the result of the traced write operation. Read traces are invoked just before the variable’s result is read. The trace command can modify the variable to affect the result returned by the read operation. Tracing is temporarily disabled for a variable during the execution of read and write trace commands. This means that a trace command can access the variable without causing traces to be invoked recursively.

If a read or write trace returns an error of any sort then the traced operation is aborted. This can be used to implement read-only variables, for example. Here is a script that forces a variable to have a positive integer value and rejects any attempts to set the variable to a non-integer value:

```
trace variable size w forceInt
proc forceInt {name element op} {
    upvar $name x ${name}_old x_old
    if ![regexp {^[0-9]*$} $x] {
        set x $x_old
        error "value must be a postive integer"
    }
    set x_old $x
}
```

By the time the trace command is invoked the variable has already been modified, so if `forceInt` wants to reject a write it must restore the old value of the variable. To do this it keeps a shadow variable with a suffix “`_old`” to hold the previous value of the variable. If an illegal value is stored into the variable, `forceInt` restores the variable to its old value and generates an error:

```
   set size 47
⇒  47
   set size red
∅  can’t set "size": value must be a postive integer
   set size
⇒  47
```

Note: The `forceInt` procedure only works for simple variables, but it could be extended to handle array elements as well.

It is legal to set a trace on a non-existent variable; the variable will continue to appear to be unset even though the trace exists. For example, you can set a read trace on an array and then use it to create new array elements automatically the first time they are read. Unsetting a variable will remove the variable and any traces associated with the variable, then invoke any unset traces for the variable. It is legal, and not unusual, for an unset trace to immediately re-establish itself on the same variable so that it can monitor the variable if it should be re-created in the future.

To delete a trace, invoke `trace vdelete` with the same arguments passed to `trace variable`. For example, the trace created on `color` above can be deleted with the following command:

```
trace vdelete color w pvar
```

If the arguments to `trace vdelete` don't match the information for any existing trace exactly then the command has no effect.

The command `trace vinfo` returns information about the traces currently set for a variable. It is invoked with an argument consisting of a variable name, as in the following example:

```
trace vinfo color
⇒ {w pvar}
```

The return value from `trace vinfo` is a list, each of whose elements describes one trace on the variable. Each element is itself a list with two elements, which give the operations traced and the command for the trace. The traces appear in the result list in the order they will be invoked. If the variable specified to `trace vinfo` is an element of an array, then only traces on that element will be returned; traces on the array as a whole will not be returned.

13.5 Renaming and deleting commands

The `rename` command can be used to change the command structure of an application. It takes two arguments:

```
rename old new
```

`Rename` does just what its name implies: it renames the command that used to have the name *`old`* so that it now has the name *`new`*. *`New`* must not already exist as a command when `rename` is invoked.

`Rename` can also be used to delete a command by invoking it with an empty string as the `new` name. For example, the following script disables file I/O from an application by deleting the relevant commands:

```
foreach cmd {open close read gets puts} {
    rename $cmd {}
}
```

Any Tcl command may be renamed or deleted, including the built-in commands as well as procedures and commands defined by an application. Renaming or deleting a built-in command is probably a bad idea in general, since it will break scripts that depend on the command, but in some situations it can be useful. For example, the `exit` command as defined by Tcl just exits the process immediately (see Section 12.5). If an application wants to have a chance to clean up its internal state before exiting, then it can create a "wrapper" around `exit` by redefining it:

```
rename exit exit.old
proc exit status {
    application-specific cleanup
    ...
    exit.old $status
}
```

In this example the `exit` command is renamed to `exit.old` and a new `exit` procedure is defined, which performs the cleanup required by the application and then calls the renamed command to exit the process. This allows existing scripts that call `exit` to be used without change while still giving the application an opportunity to clean up its state.

13.6 Unknown commands

The Tcl interpreter provides a special mechanism for dealing with unknown commands. If the interpreter discovers that the command name specified in a Tcl command doesn't exist, then it checks for the existence of a command named `unknown`. If there is such a command then the interpreter invokes `unknown` instead of the original command, passing the name and arguments for the non-existent command to `unknown`. For example, suppose that you type the following commands:

```
set x 24
createDatabase library $x
```

If there is no command named `createDatabase` then the following command is invoked:

```
unknown createDatabase library 24
```

Notice that substitutions are performed on the arguments to the original command before `unknown` is invoked. Each argument to `unknown` will consist of one fully-substituted word from the original command.

The `unknown` procedure can do anything it likes to carry out the actions of the command, and whatever it returns will be returned as the result of the original command. For example, the procedure below checks to see if the command name is an unambiguous abbreviation for an existing command; if so, it invokes the corresponding command:

```
proc unknown {name args} {
    set cmds [info commands $name*]
    if {[llength $cmds] != 1} {
        error "unknown command \"$name\""
    }
    uplevel $cmds $args
}
```

Note that when the command is re-invoked with an expanded name, it must be invoked using `uplevel` so that the command executes in the same variable context as the original command.

The Tcl script library includes a default version of `unknown` that peforms the following functions, in order:

1. If the command is a procedure that is defined in a library file, source the file to define the procedure, then re-invoke the command. This is called *auto-loading*; it is described in the next section.
2. If there exists a program with the name of the command, use the `exec` command to invoke the program. This feature is called *auto-exec*. For example, you can type "`ls`" as a command and `unknown` will invoke "`exec ls`" to list the contents of the current directory. If the command doesn't specify redirection then auto-exec will arrange for the command's standard input, standard output, and standard error to be redirected to the corresponding channels of the Tcl application. This is different than the normal behavior of `exec` but it allows interactive programs such as `more` and `vi` to be invoked directly from a Tcl application.
3. If the command name has one of several special forms such as "`!!`" then compute a new command using history substitution and invoke it. For example, the if the command is "`!!`" then the previous command is re-invoked. See Chapter 14 for more information on history substitution.
4. If the command name is a unique abbreviation for an existing command, then the abbreviated command name is expanded and the command is re-invoked.

The last three actions are intended as conveniences for interactive use, and they only occur if the command was invoked interactively. You should not depend on these features when writing scripts. For example, you should not try to use auto-exec in scripts: always use the `exec` command explicitly.

If you don't like the default behavior of the `unknown` procedure then you can write your own version or modify the library version to provide additional functions. If you don't want any special actions to be taken for unknown commands you can just delete the `unknown` procedure, in which case errors will occur whenever unknown commands are invoked.

13.7 Auto-loading

One of the most useful functions performed by the `unknown` procedure is *auto-loading*. Auto-loading allows you to write collections of Tcl procedures and place them in script files in library directories. You can then use these procedures in your Tcl applications without having to explicitly `source` the files that define them. You simply invoke the procedures. The first time that you invoke a library procedure it won't exist, so `unknown` will be called. `Unknown` will find the file that defines the procedure, source the file to define the procedure, and then re-invoke the original command. The next time the procedure is invoked it will exist so the auto-loading mechanism won't be triggered.

Auto-loading provides two benefits. First, it makes it easy to build up large libraries of useful procedures and use them in Tcl scripts. You need not know exactly which files to `source` to define which procedures, since the auto-loader takes care of that for you. The second benefit of auto-loading is efficiency. Without auto-loading an appliation must `source` all of its script files when it starts up. Auto-loading allows an application to start up without loading any script files at all; the files will be loaded later when their procedures are needed, and some files may never be loaded at all. Thus auto-loading reduces startup time and saves memory.

Using the auto-loader is straightforward and involves three steps. First, create a library as a set of script files in a single directory. Normally these files have names that end in "`.tcl`", for example `db.tcl` or `stretch.tcl`. Each file can contain any number of procedure definitions. I recommend keeping the files relatively small, with just a few related procedures in each file. In order for the auto-loader to handle the files properly, the `proc` command for each procedure definition must be at the left edge of a line, and it must be followed immediately by white space and the procedure's name on the same line. Other than this the format of the script files doesn't matter as long as they are valid Tcl scripts.

The second step is to build an index for the auto-loader. To do this, start up a Tcl application such as `tclsh` and invoke the `auto_mkindex` command as in the following example:

```
auto_mkindex . *.tcl
```

`Auto_mkindex` isn't a built-in command but rather a procedure in Tcl's script library. Its first argument is a directory name and the second argument is a glob-style pattern that selects one or more script files in the directory. `Auto_mkindex` scans all of the files whose names match the pattern and builds an index that indicates which procedures are defined in which files. It stores the index in a file called `tclIndex` in the directory. If you modify the files to add or delete procedures then you should regenerate the index.

The third step is to set the variable `auto_path` in the applications that wish to use the library. The `auto_path` variable contains a list of directory names. When the auto-loader is invoked it searches the directories in `auto_path` in order, looking in their `tclIndex` files for the desired procedure. If the same procedure is defined in several libraries then the auto-loader will use the one from the earliest directory in `auto_path`. Typically `auto_path` will be set as part of an application's startup script. For example, if an application uses a library in directory `/usr/local/tcl/lib/shapes` then it might include the following command in its startup script:

```
set auto_path \
        [linsert $auto_path 0 /usr/local/tcl/lib/shapes]
```

This will add `/usr/local/tcl/lib/shapes` to the beginning of the path, retaining all the existing directories in the path such as those for the Tcl and Tk script libraries but giving higher priority to procedures defined in `/usr/local/tcl/lib/shapes`. Once a directory has been properly indexed and added to `auto_path`, all of its procedures become available through auto-loading.

Chapter 14 History

This chapter describes Tcl’s history mechanism. In applications where you type commands interactively, the history mechanism keeps track of recent commands and makes it easy for you to re-execute them without having to completely re-type them. You can also create new commands that are slight variations on old commands without having to completely retype the old commands, for example to fix typos. Tcl’s history mechanism provides many of the features available in `csh`, but not with the same syntax in all cases. History is implemented by the `history` command, which is summarized in Table 14.1 . Only a few of the most commonly used history features are described in this chapter; see the reference documentation for more complete information.

14.1 The history list

Each command that you type interactively is entered into a *history list*. Each entry in the history list is called an *event*; it contains the text of a command plus a serial number identifying the command. The command text consists of exactly the characters you typed, before the Tcl parser peforms substitutions for `$`, `[]`, etc. The serial number starts out at `1` for the first command you type and is incremented for each successive command.

Suppose you type the following sequence of commands to an interactive Tcl program:

```
set x 24
set y [expr $x*2.6]
incr x
```

At this point the history list will contain three events. You can examine the contents of the history list by invoking `history` with no arguments:

`history`	Returns a string giving the event number and command for each event on the history list.
`history keep` *`count`*	Changes the size of the history list so that the *`count`* most recent events will be retained. The initial size of the list is 20 events.
`history nextid`	Returns the number of the next event that will be recorded in the history list.
`history redo` ?*`event`*?	Re-executes the command recorded for *`event`* and returns its result.
`history substitute` *`old new`* ?*`event`*?	Retrieve the command recorded for *`event`*, replace any occurrences of *`old`* by *`new`* in it, execute the resulting command, and returns its result. Both *`old`* and *`new`* are simple strings. The substitution uses simple equality checks: no wild cards or regular expression features are supported.

Table 14.1. A summary of some of the options for the `history` command. Several options have been omitted; see the reference documentation for details.

```
history
⇒       1 set x 24
        2 set y [expr $x*2.6]
        3 incr x
        4 history
```

The value returned by `history` is a human-readable string describing what's on the history list, which also includes the `history` command. The result of `history` is intended for printing out, not for processing in Tcl scripts; if you want to write scripts that process the history list, you'll probably find it more convenient to use other `history` options described later in the reference documentation, such as `history event`.

The history list has a fixed size, which is initially 20. If more commands than that have been typed then only the most recent commands will be retained. The size of the history list can be changed with the `history keep` command:

```
history keep 100
```

This command changes the size of the history list so that in the future the 100 most recent commands will be retained.

14.2 Specifying events

Several of the options of the `history` command require you to select an event from the history list; the symbol *`event`* is used for such arguments in Table 14.1. Events are specified as strings with one of the following forms:

Positive number:	Selects the event with that serial number.
Negative number:	Selects an event relative to the current event. `-1` refers to the last command, `-2` refers to the one before that, and so on.
Anything else:	Selects the most recent event that matches the string. The string matches an event either if it is the same as the first characters of the event's command, or if it matches the event's command using the matching rules for `string match`.

Suppose that you had just typed the three commands from page 131 above. The command "`incr x`" can be referred to as event `-1` or `3` or `inc`, and "`set y [expr $x*2.6]`" can be referred to as event `-2` or `2` or `*2*`. If an event specifier is omitted then it defaults to `-1`.

14.3 Re-executing commands from the history list

The `redo` and `substitute` options to `history` will replay commands from the history list. `History redo` retrieves a command and re-executes it just as if you had retyped the entire command. For example, after typing the three commands from page 131, the command

```
history redo
```

replays the most recent command, which is `incr x`; it will increment the value of variable `x` and return its new value (`26`). If an additional argument is provided for `history redo`, it selects an event as described in Section 14.2; for example,

```
   history redo 1
⇒  24
```

replays the first command, `set x 24`.

The `history substitute` command is similar to `history redo` except that it modifies the old command before replaying it. It is most commonly used to correct typographical errors:

```
   set x "200 illimeters"
⇒  200 illimeters
   history substitute ill mill -1
⇒  200 millimeters
```

`History substitute` takes three arguments: an old string, a new string, and an event specifier (the event specifier can be defaulted, in which case it defaults to `-1`). It retrieves the command indicated by the event specifier and replaces all instances of the old string in that command with the new string. The replacement is done using simple textual comparison with no wild-cards or pattern matching. Then the resulting command is executed and its result is returned.

14.4 Shortcuts implemented by unknown

The `history redo` and `history substitute` commands are quite bulky; in the examples above it took more keystrokes to type the `history` commands than to retype the commands being replayed. Fortunately there are several shortcuts that allow the same functions to be implemented with fewer keystrokes:

`!!`	Replays the last command: same as “`history redo`”.
`!`*`event`*	Replays the command given by *`event`*; same as “`history redo` *`event`*”.
`^`*`old`*`^`*`new`*	Replay the last command, substituting new for old; same as “`history substitute` *`old new`*”.

All of these shortcuts are implemented by the `unknown` procedure described in Section 13.6. `Unknown` detects commands that have the forms described above and invokes the corresponding `history` commands to carry them out.

Note: If your system doesn’t use the default version of `unknown` provided by Tcl then these shortcuts may not be available.

14.5 Current event number: history nextid

The command `history nextid` returns the number of the next event to be entered into the history list:

```
history nextid
⇒ 3
```

It is most commonly used for generating prompts that contain the event number. Many interactive applications allow you to specify a Tcl script to generate the prompt; in these applications you can include a `history nextid` command in the script so that your prompt includes the event number of the command you are about to type.

Part II:

Writing Scripts for Tk

Chapter 14
An Introduction to Tk

Tk is a toolkit that allows you to create graphical user interfaces for the X11 window system by writing Tcl scripts. Like Tcl, Tk is a C library package that can be included in C applications. Tk extends the built-in Tcl command set described in Part I with several dozen additional commands that you can use to create user interface elements called *widgets*, arrange them into interesting layouts on the screen using *geometry managers*, and connect them with each other, with the enclosing application, and with other applications. This part of the book describes Tk's Tcl commands.

In addition to its Tcl commands, Tk also provides a collection of C library functions that can be invoked from C code in a Tk-based application. The library functions allow you to implement new widgets and geometry managers in C. They are discussed in Part IV of the book.

This chapter introduces the basic structures used for creating user interfaces with Tk, including the hierarchical arrangements of widgets that make up interfaces and the main groups of Tcl commands provided by Tk. Later chapters will go over the individual facilities in more detail.

Note: *I've taken the liberty of describing things in the way I expect them to be when the book is finally published, so the descriptions in this draft do not always correspond to the current version of Tk (3.2). The following discrepancies exist between this draft and Tk 3.2: (a) the* `pack` *command syntax as described here is different than what exists in 3.2, although it provides almost exactly the same set of features; (b) Tk 3.2 doesn't contain all of the built-in bitmaps listed here (c)* `groove` *and* `ridge` *reliefs are not supported in Tk 3.2, and (d) embedded widgets are not yet supported in text widgets. As new versions of Tk are released the discrepancies should gradually disappear.*

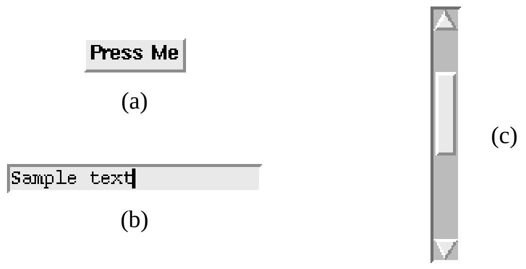


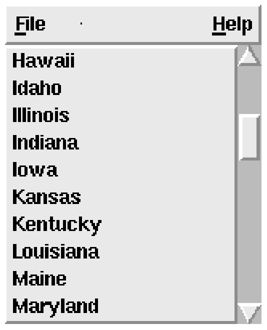
Figure 14.1. Examples of widgets in Tk: (a) a button widget displays a text string and invokes a given Tcl command when a mouse button is clicked over it; (b) an entry widget displays a one-line text string and allows the text to be edited with the mouse and keyboard; (c) a scrollbar widget displays a slider and two arrows, which can be manipulated with the mouse to adjust the view in some other widget.

14.1 Widgets and windows

The basic user interface elements in Tk are called *widgets*. Examples of widgets are labels, buttons, pull-down menus, scrollbars, and text entries (see Figure 14.1). Widgets are grouped into *classes*, where all of the widgets in a class have a similar appearance on the screen and similar behavior when manipulated with the mouse and keyboard. For example, widgets in the button class display a text string or bitmap as shown in Figure 14.1(a). Different buttons may display their strings or bitmaps in different ways (e.g. in different fonts and colors), but each one displays a single string or bitmap. Each button also has a Tcl script associated with it, which is invoked whenever mouse button 1 is pressed with the mouse cursor over the widget. Different button widgets may have different commands associated with them but each one has an associated command. When you create a widget you select its class and provide additional class-specific *options*, such as a string or bitmap to display or a command to invoke.

Tk's built-in widget classes implement the Motif^{TM} look-and-feel standard specified by the Open Software Foundation. The Motif standard determines the three-dimensional look that you'll see in the Tk widgets and many aspects of their behavior.

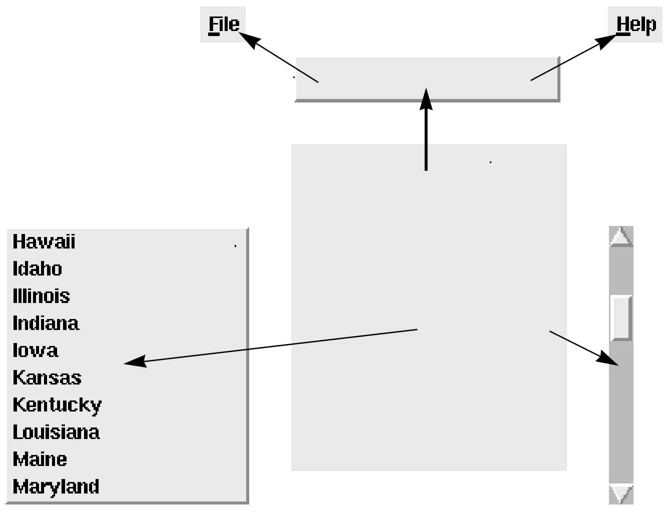
Each widget is implemented using one window in the X window system, and the terms "window" and "widget" are used interchangeably in this book. Widgets may be nested in hierarchical arrangements with widgets containing other widgets that contain still other widgets. The result is a tree-like structure such as the one shown in Figure 14.2. Each widget can contain any number of children and the widget tree can have any depth. The widgets with behavior that is meaningful to the user are usually at the leaves of the widget tree; the higher-level widgets are usually just containers for organizing and arranging the leaf widgets.



(a)

$$\begin{tikzcd}
 & . \arrow[dl, no head] \arrow[d, no head] \arrow[dr, no head] & \\
.listbox & .menu \arrow[dl, no head] \arrow[d, no head] & .scroll \\
.menu.file & .menu.help &
\end{tikzcd}$$

(b)



(c)

Figure 14.2. Widgets are arranged hierarchically. A collection of widgets is shown in (a) as it appears on the screen, and the hierarchical structure of the collection is shown in (b). An exploded view of the screen is shown in (c) to clarify the widget structure. The topmost widget in the hierarchy (“.”) contains three children: a menu bar across the top, a scrollbar along the right side, and a listbox filling the remainder. The menu bar contains two children of its own, a `File` menu button on the left and a `Help` menu button on the right. Each widget has a name that reflects its position in the hierarchy, such as `.menu.help` for the `Help` menu button.

Each widget/window has a textual name that is used to refer to it in Tcl commands. Window names are similar to the hierarchical path names used to name files in Unix, except that "`.`" is used as the separator character instead of "`/`". The name "." refers to the topmost window in the hierarchy, which is called the *main window.* The name `.a.b.c` refers to a window `c` that is a child of window `.a.b`, which in turn is a child of `.a`, which is a child of the main window.

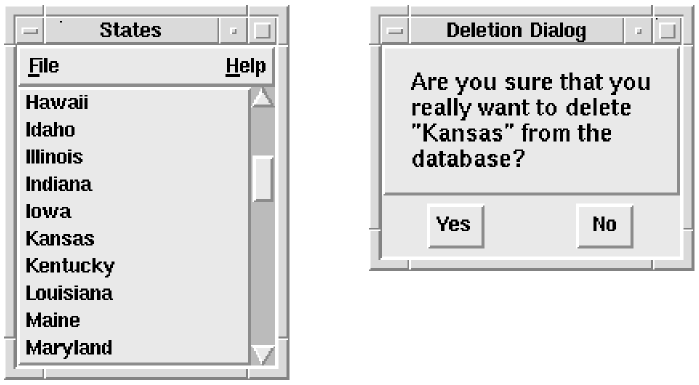
14.2 Screens, decorations, and toplevel windows

Tk creates the main window of an application as a child of the root window of a particular screen. This causes the main window to appear on that screen. Your window manager will then create a decorative frame around the main window, which usually displays a title and provides controls that you can use to move and resize the window. A given window manager will decorate all applications in the same way, but different window managers may use different styles of decoration. Figure 14.2 showed a main window without any window manager decoration; other figures will show decorations as provided by the `mwm` window manager (e.g. see Figure 14.3).

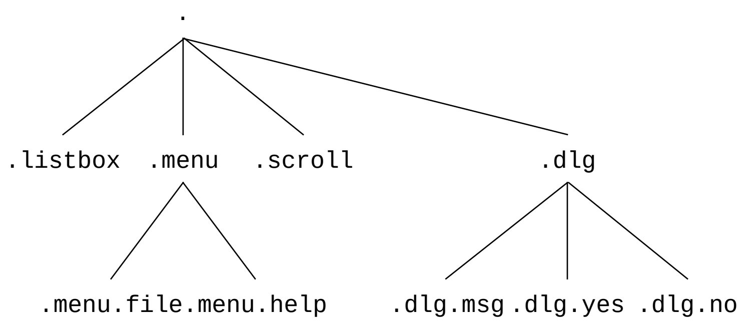
X clips each window to the area of its parent: it will not display any part of a window that lies outside the area of its parent. The descendants of the main window are called *internal windows* to reflect the fact that they appear inside the area of the main window. However, applications often need to create widgets that are don't lie inside the main window. For example, it might be useful to position a dialog box in the center of the screen regardless of the position of the main window, or an application might wish to post several panels that the user can move around on the screen independently. For situations like this Tk provides a third kind of window called a *top-level window.* A top-level window appears like an internal window in the application's widget hierarchy (e.g. it might have a name like `.a.b`) but its X window is created as a child of the screen's root rather than its parent in the Tk widget hierarchy. The window manager will treat top-level windows just like main windows, so the user will be able to move and resize and iconify each top-level window separately from the main window and other top-level windows. Top-level windows are typically used for panels and dialog boxes. See Figure 14.3 for an example.

It is not necessary for all of the widgets of an application to appear on the same screen or even the same display. When you create a top-level widget you can specify a screen for it. The screen defaults to the screen of the widget's parent in the Tk hierarchy, but you can specify any screen whose X server will accept a connection from the application. For example, it's possible to create a Tk application that broadcasts an announcement to a number of wokstations by opening a top-level window on each of their screens.

Once a widget is created on a particular screen, it cannot be moved to another screen. This is a limitation imposed by the X window system. However, you can achieve the same effect as moving the widget by deleting it and recreating it on a different screen.



(a)



(b)

Figure 14.3. Top-level widgets appear in the Tk widget hierarchy just like internal widgets, but they are positioned on the screen independently from their parents in the hierarchy. In this example the dialog box `.dlg` is a top-level window. Figure (a) shows how the windows appear on the screen (with decorations provided by the `mwm` window manager) and Figure (b) shows Tk's widget hierarchy for the application.

14.3 Applications and processes

In Tk the term *application* refers to a single widget hierarchy (one main window and any number of internal and top-level windows descended from it), a single Tcl interpreter associated with the widget hierarchy, plus all the commands provided by that interpreter. Each application is usually a separate process, but Tk also allows a single process to manage several applications, each with its own widget hierarchy and Tcl interpreter. Tk does not provide any particular support for multi-threading (using a collection of processes to manage a single application); it is conceivable that Tk could be used in a multi-threaded environment but it would not be trivial and I know of no working examples.

14.4 Scripts and events

Tk applications are controlled by two kinds of Tcl scripts: an *initialization script* and *event handlers*. The initialization script is executed when the application starts up. It creates the application's user interface, loads the application's data structures, and performs any other initialization needed by the application. Once initialization is complete the application enters an *event loop* to wait for user interactions. Whenever an interesting event occurs, such as the user invoking a menu entry or moving the mouse, a Tcl script is invoked to process that event. These scripts are called event handlers; they can invoke application-specific Tcl commands (e.g. enter an item into a database), modify the user interface (e.g. post a dialog box), or do many other things. Some event handlers are created by the initialization script, but event handlers can also be created and modified by other event handlers.

Most of the Tcl code for a Tk application is in the event handlers and the procedures that they invoke. Complex applications may contain hundreds of event handlers, and the handlers may create other panels and dialogs that have additional event handlers. Tk applications are thus *event-driven*. There is no well-defined flow of control within the application's scripts, since there is no clear task for the application to carry out. The application presents a user interface with many features and the user decides what to do next. All the application does is to respond to the events corresponding to the user's actions. The event handlers implement the responses; they tend to be short scripts, and they are mostly independent of each other.

14.5 Wish: a windowing shell

While you're reading this book you may find it useful to experiment with a program called `wish` (for "windowing shell"). `Wish` is the simplest possible Tk application. The only Tcl commands it contains are the Tcl built-ins and the additional commands provided by Tk. If you invoke `wish` with no arguments then it creates a main window and acts like a shell, reading Tcl commands from its standard input and executing them. For example, try typing the following commands to `wish`:

```
button .b -text "Hello, world!" -command "destroy ."
pack .b
```

This creates the application shown in Figure 14.4, consisting of a single button that displays the text "`Hello, world`". It also creates one event handler: if the user clicks mouse button 1 over the widget then Tk will invoke the command "`destroy .`", which

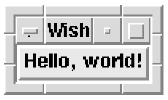


Figure 14.4. A simple Tk application created by typing commands to `wish`.

destroys the application's main window and all its descendants and thereby causes `wish` to exit. `Wish` responds to events for the application's windows as well as to commands typed on its standard input.

You can also use `wish` to invoke scripts that have been saved in files. For example, you could create a file named `hello` that contains the above two commands. Then you could start up `wish` and type

```
source hello
```

to process the file. Or, you could invoke `wish` with the following shell command:

```
wish -f hello
```

In this case `wish` will not read commands from standard input. Instead, it will execute the script contained in the file `hello` and then enter an event loop where it responds only to events from the application's windows.

Wish scripts can also be invoked using the same mechanism that's used for shell scripts in UNIX. To do this, enter the following comment as the first line of `hello`:

```
#!/usr/local/bin/wish -f
```

Then mark the script file as executable. You can now invoke `hello` directly from the shell like any other executable program:

```
hello
```

This will run `wish` and cause it to process the script file just as if you'd typed "`wish -f hello`".

See the `wish` reference documentation for details on other features provided by `wish`, such as command-line arguments for `wish` scripts. If `wish` isn't installed in `/usr/local/bin` on your system then you'll need to use a different comment in your script files that reflects the location of `wish`.

14.6 Widget creation commands

Tk provides four main groups of Tcl commands; they create widgets, arrange widgets on the screen, communicate with existing widgets, and interconnect widgets within and between applications. This section and the three following sections introduce the groups of commands to give you a general feel for Tk's features. All of the commands are discussed in more detail in later chapters.

To create a widget, you invoke a command named after the widget's class: `button` for button widgets, `scrollbar` for scrollbar widgets, and so on.. For example, the following command creates a button that displays the text "`Press me`" in red:

```
button .b -text "Press me" -foreground red
```

All of the widget creation commands have a form similar to this. The command's name is the same as the name of the class of the new widget. The first argument is a name for the new widget in the widget hierarchy, `.b` in this case. This widget must not already exist but its parent must exist. The command will create the widget and its corresponding X window.

The widget name is followed by any number of pairs of arguments, where the first argument of each pair specifies the name of a *configuration option* for the widget (e.g. `-text` or `-foreground`) and the second argument specifies a value for that option (e.g. "`Press me`" or `red`). Each widget class supports a different set of configuration options but many options, such as `-foreground`, are used in the same way by different classes. You need not specify a value for every option supported by a widget; defaults will be chosen for the options you don't specify. For example, buttons support about twenty different options but only two were specified in the example above. Chapter 16 discusses configuration options in more detail.

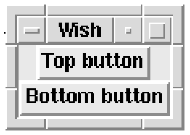
14.7 Geometry managers

Widgets don't determine their own sizes and locations on the screen. This function is carried out by *geometry managers*. Each geometry manager implements a particular style of layout. Given a collection of widgets to manage and some controlling information about how to arrange them, a geometry manager assigns a size and location to each widget. For example, you might tell a geometry manager to arrange a set of widgets in a vertical column. It would then position the widgets so that they are adjacent but don't overlap. If one widget should suddenly need more space (e.g. its font is changed to a larger one) it will notify the geometry manager and the geometry manager will move other widgets down to preserve the proper column structure.

The second main group of Tk commands consists of those for communicating with geometry managers. Tk currently contains four geometry managers. The *placer* is a simple fixed-placement geometry manager. You give it instructions like "place window `.x` at location (10,100) in its parent and make it 2 cm wide and 1 cm high." The placer is simple to understand but limited in applicability because it doesn't consider interactions between widgets. Chapter 17 describes the placer in detail.

```
button .top -text "Top button"
pack .top
button .bottom -text "Bottom button"
pack .bottom
```

(a)



(b)

Figure 14.5. The script in (a) creates two button widgets and arranges them in a vertical column with the first widget above the second. The application's appearance on the screen is shown in (b).

The second geometry manager is called the *packer.* It is constraint-based and allows you to implement arrangements like the column example from above. It is more complex than the placer but much more powerful and hence more widely used. The packer is the subject of Chapter 18.

Two other geometry managers are implemented as part of the canvas and text widgets. The canvas geometry manager allows you to mix widgets with structured graphics, and the text geometry manager mixes widgets with text. See the reference documentation for canvas and text widgets for descriptions of these geometry managers.

When you invoke a widget creation command like `button` the new widget will not immediately appear on the screen. It will only be displayed after you have asked a geometry manager to manage it. If you want to experiment with widgets before reading the full discussion of geometry managers, you can make a widget appear by invoking the `pack` command with the widget's name as argument. For example, the following script creates a button widget and displays it on the screen:

```
button .b -text "Hello, world!"
pack .b
```

This will size the main window so that it is just large enough to hold the button and it will arrange the button so that it fills the space of the main window. If you create other widgets and pack them in a similar fashion, the packer will arrange them in a column inside the main window, making the main window just large enough to accommodate them all. See Figure 14.5 for an example.

14.8 Widget commands

Whenever a new widget is created Tk also creates a new Tcl command whose name is the same as the widget's name. This command is called a *widget command*, and the set of all widget commands (one for each widget in the application) constitutes the third major group of Tk's commands. Thus after the above `button` command was executed above, a widget command whose name is `.b` appeared in the application's interpreter. This command will exist as long as the widget exists; if the widget is deleted then the command will be deleted too.

Widget commands are used to communicate with existing widgets. Here are some commands that could be invoked after the `button` command from Section 14.6:

```
.b configure -foreground blue
.b flash
.b invoke
```

The first command changes the color of the button's text to blue, the second command causes the button to flash briefly, and the third command invokes the button just as if the user had clicked mouse button 1 on it. In widget commands the command name is the name of the widget and the first argument specifies an operation to invoke on the widget, such as `configure`. Some widget commands, like `configure`, take additional arguments; the nature of these arguments depends on the specific command.

The set of widget commands supported by a given widget is determined by its class. All widgets in the same class support the same set of commands, but different classes have different command sets. Some common commands are supported by multiple classes. For example, every widget class supports a `configure` widget command, which can be used to query and change any of the configuration options associated with the widget.

14.9 Commands for interconnection

The fourth group of Tk commands is used for interconnection. These commands are used to make widgets work together, to make them work cooperatively with the objects defined in the application, and to allow different applications sharing the same display to work together in interesting ways.

Some of the interconnection commands are implemented as event handlers. For example, each button has a `-command` option that specifies a Tcl script to invoke whenever mouse button 1 is clicked over the widget. This option was used in Section 14.5 to terminate the application. Scrollbars provide another example of interconnection via event handlers. Each scrollbar is used to control the view in some other widget: when you click in the scrollbar or drag its slider, the view in the associated widget should change. This connection between widgets is implemented by specifying a Tcl command for the scrollbar to invoke whenever the slider is dragged. The command invokes a widget command for the asscociated widget to change its view. In addition to event handlers that are defined by widgets, you can create custom event handlers using the `bind` command described in Chapter 19.

Tk supports five other forms of interconnection in addition to event handlers: the selection, the input focus, the window manager, the `send` command, and grabs. The selection is a distinguished piece of information on the screen, such as a range of text or a graphic. The X window system provides a protocol for applications to claim ownership of the selection and retrieve the contents of the selection from whichever application owns it. Chapter 20 discusses the selection in more detail and describes Tk's `select` command, which is used to manipulate it.

At any given time, keystrokes typed for an application are directed to a particular widget, regardless of the mouse cursor's location. This widget is referred to as the *focus widget* or *input focus*. Chapter 21 describes the `focus` command, which is used to move the focus among the widgets of an application.

Chapter 22 describes Tk's `wm` command, which is used for communicating with the window manager. The window manager acts as a geometry manager for main windows and top-level windows, and the `wm` command can be used to make specific geometry requests from the window manager, such as "don't let the user make this window smaller than 20 pixels across." In addition, `wm` can be used to specify a title to appear in the window's decorative border, a title and/or icon to display when the window is iconified, and many other things.

Chapter 23 describes the `send` command, which provides a general-purpose means of communication between applications. With `send`, you can issue an arbitrary Tcl command to any Tk application on the display; the command will be transmitted to the target application, executed there, and the result will be returned to the original application. `Send` allows one application to control another application in intimate and powerful ways. For example, a debugger can send commands to an editor to highlight the current line of execution, or a spreadsheet can send commands to a database application to retrieve new values for cells in the spreadsheet, or a mail reader can send commands to a video application to play a video clip identifying the sender of a message.

The last form of interconnection is *grabs*, which are described in Chapter 24. A grab restricts keyboard and mouse events so that they are only processed in a subtree of the widget hierarchy; windows outside the grab subtree become lifeless until the grab is released. Grabs are used to disable parts of an application and force the user to deal immediately with a high-priority window such as a dialog box.

Chapter 15
Tour Of The Tk Widgets

This chapter introduces the fifteen widget classes that are currently implemented by Tk. The descriptions are not intended to explain every feature of every class; for that you should refer to the reference documentation for the individual widget classes. In fact, no specific Tk commands will be mentioned in this chapter. This chapter gives an overview of the behavior of the widgets as seen by users and the features provided by the widgets to interface designers. The purpose of this chapter is to provide you with general information about the capabilities of Tk's widgets so that it will be easier to understand the specific commands described in later chapters.

The widget behavior described in this chapter is not hard-coded into the widgets. Instead, Tk contains a startup script that generates default behaviors for the widgets using the binding mechanism described in Chapter 19. The descriptions in this chapter correspond to the default behaviors, and most widgets in most applications will use the default behaviors. However, it is possible to extend or override the defaults, so some Tk applications may contain widgets that behave differently than described here.

If you have access to the `wish` program and the Tk demonstration scripts (both of which are included in the Tk distributions) then you can experiment with real widgets as you read through the chapter. To do this, execute the `widget` demonstration script and use the menus to bring up various examples.

15.1 Frames and toplevels

Frames and toplevels are the simplest widgets. They have almost no interesting properties. A frame appears as a rectangular region with a color and possibly a border that gives the

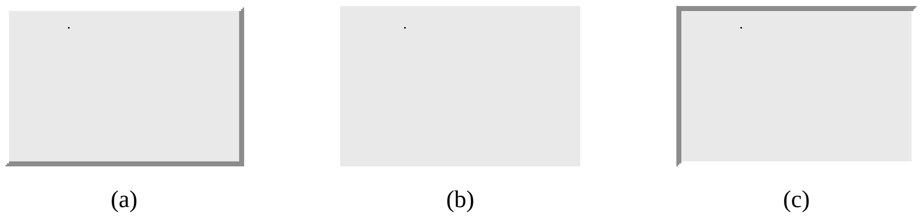


Figure 15.1. Frame and toplevel widgets have no visual characteristics except for a color and an optional three-dimensional border that can give the widget one of several appearances, such as raised as in (a), flat as in (b), or sunken as in (c).

frame a raised or sunken appearance as shown in Figure 15.1. Frames serve two purposes. First, they can be used to generate decorations such as a block of color or a raised or sunken border around a group of widgets. Second, they serve as containers for grouping other widgets; most of the non-leaf widgets in the widget hierarchy are frames, and you'll see in Chapter 18 that frames are particularly important for building up nested layouts with geometry managers. When used in this way, frames are often invisible to the user. Frames do not normally respond to mouse or keyboard actions.

Toplevel widgets are identical to frames except that, as the name implies, they are top-level widgets whereas frames (and almost all other widgets) are internal widgets. This means that a toplevel widget can be positioned anywhere on its screen, independent of its parent in the widget hierarchy, and it need not even appear on the same screen as its parent. Toplevels are typically used as the outermost containers for panels and dialog boxes. When you create a toplevel you can specify a screen for it to be displayed on.

15.2 Labels, buttons, checkbuttons, and radiobuttons

Labels, buttons, checkbuttons, and radiobuttons make up a family of widget classes with similar characteristics. Each member of the family builds on the behavior of earlier members. Labels are the simplest member of the family. They are similar to frames except that each one can display a text string or a bitmap (see Figure 15.2). Like frames, labels do not normally respond to the mouse or keyboard; they simply provide decoration in the form of a text string or bitmap.

Buttons are similar to labels except that they also respond to the mouse. When the mouse cursor moves over a button, the button lights up. This indicates that pressing a mouse button will cause something to happen. It is a general property of Tk widgets that they light up if the mouse cursor passes over them when they are prepared to respond to

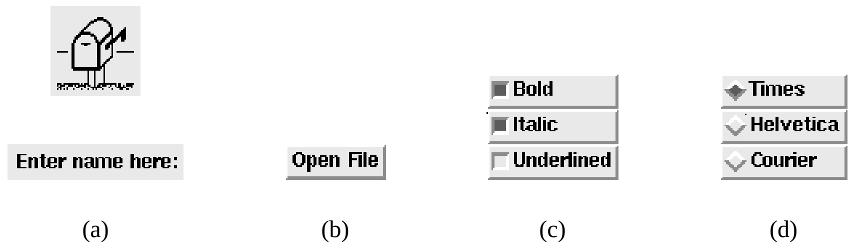


Figure 15.2. Members of the label/button family of widgets. Two labels are shown in (a); the top one displays a bitmap and the bottom one displays a text string. Figure (b) shows a button widget. Three checkbuttons appear in (c); any combination of the checkbuttons may be selected at once. A group of three radiobuttons appears in (d); only one of the radiobuttons may be selected at anygiven time. Although a bitmap only appears in (a), any of the classes can display a bitmap as well as a string.

button presses. A button or other widget lit up in this way it is said to be *active*. Buttons become inactive again when the mouse cursor leaves them.

If mouse button 1 is pressed when a button is active then the button's appearance changes to make it look sunken, as if a real button had been pressed. When the mouse button is released, the widget's original appearance is restored. Furthermore, when the mouse button is released a Tcl script associated with the button is automatically executed. The script is a configuration option for the button.

Checkbuttons allow users to make binary choices such as enabling or disabling underlining or grid-alignment. They are similar to regular buttons except for two things. First, whenever mouse button 1 is clicked over a checkbutton a Tcl variable toggles between two values, one representing an "on" state and the other representing an "off" state. The name of the variable and the values corresponding to the "on" and "off" states are configuration options for the widget. Second, the checkbutton displays a small rectangular *selector* to the left of its text or bitmap. If the variable has the "on" value then the selector is displayed in a bright color and the button is said to be *selected*. If the variable has the "off" value then the selector box appears empty. Each checkbutton monitors the value of its associated variable and if the variable's value changes (e.g. because of a `set` command) the checkbutton updates the selector display.

The last member of the label/button family is the radiobutton class. Radiobuttons are typically arranged in groups and used to select one from among several mutually-exclusive choices, such as one of several colors or one of several styles of dashed lines. Radiobuttons are named after the radio selector buttons on older cars, where pressing the button for one station caused all the other buttons to be released. When mouse button 1 is clicked over a radiobutton, the widget sets the variable to the “on” value associated with that radiobutton. All of the radiobuttons in a group will share the same variable but each will have a different “on” value. A radiobutton displays a diamond-shaped selector to the left of its text or bitmap and lights up the selector when the widget is selected. Each radiobutton monitors its variable so if some other radiobutton resets the variable to select itself the previously-selected widget can turn off its selector diamond. If you change the value of the variable using the Tcl `set` command then all of the associated radiobuttons will redisplay their selectors to match the new value of the variable.

The members of the label/button family also have two additional features. First, you can specify that the string to be displayed in the widget should be taken from a Tcl variable. The widget will monitor the variable and update its display to reflect the current contents of the variable. Second, you can *disable* the widget. While a widget is disabled it is displayed in dimmer colors, it doesn’t activate when the mouse cursor passes over it, and it doesn’t respond to button presses.

15.3 Menus and menubuttons

Tk’s menu widget provides a general-purpose facility for implementing pull-down menus, pop-up menus, cascading menus, and many other things. A menu is a top-level widget that contains a collection of *entries* arranged in a column (see Figure 15.3(a)). Menu entries are not distinct widgets but they behave much like the members of the label/button family described in Section 15.2 above. The following types of entries may be used in menus:

Command: similar to a button widget. Displays a textual string or bitmap and invokes a Tcl script when mouse button 1 is released over it.

Checkbutton: similar to a checkbutton widget. Displays a string or bitmap and toggles a variable between “on” and “off” values when button 1 is released over the entry. Also displays a square selector indicating whether the variable is currently in its “on” or “off” state.

Radiobutton: similar to a radiobutton widget. Displays a string or bitmap and sets a variable to an “on” value associated with the enry when button 1 is released over it. Also displays a diamond-shaped selector indicating whether or not the variable has the value for this entry.

Cascade: similar to a menubutton widget. Posts a cascaded sub-menu when the mouse passes over it. See below for more details.

Separator: Displays a horizontal line for decoration. Does not respond to the mouse.

Unlike most other widgets, menus do not normally appear on the screen. They spend most of their time in an invisible state called *unposted*. When a user wants to invoke a menu entry, he or she *post*s the menu, which makes it appear on the screen. Then the user moves the mouse over the desired entry and releases button 1 to invoke that entry. Once

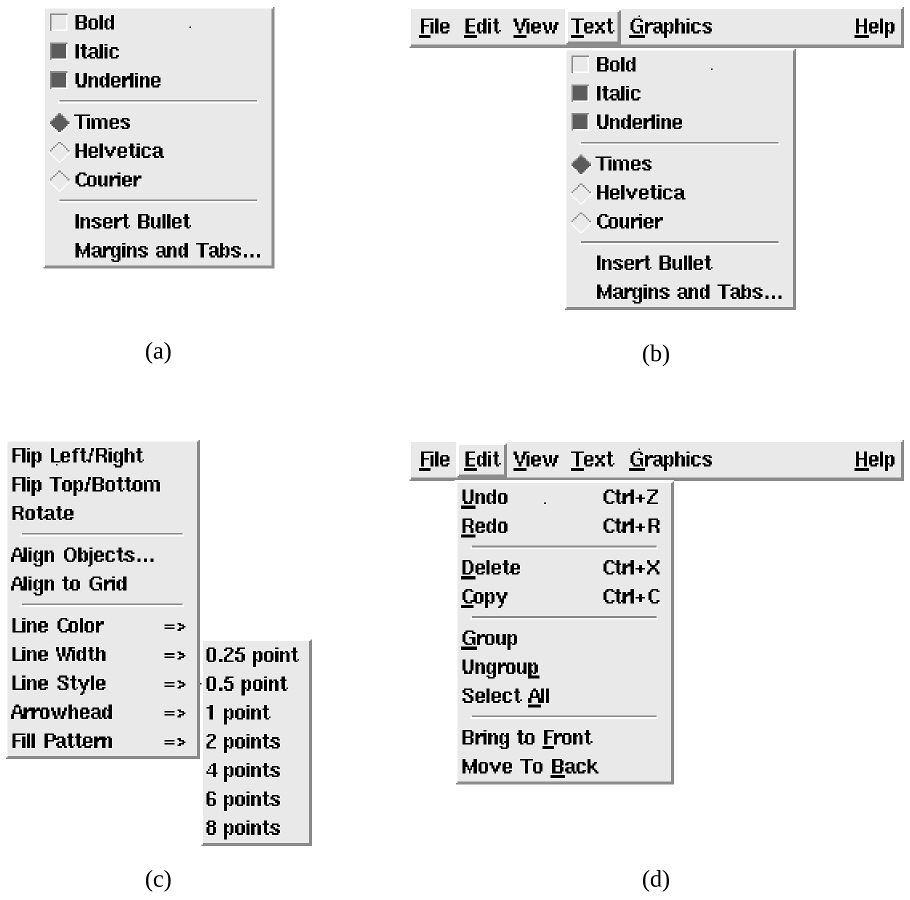


Figure 15.3. Examples of menus. Figure (a) shows a single menu with three checkbutton entries, three radiobutton entries, and two command entries. The groups of entries are separated by separator entries. Figure (b) shows the menu being used in pull-down fashion with a menu bar and several menubutton widgets. Figure (c) shows a cascaded series of menus; cascade entries in the parent (leftmost) menu display => at their right edges, and the `Line Width` entry is currently active. Figure (d) contains a menu that supports keyboard traversal and shortcuts. The underlined characters in the menubuttons and menu entries can be used to invoke them from the keyboard, and the key sequences at the right sides of some of the menu entries (such as `Ctrl+X`) can be used to invoke the same functions as menu entries without even posting the menu.

the menu has been invoked it is usually unposted until it is needed again. Menus are posted or unposted by invoking their widget commands, which gives the interface designer a lot of flexibility in deciding when to post and unpost them. The subsections below describe four of the most common approaches.

15.3.1 Pull-down menus

Menus are most commonly used in a *pull-down* style. In this style the application displays a *menu bar* near the top of its main window. A menu bar is a frame widget that contains several menubutton widgets as shown in Figure 15.3(b). Menubuttons are similar to button widgets except that instead of executing Tcl scripts when they are invoked they post menu widgets. When a user presses mouse button 1 over a menubutton it posts its associated menu underneath the menubutton widget. Then the user can slide the mouse down over the menu with the button still down and release the mouse button over the desired entry. When the button is released the menu entry is invoked and the menu is unposted. The user can release the mouse button outside the menu to unpost it without invoking any entry.

If the user releases the mouse button over the menubutton then the menu stays posted and the user will not be able to do anything else with the application until the menu is unposted either by clicking on one of its entries (which invokes that entry and unposts the menu) or clicking outside of the menu (which unposts the menu without invoking any entry). Situations like this where a user must respond to a particular part of an application and cannot do anything with the rest of the application until responding are called *modal* user interface elements. Menus and dialog boxes are examples of modal interface elements. Modal interface elements are implemented using the grab mechanism described in Chapter 24.

15.3.2 Pop-up menus

The second common style of menu usage is called *pop-up* menus. In this approach, pressing one of the mouse buttons in a particular widget causes a menu to post next to the mouse cursor and the user can slide the mouse over the desired entry and release it there to invoke the entry and unpost the menu. As with pull-down menus, releasing the mouse button outside the menu causes it to unpost without invoking any of its entries.

15.3.3 Cascaded menus

The third commonly used approach to posting menus is called *cascaded menus*. Cascaded menus are implemented using cascade menu entries in other menus, such as pull-down and pop-up menus. Each cascade menu entry is similar to a menubutton in that it is associated with a menu widget. When the mouse cursor passes over the cascade entry, its associated menu is posted just to the right of the cascade entry, as shown in Figure 15.3(c). The user can then slide the mouse to the right onto the cascaded menu and select an entry in the cascaded menu. Menus can be cascaded to any depth.

15.3.4 Keyboard traversal and accelerators

Pull-down menus can also be posted from the keyboard using a technique called *keyboard traversal*. One of the letters in each menubutton is underlined to indicate that it is the traversal character for that menubutton. If that letter is typed while holding the `Alt` key down then the menubutton's menu will be posted. Once a menu has been posted the arrow keys can be used to move among the menus and their entries. The left and right arrow keys move left or right among the menubuttons, unposting the menu for the previous menubutton and posting the menu for the new one. The up and down keys move among the entries in a menu, activating the next higher or lower entry. The `Return` key can be used to invoke the active menu entry. In addition, the labels in menu entries are typically drawn with one character underlined; if this character is typed when the menu is posted then the entry is invoked immediately.

Lastly, in many cases it is possible to invoke the function of a menu entry without even posting the menu by typing *keyboard shortcuts*. If there is a shortcut for a menu entry then the keystroke for the shortcut will be displayed at the right side of the menu entry (e.g. `Ctrl+X` is displayed in the `Delete` menu entry in Figure 15.3(d)). This key combination may be typed in the application to invoke the same function as the menu entry (e.g. type `x` while holding the `Control` key down to invoke the `Delete` operation without going through the menu).

15.4 Listboxes

A listbox is a widget that allows the user to select one or more possibilities from a range of alternatives, such as a file name from those in the current directory or a color from a database of defined colors. A listbox contains one or more entries, each of which displays a one-line string as shown in Figure 15.4. The widget commands for listboxes allow entries to be created, destroyed, and queried.

If there are more entries than there are lines in the listbox's window then only a few of them are displayed at a time; the user can control which portion is displayed by using a separate scrollbar widget associated with the listbox (see Section 15.6). The view in a listbox can also be controlled by pressing mouse button 2 in the widget and dragging up or down. This is called *scanning*: it has the effect of dragging the listbox contents past the window at high speed. Most Tk widgets that support scrollbars also support scanning. If the strings in the listbox are too long to fit in the window then the listbox can also be scrolled and scanned in the horizontal direction.

Typically listboxes are configured so that the user can select an entry by clicking on it with mouse button 1. In some cases the user can also select a range of entries by pressing and dragging with button 1. Selected entries appear in a different color and usually have a raised 3-D effect. Once the desired entries have been selected, the user will typically use those entries by invoking another widget, such as a button widget or menu entry. For

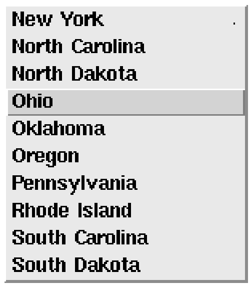

New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
South Dakota

Figure 15.4. An example of a listbox widget displaying the names of all the states in the U.S.A. Only a few of the entries are visible in the window at one time. The `Ohio` entry is selected.

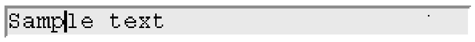

Sample text

Figure 15.5. An example of an entry widget. The vertical bar is the insertion cursor ,which identifies the point at which new text will be inserted.

example, the user might select one or more file names from a listbox and then click on a button widget to delete the selected files; the Tcl command associated with the button widget can read out the strings from the selected listbox entries. It's also common for listboxes to support double-clicking, which both selects an entry and invokes some operation on it. For example, in a file-open dialog box, double-clicking on a file name might cause that file to be opened by the application.

15.5 Entries

An entry is a widget that allows the user to type in and edit a one-line text string. For example, if a document is being saved to disk for the first time then the user will have to provide a file name to use. The user might type the file name in an entry widget, then click on a button widget whose Tcl command retrieves the file name from the entry and saves the document in that file. Figure 15.5 shows an example of an entry widget.

To enter text into an entry the user clicks mouse button 1 in the entry. This makes a blinking vertical bar appear, called the *insertion cursor.* The user can then type characters

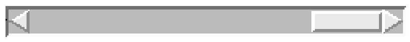


Figure 15.6. A horizontal scrollbar widget. The rectangular slider indicates how much of the document in an associated widget is visible in its window (in this case the rightmost 20% is visible). The user can adjust the view in the associated widget by dragging the slider with mouse button 1 or by clicking on the arrows or the slider region.

and they will be inserted into the entry at the point of the insertion cursor. The insertion cursor can be moved by clicking anywhere in the entry's text. Text in an entry can be selected by pressing and dragging with mouse button 1, and it can be edited with a variety of keyboard actions; see the reference documentation for details.

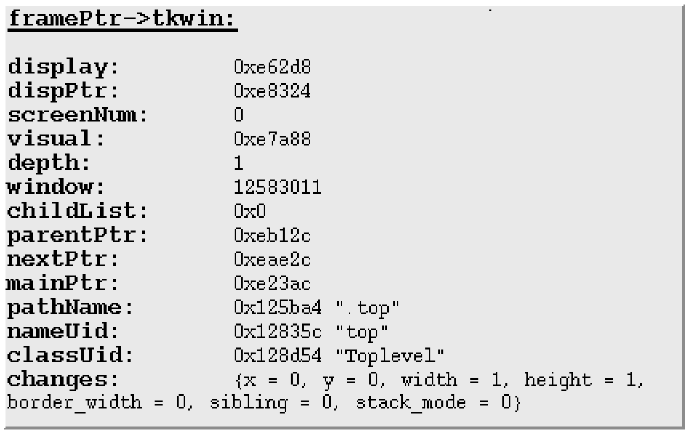
If the text for an entry is too long to fit in its window then only a portion of it is displayed and the view can be adjusted using an associated scrollbar widget or by scanning with mouse button 2. Entries can be disabled so that no insertion cursor will appear and the text in the entry cannot be modified. The text in an entry can be associated with a Tcl variable so that changes to the variable are reflected in the entry and changes made in the entry are reflected in the variable.

15.6 Scrollbars

Scrollbar widgets are used to control what is displayed in other widgets. Each scrollbar is associated with some other widget such as a listbox or entry. The scrollbar is typically displayed next to the other widget and when the user clicks and drags on the scrollbar the view in the associated widget will change. A scrollbar appears as shown in Figure 15.6 with an arrow at each end and a slider in the middle. The size and position of the slider correspond to the portion of the associated widget's document that is currently visible in its window. For example, if the slider covers the rightmost 20% of the region between the two arrows as in Figure 15.6 it means that the rightmost 20% of the document is visible in the window. Scrollbars can be oriented either vertically or horizontally.

Users can adjust the view by clicking mouse button 1 on the arrows, which moves the view a small amount in the direction of the arrow, or by clicking in the empty space on either side of the slider, which moves the view by one screenful in that direction. The view can also be changed by pressing on the slider and dragging it.

A scrollbar interacts with its associated widget using Tcl scripts. One of a scrollbar's configuration options is a Tcl script to invoke to change the view; typically this script invokes the widget command for the associated widget. When the user manipulates the



```
framePtr->tkwin:

display:          0xe62d8
dispPtr:          0xe8324
screenNum:        0
visual:           0xe7a88
depth:            1
window:           12583011
childList:        0x0
parentPtr:        0xeb12c
nextPtr:          0xeae2c
mainPtr:          0xe23ac
pathName:         0x125ba4 ".top"
nameUid:          0x12835c "top"
classUid:         0x128d54 "Toplevel"
changes:          {x = 0, y = 0, width = 1, height = 1,
border_width = 0, sibling = 0, stack_mode = 0}
```

Figure 15.7. An example of a text widget. This widget displays the contents of a structure as part of a symbolic debugger. Tags are used to display field names in bold and to underline the name of the structure.

scrollbar, the scrollbar invokes the script, including additional information about the new view that the user requested. The associated widget changes its view and then invokes another Tcl script (one of its configuration options) that tells the scrollbar exactly what information is now displayed in the window, so the scrollbar can display the slider correctly. The scrollbar doesn't update its slider until told to do so by the associated widget; this makes it possible for the associated widget to reject or modify the user's request (e.g. to prevent the user from scrolling past the ends of the information in the widget).

15.7 Text

A text widget is similar to an entry except that it allows the text to span more than one line (see Figure 15.7 for an example). Text widgets are optimized to handle large amounts of text, such as files containing thousands of lines. As with entries, the user can click mouse button 1 to set the insertion cursor and then type new information into a text. Information in a text widget can be selected with the mouse just as for entries, and a number of mouse and keyboard actions are defined to assist in editing (see the reference documentation for details). Text widgets support scrolling and scanning, and they can be disabled to temporarily prevent edits.

In addition to the basic features described above, text widgets support three kinds of *annotations* on the text: marks, tags and embedded widgets. A mark associates a name with a particular position in the text (the gap between two adjacent characters). Marks are used to keep track of interesting locations in the text as characters are added and deleted.

A *tag* is a string that is associated with ranges of characters in a text widget. Each tag may be associated with any number of ranges of characters in the text, and the ranges of different tags may overlap. Tags are different from marks in that they are associated with particular characters, so they disappear when the characters are deleted. Tags are used for two purposes in texts: formatting and binding.

Each tag may contain formatting information such as background and foreground colors, font, and stippling and underlining information. If a character has been tagged then the formatting information in the tag overrides the default formatting information for the widget as a whole. This makes it possible to display text with multiple fonts and colors. In addition, the formatting information for a tag can be changed at any time. For example, you can apply a tag to all instances of a particular word in the text, then modify the tag's formatting information to make the words blink on and off.

The second use of tags is for *bindings*. A binding specifies a Tcl script to be invoked when certain events occur; each tag may have one or more bindings associated with it. For example, you can arrange for a script to be invoked whenever the mouse cursor passes over text with a particular tag, or whenever a mouse button is clicked over a particular item (see Chapter 19 for more information on bindings). This can be used to produce hypertext effects such as displaying a figure whenever the user clicks on the name of the figure in a text widget.

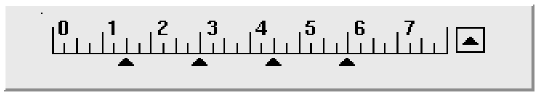
The third form of annotation in texts consists of embedded widgets. It is possible to embed other widgets in a text so that the other widgets are displayed at particular positions in the text. For example, you can arrange for a button widget to appear in a text widget as another way of getting hypertext-like capabilities, or you can embed canvas widgets to include figures inside texts, and so on.

Note: Embedded widgets are not supported in Tk version 3.2.

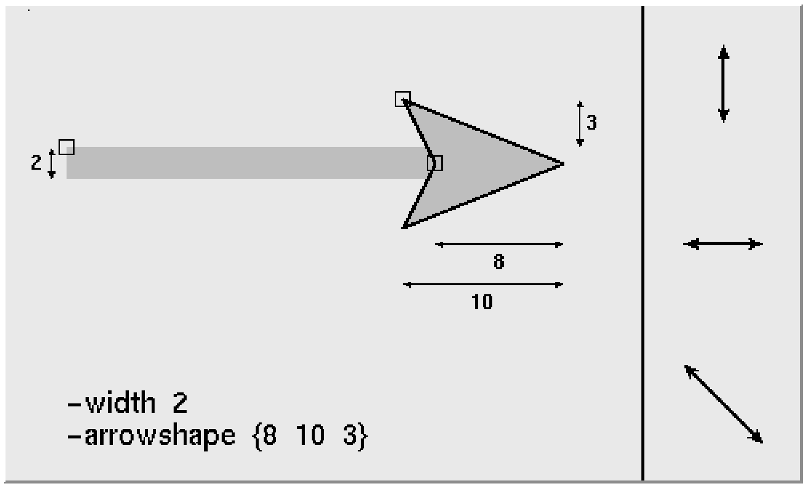
Text annotations allow you to configure a given text widget in a variety of interesting ways, so different text widgets may have very different behavior. For example, a file editor might use a text widget to display an entire file in a single font with no special formatting or bindings. In contrast, a debugger might use a text widget to display a structure as shown in Figure 15.7, where the names of the structure's fields are formatted differently than their values and bindings are set up so that the user can click on fields to open new windows on the structures pointed to by the fields.

15.8 Canvases

A canvas is a widget that displays a drawing surface and any number of graphical and textual *items*. The items can include rectangles, ellipses, arcs, lines, curves, polygons, curvagons, editable text, bitmaps, and embedded widgets. See Figure 15.8 for examples.



(a)



```
-width 2
-arrowshape {8 10 3}
```

(b)

Figure 15.8. Canvas widget examples. Figure (a) shows a ruler with a tab well to the right. The user can create new tab stops by pressing mouse button 1 in the tab well and dragging out a new tab stop. Four existing tab stops appear underneath the ruler; they can be repositioned by dragging them with the mouse. Figure (b) shows an editor for arrowhead shapes. The user can edit the arrowhead shape and line width by dragging the three small squares attached to the oversized arrow. Changes to this shape are reflected in the normal-size arrows on the right side of the canvas, in the dimensions displayed next to the oversize arrow, and in the configuration option strings in the bottom left corner.

Items can be created and deleted at any time, and their display attributes (such as line width and color) can also be modified dynamically. Items can be moved and scaled but rotations are not currently supported.

Canvases also provide a tagging mechanism similar to the tags in text widgets. Each item may have any number of textual tags associated with it. Tags serve two purposes in canvases. First, they make it easy to operate on groups of items all at once; for example, in a single command you can move or delete or recolor all items with a given tag. Second, tags can have bindings associated with them just as in texts. This allows you to achieve

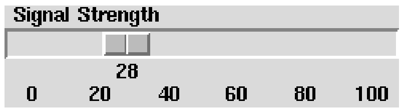


Figure 15.9. A scale widget. The scale’s value can be adjusted by dragging the slider with the mouse.

hypergraphic effects such as invoking some operation whenever a mouse button is clicked over an item, or allowing some items to be dragged with the mouse.

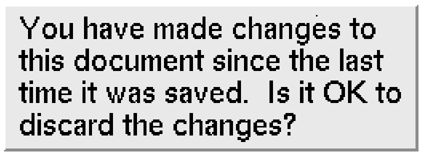
As with texts, the features provided by canvases are flexible enough to achieve many different effects, so different canvases may appear and behave very differently. Canvases can be used to provide non-interactive graphical displays, such as pie-charts or figures, or they can be used to create new kinds of editors and interactive widgets.

15.9 Scales

A scale is a widget that displays a numerical value and allows the user to edit the value (see Figure 15.9). A scale widget appears as a linear scale with optional numerical labels and a slider that shows the current value. The user can adjust the value by clicking mouse button 1 in the scale or by dragging the slider with mouse button 1. Each scale can be configured with a Tcl script to invoke whenever its value changes; the script can propagate the new value to other parts of the application. For example, three scales might be used to edit the hue, saturation, and intensity values for a color; as the user modifies the scale values, the new values can be used to update the color for an item in a canvas so that the item is always displayed in the color selected by the scales.

15.10 Messages

A message widget displays a multi-line string of text like the one shown in Figure 15.10. Messages are less powerful than texts (e.g. they don’t allow their text to be selected or edited, they don’t provide annotations, they don’t support scrolling, and they don’t handle large amounts of text efficiently), but they are simpler to create and configure. Messages are typically used for simple things like multi-line messages in dialog boxes.



You have made changes to this document since the last time it was saved. Is it OK to discard the changes?

Figure 15.10. A message widget displays a string, breaking it into multiple lines if necessary. Messages provide little other functionality (e.g. no edit capability).

Chapter 16
Configuration Options

Most of the state of a widget exists as a set of *configuration options* for the widget. For example, the colors and font and text for a button widget are configuration options, as is the Tcl script to invoke when the user clicks on the button. Each configuration option has a name (e.g., `-relief`) and a value (e.g. `raised`). Widgets typically have 15-30 configuration options. For widgets such as texts and canvases that have complex internal structures, the configuration options don't provide complete access to the internal structures; special widget commands exist for this purpose. However, state that is shared among all the objects in the internal structures (such as a default font for text widgets) is still represented as configuration options.

This chapter describes Tk's mechanisms for dealing with configuration options. Section 16.1 gives an overview of how the values of options are set. Sections 16.2-16.11 describe some of the common configuration options that are used in the Tk widget set. Finally, Sections 16.12 and 16.13 explain the `configure` widget command and the option database in more detail. Table 16.1 summarizes the commands for manipulating configuration options. For a complete list of the options available for a given class, see the reference documentation for the command that creates widgets of that class (e.g. the `button` command)

16.1 How options are set

Configuration options may be specified in four ways. First, you can specify configuration options in the command that creates a widget. For example, the command

Command	Description
`class window ?optionName value optionName value ...?`	Create a new widget with class *`class`* and path name *`window`*, and set options for the new widget as given by *`optionName`*-*`value`* pairs. Unspecified options are filled in using the option database or widget defaults. Returns *`window`* as result.
`window` `config`	Returns a list whose elements are sublists describing all of the options for *`window`*. Each sublist describes one option in the form described below.
`window` `config` *`optionName`*	Returns a list describing option *`optionName`* for *`window`*. The list will normally contain five values: *`optionName`*, the option's name in the option database, its class, its default value, and its current value. If the option is a synonym for another option, then the list contains two values: the option name and the database name for the synonym.
`window` `config` *`optionName value`*	Set the value for option *`optionName`* of *`window`* to value.
`option add` *`pattern value`* ?*`priority`*?	Add a new option to the option database as specified by *`pattern`* and *`value`*. *`Priority`* must be either a number between `0` and `100` or a symbolic name (see the reference documentation for details on symbolic names).
`option clear`	Remove all entries from the option database.
`option get` *`window name class`*	If the option database contains a pattern that matches *`window`*, *`name`*, and *`class`*, return the value for the highest priority matching pattern. Otherwise return an empty string.
`option readfile` *`fileName`* ?*`priority`*?	Read *`fileName`*, which must have the standard format for a `.Xdefaults` file, and add all the options specified in that file to the option database at priority level *`priority`*.

Table 16.1. The commands for manipulating widget configuration options.

```
button .help -text Help -foreground red
```

creates a new button widget and specifies the `-text` and `-foreground` options for it. Every widget creation command has this form, where the command name is the name of the widget class, the first argument is the name of the new widget in the Tk widget hierarchy, and additional arguments (if any) are name-value pairs specifying options.

The second way to specify configuration options is through the *option database*. If no value is given for a configuration option on the command line that creates a widget, then Tk checks the option database to see if a value has been specified for the option. The option database is similar to the resource database in other X toolkits. It allows users to specify values for options in the `RESOURCE_MANAGER` property on the root window or in a `.Xdefaults` file. Entries in the database can contain wildcard characters so that, for example, a single entry in the option database can set the background color for all buttons to blue. See Section 16.13 for more information on the option database.

The third way that configuration options are specified is through default values for each widget class. Class defaults are used for options that aren't specified in the widget creation command and aren't defined in the option database. The class defaults are intended to produce a reasonable effect so that you don't need to specify most options either on the command line or in the option database. The class defaults are compiled into the Tk library so you can't change them without recompiling Tk, but you can always override them with values in the option database.

The final way to specify configuration options for a widget is with its `configure` widget command. Every widget class supports a `configure` widget command. For example, the following command changes the text in the button widget created above and also specifies a Tcl script to invoke when the user clicks on the widget:

```
.help configure -text Quit -command exit
```

The `configure` widget command allows you to change the configuration options for a widget at any time and it also allows you to query the current state of the configuration options (see Section 16.12 for details on this).

16.2 Colors

Although each widget class defines its own set of configuration options, the options tend to be used in a consistent fashion by different classes. This section and the ones that follow provide an overview of the most common options. These options have the same names and legal values in many different widget classes.

The most common options are those for specifying colors. Every widget class supports a `-background` option, which determines the background color of the widget and is also used to compute the light and dark shadows if there is a 3D border drawn around the widget. Nearly every widget class also supports a `-foreground` option, which is used when displaying text and graphics in the widget. Table 16.2 lists all of the common color options.

Color values may be specified either symbolically or numerically. A symbolic color value is a name such as `white` or `red` or `SeaGreen2`. The valid color names are defined in a file named `rgb.txt` in your X library directory. Common names such as `black` and `white` and `red` should be defined in every X environment, but names like `SeaGreen2` might not be available everywhere. Color names are not case-sensitive: `black` is the same as `Black` or `bLaCk`.

Colors can also be specified numerically in terms of their red, green, and blue components. Four forms are available, in which the components are specified with 4-bit, 8-bit, 12-bit, or 16-bit vales:

Name on Command Line	Usage
`-background`	Background areas of widgets.
`-foreground`	Text and graphics.
`-activebackground`	Background color when widget is active (mouse cursor is over widget and pressing a mouse button will invoke some action).
`-activeforeground`	Foreground color when widget is active.
`-selectbackground`	Background color for areas occupied by selected information within widget.
`-selectforeground`	Foreground color for selected text and graphics.
`-insertbackground`	Color for insertion cursor.
`-disabledforeground`	Foreground color when widget has been disabled.

Table 16.2. Commonly-used color options. The left column gives the name of the option as specified in widget creation commands and `configure` widget commands. The right column describes how the option is used.

```
#RGB
#RRGGBB
#RRRGGGBBB
#RRRRGGGGBBBB
```

Each `R`, `G`, or `B` in the above examples represents one hexadecimal digit of red, green, or blue intensity, respectively. The first character of the specification must be `#`, and the same number of digits must be provided for each component. If fewer than 16 bits are given for the color components, they represent the most significant bits of the values. For example, `#3a7` is equivalent to `#3000a0007000`. A value of all ones represents “full on” for that color, and a value of zero represents “off.” Thus `#000` is black, `#f00` is red, `#ff0` is yellow, and `#fff` is white.

If you specify a color other than black or white for a monochrome display, then Tk will use black or white instead, depending on the overall intensity of the color you requested. Furthermore, if you are using a color display and all of the entries in its color map are in use (e.g. because you’re displaying a complex image on the screen) then Tk will treat the display as if it were monochrome.

Name on Command Line	Usage
`-borderwidth`	Width of 3D border drawn around widget.
`-activeborderwidth`	Width of 3D border drawn around active elements within widget.
`-selectborderwidth`	Width of 3D border drawn around selected text.
`-insertwidth`	Total width of insertion cursor including its border, if any.
`-insertborderwidth`	Width of 3D border for insertion cursor.
`-padx`	Additional space to leave on left and right sides of information displayed in widget.
`-pady`	Additional space to leave above and below information displayed in widget.

Table 16.3. Common options for specifying distances. The left column gives the name of the option as specified in widget creation commands and `configure` widget commands. The right column describes how the option is used.

16.3 Screen distances

Several options are used to specify distances on the screen. The most common of these options is `-borderwidth`, which determines the width of the 3D border drawn around a widget. Every widget class supports the `-borderwidth` option. Table 16.3 lists several other common distance options.

Ultimately, each distance option must reduce to a distance in screen pixels. However, Tk allows distances to be specified either in pixels or in absolute units that are independent of the screen resolution. A distance is specified as an integer or floating-point value followed optionally by a single character giving the units. If no unit specifier is given then the units are pixels. Otherwise the unit specifier must be one of the following characters:

`c`	centimeters
`i`	inches
`m`	millimeters
`p`	printer's points (1/72 inch)

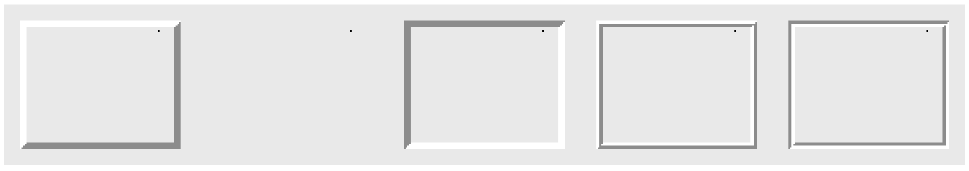


Figure 16.1. The three-dimensional effects produced by different values for the `-relief` option.

For example, a distance specified as `2.2c` will be rounded to the number of pixels that most closely approximates 2.2 centimeters; this may be a different number of pixels on different screens.

16.4 Reliefs

Every widget class supports an option named `-relief`, which determines the three-dimensional appearance of the widget. The option must have one of the values `raised`, `flat`, `sunken`, `ridge`, or `groove`. Figure 16.1 illustrates the effect produced by each value. Tk draws widget borders with combinations of light and dark shadows to produce the different effects. For example, if a widget's relief is `raised` then Tk draws the top and left borders in a lighter color than the widget's background and it drawns the lower and right borders in a darker color. This makes the widget appear to protrude from the screen.

The width of a widget's 3D border is determined by its `-borderwidth` option. If the border width is 0 then the widget will appear flat regardless of its `-relie`f option.

16.5 Fonts

The `-font` option is used to specify a font for widgets that display text, such as buttons, listboxes, entries, and texts. Tk uses standard X font names, which are illustrated in Figure 16.2 The name of a font consists of twelve fields separated by hyphens. The fields have the following meanings:

foundry	The type foundry that supplied the font data.
family	Identifies a group of fonts with a similar typeface design.

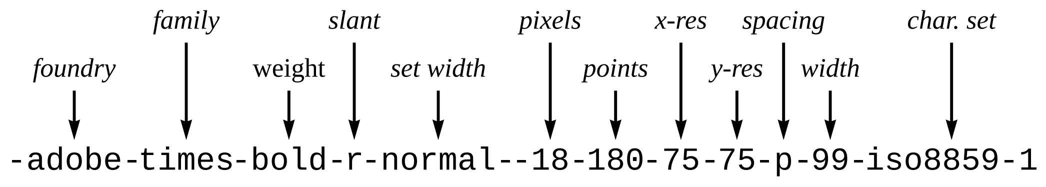


Figure 16.2. The fields of an X font name.

weight	Typographic weight of font, such as `medium`, `normal`, or `bold`.
slant	Posture of font, such as `r` for roman or upright, `i` for italic, or `o` for oblique.
set width	Proportionate width of font, such as `normal` or `condensed` or `narrow`.
pixels	Size of font in pixels.
points	Size of font in tenths of points, assuming screen has x-res and y-res specified for font.
x-res	Horizontal resolution of screen for which font was designed, in dots per inch.
y-res	Vertical resolution of screen for which font was designed, in dots per inch.
spacing	Escapement class of font, such as `m` for monospace (fixed-width) or `p` for proportional (variable-width).
width	Average width of characters in font, in tenths of pixels.
char. set	Character set that identifies the encoding of characters in the font.

When `-font` values you can use `*` and `?` wildcards: `?` matches any single character in a font name, and `*` matches any group of characters. For example, the font name

```
*-times-medium-r-normal--*-100-*
```

requests a 10-point Times Roman font in a medium (normal) weight and normal width. It specifies “don’t care” for the foundry, the pixel size, and all fields after the point size. If multiple fonts match this pattern then the X server will pick one of them. I recommend specifying the point size for fonts but not the pixel size, so that characters will be the same size regardless of the display resolution.

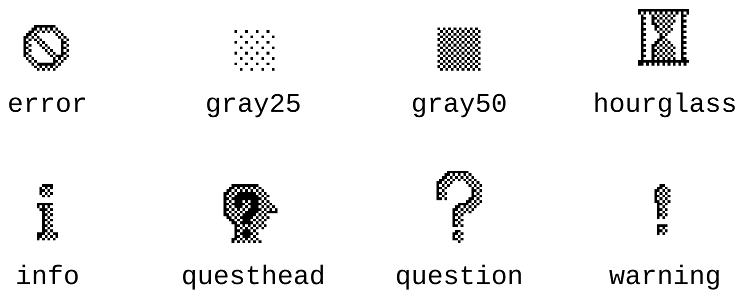


Figure 16.3. Bitmaps defined internally by Tk.

16.6 Bitmaps

Many widgets, such as labels and menubuttons, can display *bitmaps*. A bitmap is an image with two colors, foreground and background. Bitmaps are specified using the `-bitmap` option, whose values may have two forms. If the first character of the value is `@` then the remainder of the value is the name of a file containing a bitmap in the standard X11 bitmap file format. Such files are generated by the `bitmap` program, among others. Thus "`-bitmap @face.bit`" specifies a bitmap contained in the file `face.bit`.

If the first character of the value isn't `@` then the value must be the name of a bitmap defined internally. Tk defines several internal bitmaps itself (see Figure 16.3) and individual applications may define additional ones.

The `-bitmap` option only determines the pattern of 1's and 0's that make up the bitmap. The foreground and background colors used to display the bitmap are determined by other options (typically `-foreground` and `-background`). This means that the same bitmap can appear in different colors at different places in an application, or the colors of a given bitmap may be changed by modifying the options that determine them.

16.7 Cursors

Every widget class in Tk supports a `-cursor` option, which determines the image to display in the mouse cursor when it is over that widget. If the `-cursor` option isn't specified or if its value is an empty string then the widget will use its parent's cursor. Otherwise the value of the `-cursor` option must be a proper Tcl list with one of the following forms:

```
name fgColor bgColor
name fgColor
```

```
name
@sourceFile maskFile fgColor bgColor
@sourceFile fgColor
```

In the first three forms *`name`* refers to one of the cursors in the standard X cursor font. You can find a complete list of all the legal names in the X include file `cursorfont.h`. The names in that file all start with `XC_`, such as `XC_arrow` or `XC_hand2`; when using one of these names in a `-cursor` option, omit the `XC_`, e.g. `arrow` or `hand2`. Most of the Xlib reference manuals also include a table showing the names and images of all the cursors in the X cursor font; for example, see Appendix B of *X Window System: The Complete Reference to Xlib, X Protocol, ICCM, and XLFD*, by Scheifler and Gettys, Second Edition. If *`name`* is followed by two additional list elements as in the following widget command:

```
.f config -cursor {arrow red white}
```

then the second and third elements give the foreground and background colors to use for the cursor; as with all color values, they may have any of the forms described in Section 16.2. If only one color value is supplied then it gives the foreground color for the cursor; the background will be transparent. If no color values are given then black will be used for the foreground and white for the background.

If the first character in the `-cursor` value is `@` then the image(s) for the cursor are taken from files in bitmap format rather than the X cursor font. If two file names and two colors are specified for the value, as in the following widget command:

```
.f config -cursor {@cursors/bits cursors/mask red white}
```

then the first file is a bitmap that contains the cursor's pattern (1's represent foreground and 0's background) and the second file is a mask bitmap. The cursor will be transparent everywhere that the mask bitmap has a 0 value; it will display the foreground or background wherever the mask is 1. If only one file name and one color are specified then the cursor will have a transparent background.

16.8 Anchors

An *anchor position* indicates how to attach one object to another. For example, if the window for a button widget is larger than needed for the widget's text, a `-anchor` option may be specified to indicate where the text should be positioned in the window. Anchor positions are also used for other purposes, such as telling a canvas widget where to position a bitmap relative to a point or telling the packer geometry manager where to position a window in its frame.

Anchor positions are specified using one of the following points of the compass:

`n`	Center of object's top side.
`ne`	Top right corner of object.

`e`	Center of object’s right side.
`se`	Lower right corner of object.
`s`	Center of object’s bottom side.
`sw`	Lower left corner of object.
`w`	Center of object’s left side.
`nw`	Top left corner of object.
`center`	Center of object.

The anchor position specifies *the point on the object by which it is to be attached*, as if a push-pin were stuck through the object at that point and then used to pin the object someplace. For example, if a `-anchor` option of `w` is specified for a button, it means that the button’s text or bitmap is to be attached by the center of its left side, and that point will be positioned over the corresponding point in the window. Thus `w` means that the text or bitmap will be centered vertically and aligned with the left edge of the window. For bitmap items in canvas widgets, the `-anchor` option indicates where the bitmap should be positioned relative to a point associated with the item; in this case, `w` means that the center of the bitmap’s left side should be positioned over the point, so that the bitmap actually lies to the east of the point. Figure 16.4 illustrates these uses of anchor positions.

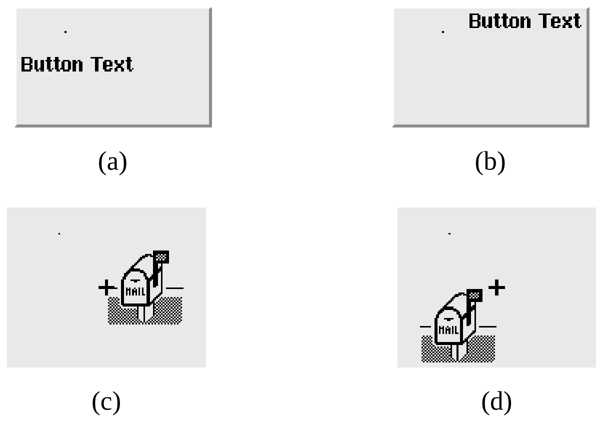


Figure 16.4. Examples of anchor positions used for button widgets and for bitmap items within canvases. Figure (a) shows a button widget with text anchored `w`, and (b) shows the same widget with an anchor position of `ne`. Figure(c) shows a canvas containing a bitmap with an anchor position of `w` relative to its point (the point appears as a cross, even though it wouldn’t appear in an actual canvas). Figure (d) shows the same bitmap item with an anchor point of `ne`.

16.9 Script options and scrolling

Script options are used in many places in Tk widgets. The most common usage is for widgets like buttons and menus that are supposed to take action when invoked by the user. This is handled by specifying a Tcl script as a configuration option for the widget. For example, button widgets support a `-command` option, which should contain a Tcl script. When the user invokes the widget by clicking over it with the mouse button, the widget causes the script to be executed. Similarly, each entry in a menu widget has a script associated with it, which is executed when the user invokes the menu entry.

Script options are also used for communicating between widgets. Typically, one widget will be configured with *part* of a Tcl command (e.g. the name of another widget's widget command and the first argument to that command). At appropriate times, the widget will invoke the command. Before invoking the command the widget will augment it with additional information that is relevant to the specific invocation. The best example of this is the communication between scrollbars and other widgets, which is described in the rest of this section.

When a scrollbar is associated with another widget and used to change its view, the communication between the scrollbar and the associated widget is controlled by two options, one for the associated widget and one for the scrollbar. In normal usage, each of these options invokes a widget command for the other widget.

The associated widget must inform the scrollbar about what it is currently displaying, so that the scrollbar can display the slider in the correct position. To do this, the scrollbar provides a widget command of the following form:

```
window set totalUnits windowUnits first last
```

`Window` is the name of the scrollbar widget (i.e. the name of the widget command for the scrollbar). *`TotalUnits`* indicates the total size of the information being displayed in the associated widget in the dimension being scrolled, such as the number of lines in a listbox or the number of characters in a text entry. *`WindowUnits`* indicates how much of the information can be displayed in the widget at one time given the current size of its window, and *`first`* and *`last`* give the indices of the top and bottom elements currently visible in the widget's window (for horizontal scrollbars *`first`* and *`last`* refer to the leftmost and rightmost visible elements).

The associated widget invokes the scrollbar's `set` command whenever information of interest to the scrollbar changes in the widget. To do this, scrollable widgets provide a `-xScrollCommand` option if they support horizontal scrolling and a `-yScrollCommand` option if they support vertical scrolling. For example, a listbox might be created with a vertical scrollbar using the following commands:

```
listbox .l -yscrollcommand {.vscroll set}
scrollbar .vscroll -orient vertical
pack .l -side left
pack .vscroll -side right
```

The value of the `-yscrollcommand` option is a Tcl command prefix. When the view in the listbox changes (e.g. because elements were deleted), the listbox takes the value of the `-yscrollcommand` option ("`.vscroll set`" in this case) and appends four integer values corresponding the the `totalUnits`, `windowUnits`, `first`, and `last` arguments described above. This will produce a Tcl command such as

```
.vscroll set 100 20 38 57
```

Then the listbox invokes the command, which causes the scrollbar to redraw its slider to reflect the new view. If horizontal scrolling is desired for the listbox as well, an additional scrollbar could be created and a `-xscrollcommand` option could be specified for the listbox.

A similar form of communication is used by the scrollbar to notify the associated widget when the user manipulates the scrollbar to request a new view. Each scrollbar provides a `-command` option, which specifies a Tcl command prefix for communicating new views to the associated widget. It can be set for the `.vscroll` widget above using the following command:

```
.vscroll config -command {.l yview}
```

Then when the user clicks in the scrollbar to change the view the scrollbar takes the `-command` option and appends the index of the element that should now appear at the top of the window. The result is a command like the following:

```
.l yview 39
```

The scrollbar widget then invokes this command. Listboxes and other widgets that support scrolling provide a `yview` widget command with exactly the above syntax that causes the widget to adjust its view. After adjusting its view, the listbox uses its `-yscrollcommand` option to notify the scrollbar of the new view so the scrollbar can redraw its slider.

This scheme has the advantage that neither widget needs any built-in information about the other; both the name of the other widget and the widget command to invoke are provided with options that can be configured by the application designer. In fact, the command options need not even correspond to widget commands. For example, a single scrollbar could be made to control two widgets simultaneously by using a Tcl procedure name as its `-command` option:

```
.vscroll config -command scrollProc
proc scrollProc index {
       .l yview $index
       .l2 yview $index
}
```

Then the commands invoked by the scrollbar will look like

```
scrollProc 39
```

and `scrollProc` will invoke `yview` widget commands in each of the two associated widgets.

16.10 Variables

Another common form for options is variable names. These options are used to associate one or more Tcl global variables with a widget so that the widget can set the variable under certain conditions or monitor its value and react to changes in the variable.

For example, many of the widgets that display text, such as labels and buttons and messages and entries, support a `-textvariable` option. The value of the option is the name of a global variable that contains the text to display in the widget. The widget monitors the value of the variable and updates the display whenever the variable changes value. In addition, for widgets like entries that can modify their text, the widget updates the variable to track changes made by the user.

Checkbuttons and radiobuttons also support a `-variable` option, which contains the name of a global variable. For checkbuttons there are two additional options (`-onvalue` and `-offvalue`) that specify values to store in the variable when the checkbutton is "on" and "off." As the user clicks on the checkbutton with the mouse, it updates the variable to reflect the checkbutton's state. The checkbutton also monitors the value of the variable and changes its on/off state if the variable's value is changed externally. Each checkbutton typically has its own variable.

With radiobuttons a group of widgets shares the same variable but each radiobutton has a distinct value that it stores into the variable (the `-value` option). When the user clicks on a radiobutton it sets the variable to its value and selects itself. The radiobutton monitors the variable so that it can deselect itself when some other radiobutton stores a different value into the variable. If the variable's value is changed externally then all of the radiobuttons associated with the variable update their selected/deselected state to reflect the variable's new value.

16.11 Time intervals

Several widget classes provide options that specify time intervals, such as the blink rate for the insertion cursor or the rate at which mouse buttons should auto-repeat. Table 16.4 summarizes the most commonly used options for specifying intervals. Time intervals are always specified as integer numbers of milliseconds: an interval of `100` means 100ms, `1000` means one second, and so on.

16.12 The configure widget command

Every widget class supports a `configure` widget command. This command comes in three forms, which can be used both to change the values of options and also to retrieve information about the widget's options. See Table 16.1 for a summary of these forms.

Name on Command Line	Usage
`-insertoffTime`	How long to leave insertion cursor turned off in each blink cycle. Zero means cursor doesn't blink.
`-insertOnTime`	How long to leave insertion cursor turned on in each blink cycle.
`-repeatDelay`	How long to wait before auto-repeating a button or keystroke.
`-repeatInterval`	Once auto-repeat starts, how long to wait from one auto-repeat to the next.

Table 16.4. Commonly-used time interval options. The left column gives the name of the option as specified in widget creation commands and `configure` widget commands. The right column describes how the option is used.

If `configure` is given two additional arguments then it changes the value of an option as in the following example:

```
.button configure -text Quit
```

If the `configure` widget command is given just one extra argument then it returns information about the named option. The return value is normally a list with five elements:

```
.button configure -text
-text text Text { } Quit
```

The first element of the list is the name of the option as you'd specify it on a Tcl command line when creating or configuring a widget. The second and third elements are a name and class to use for looking up the option in the option database (see Section 16.13 below). The fourth element is the default value provided by the widget class (a single space character in the above example), and the fifth element is the current value of the option.

Some widget options are just synonyms for other options (e.g. the `-bg` option for buttons is the same as the `-background` option). Configuration information for a synonym is returned as a list with two elements consisting of the option's command-line name and the option database name of its synonym:

```
.button configure -bg
-bg background
```

If the `configure` widget command is invoked with no additional arguments then it returns information about all of the widget's options as a list of lists with one sub-list for each option:

```
.button configure
{-activebackground activeBackground Foreground Black 
Black} {-activeforeground activeForeground Background 
White White} {-anchor anchor Anchor center center} 
{-background background Background White White} {-bd 
borderWidth} {-bg background} {-bitmap bitmap Bitmap {} 
{}} {-borderwidth borderWidth BorderWidth 2 2} {-command 
command Command {} {}} {-cursor cursor Cursor {} {}} 
{-disabledforeground disabledForeground 
DisabledForeground {} {}} {-fg foreground} {-font font 
Font -Adobe-Helvetica-Bold-R-Normal-*-120-* -Adobe-
Helvetica-Bold-R-Normal-*-120-*} {-foreground 
foreground Foreground Black Black} {-height height 
Height 0 0} {-padx padX Pad 1 1} {-pady padY Pad 1 1} 
{-relief relief Relief raised raised} {-state state 
State normal normal} {-text text Text { } Quit} 
{-textvariable textVariable Variable {} {}} {-width 
width Width 0 0}
```

16.13 The option database

The option database supplies values for configuration options that aren't specified explicitly by the application designer. The option database is consulted when widgets are created: for each option not specified on the command line, the widget queries the option database and uses the value found there, if any. If there is no value in the option database then the widget supplies a default value. Values in the option database are usually provided by the user to personalize applications, e.g. by using consistently larger fonts. Tk supports the `RESOURCE_MANAGER` property and `.Xdefaults` file in the same way as other X toolkits like Xt.

16.13.1 Patterns

The option database contains any number of entries, where each entry consists of two strings: a *pattern* and a *value*. The pattern determines whether the entry applies to a given option for a given widget, and the value is a string to use for options that match the pattern.

In its simplest form, a pattern consists of an application name, a window name, and an option name, all separated by dots. For example, here are two options in this form:

```
wish.a.b.foreground
wish.background
```

The first pattern applies to the `foreground` option in the window `.a.b` in the application `wish`, and the second pattern applies to the `background` option in the main window for `wish`. Each of these patterns applies to only a single option for a single widget.

Patterns may also contain classes or wildcards, which allow them to match many different options or widgets. Any of the window names in the pattern may be replaced by a class, in which case the pattern matches any widget that is an instance of that class. For example, the pattern below applies to all children of `.a` that are buttons:

```
wish.a.Button.foreground
```

Application and option names may also be replaced with classes. The class for an application is the class of its main window; names and classes for applications are discussed in more detail in Chapter 22. Individual options also have classes. For example, the class for the `foreground` option is `Foreground`. Several other options, such as `activeBackground` and `insertBackground`, also have the class `Foregound`, so the following pattern applies to any of these options for any button widget that is a child of `.a` in `wish`:

```
wish.a.Button.Foreground
```

Lastly, patterns may contain `*` wildcard characters. A `*` matches any number of window names or classes, as in the following examples:

```
*Foreground
wish*Button.foreground
```

The first pattern applies to any option in any widget of any application as long as the option's class is `Foreground`. The second pattern applies to the `foreground` option of any button widget in the `wish` application. The `*` wildcard may only be used for window or application names; it cannot be used for the option name (it wouldn't make much sense to specify the same value for all options of a widget).

This syntax for patterns is the same as that supported by the standard X resource database mechanisms in the X11R3 and X11R4 releases. The `?` wildcard, which was added in the X11R5 release, is not yet supported by Tk's option database.

In order to support the above matching rules, each option has three names:

1. the name that can be typed on a command line, which always starts with a `-` and has no upper-case letters, as in `-activeborderwidth`;
2. the name of the option in the database, which is typically the same as the command-line name except that it contains no `-` and uses capital letters to mark internal word boundaries, as in `activeBorderWidth`;
3. the class of the option, which always starts with a capital letter and may contain additional capital letters to mark internal boundaries, as in `BorderWidth`.

When you query an option with the `configure` widget command all three of these names are returned. It's important to remember that in Tk classes *always* start with an initial capital letter, and any name starting with an initial capital letter is assumed to be a class.

16.13.2 RESOURCE_MANAGER property and .Xdefaults file

When a Tk application starts up, Tk automatically initializes the option database. If there is a `RESOURCE_MANAGER` property on the root window, then the database is initialized from it. Otherwise Tk checks the user's home directory for a `.Xdefaults` file and uses it if it exists. The initialization information has the same form whether it comes from the `RESOURCE_MANAGER` property or the `.Xdefaults` file. The syntax described below is the same as that supported by other toolkits such as Xt.

Each line of the initialization data specifies one entry in the resource database in a form like the following:

```
*Foreground: blue
```

The line consists of a pattern (`*Foreground` in the example) followed by a colon followed by whitespace and then a value to associate with that pattern (`blue` in the example). If the value is too long to fit on one line then it can be placed on multiple lines with each line but the last ending in a backslash-newline sequence:

```
*Gizmo.text: This is a very long initial \
value to use for the text option in all \
"Gizmo" widgets.
```

The backslashes and newlines will not be part of the value.

Blank lines are ignored, as are lines whose first non-blank character is # or `!`.

16.13.3 Priorities

It is possible for several patterns in the option database to match a particular option. When this happens Tk uses a two-part priority scheme to determine which pattern applies. Tk's mechanism for resolving conflicts is different than the standard mechanism supported by the Tk toolkit, but I think it's simpler and easier to work with.

For the most part the priority of an option in the database is determined by the order in which it was entered into the database: newer options take priority over older ones. When specifying options (e.g. by typing them into your `.Xdefaults` file) you should specify the more general options first, with more specific overrides following later. For example, if you want button widgets to have a background color of `Bisque1` and all other widgets to have white backgrounds, then put the following lines in your `.Xdefaults` file:

```
*background: white
*Button.background: Bisque1
```

The `*background` pattern will match any option that the `*Button.background` pattern matches, but the `*Button.background` pattern has higher priority since it was specified last. If the order of the patterns had been reversed then all widgets (including buttons) would have white backgrounds and the `*Button.background` pattern would have no effect.

In some cases it may not be possible to specify general patterns before specific ones (e.g. you might add a more general pattern to the option database after it has already been initialized with a number of specific patterns from the RESOURCE_MANAGER property). To accommodate these situations, each entry also has an integer priority level between 0 and 100, inclusive. An entry with a higher priority level takes precedence over entries with lower priority levels, regardless of the order in which they were inserted into the option database. Priority levels are not used very often in Tk; for complete details on how they work, please refer to the reference documentation.

Tk's priority scheme is different that the scheme used by other X toolkits such as Xt. Xt gives higher priority to the most specific pattern, e.g. `.a.b.foreground` is more specific than `*foreground` so it receives higher priority regardless of the order in which the patterns appear. In most cases this won't be a problem: specify options for Xt applications using the Xt rules, and for Tk applications using the Tk rules. In cases where you want to specify options that apply both to Tk applications and Xt applications, use the Xt rules but also make sure that the patterns considered higher-priority by Xt also appear later in your `.Xdefaults` file. In general, you shouldn't need to specify very many options to Tk applications (if you do, it suggests that the applications haven't been designed well), so the issue of pattern priority shouldn't come up often.

It's important to remember that the option database is only queried for options not specified explicitly in the widget creation command. This means that the user will not be able to override any option that was specified on the command line. If you want to specify a value for an option but allow the user to override that value through the RESOURCE_MANAGER property, you should specify the value for the option using the `option` command described below.

16.13.4 The option command

The `option` command allows you to manipulate the option database while an application is running. The command `option add` will create a new entry in the database. It takes two or three arguments. The first two arguments are the pattern and value for the new entry and the third argument, if specified, is a priority level for the new entry. For example,

```
option add *Button.background Bisque1
```

adds an entry that sets the background color for all button widgets to `Bisque1`.

The command

```
option clear
```

will remove all entries from the option database. The `option readfile` command will read a file in the format described above for the RESOURCE_MANAGER property and make entries in the option database for each line. For example, the following script discards any existing options (including those loaded automatically from the RESOURCE_MANAGER property) and reloads the database from file `newOptions`:

```
option clear
option readfile newOptions
```

The `option readfile` command can also be given a priority level as an extra argument after the file name.

To query whether there is an entry in the option database that applies to a particular option, use the `option get` command:

```
option get .a.b background Background
```

This command takes three arguments, which are the path name of a widget (`.a.b`), the database name for an option (`background`) and the class for that option (`Background`). The command will search the option database to see if any entries match the given window, option, and class. If so, the value of the highest-priority matching option is returned. If no entry matches then an empty string is returned.

Chapter 17
Geometry Managers: The Placer

Geometry managers are the entities that determine the dimensions and locations of widgets. Tk is similar to other X11 toolkits in that it doesn't allow individual widgets to determine their own geometry. A widget will not even appear on the screen unless it is managed by a geometry manager. This separation of geometry management from internal widget behavior allows multiple geometry managers to exist simultaneously and it allows any widget to be used with any geometry manager. If widgets selected their own geometry then this flexibility would be lost: every existing widget would have to be modified to introduce a new style of layout.

This chapter describes the overall structure for geometry management and then presents the placer, which is Tk's simplest geometry manager . The placer manages windows independently without considering other related windows, so it isn't very flexible in the layouts it produces. Because of this, the placer tends to be used only in special situations. Chapter 18 describes a more powerful geometry manager called the packer. The packer lays out groups of windows together, considering the needs of each of the windows when laying out the group. This produces more flexible layouts but also makes the packer harder to understand.

17.1 An overview of geometry management

A geometry manager's job is to arrange one or more *slave* windows relative to a *master* window. For example, it might arrange three slaves in a row from left to right across the area of the master, or it might arrange two slaves so that they split the space of the master with one slave occupying the top half and the other occupying the bottom half. Different

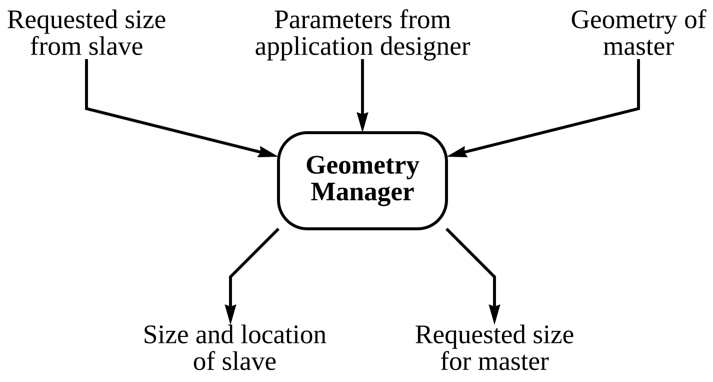

Requested size from slave
Parameters from application designer
Geometry of master
Geometry Manager
Size and location of slave
Requested size for master

Figure 17.1. A geometry manager receives three kinds of inputs: a requested size for each slave (which usually reflects the information to be displayed in the slave), commands from the application designer (such as "arrange these three windows in a row"), and the actual geometry of the master window. The geometry manager then assigns a size and location to each slave. It may also set the requested size for the master window, which can be used by a higher-level geometry manager to manager the master.

geometry managers embody different styles of layout. The master is often the parent of the slave but there are times when it's convenient to use other windows as masters (you'll see examples of this later).

A geometry manager receives three sorts of information for its use in computing a layout (see Figure 17.1). First, each slave widget requests a particular width and height. These are usually the minimum dimensions needed by the widget to display its information. For example, a button widget requests a size just large enough to display its text or bitmap along with the border specified for the widget. Although geometry managers aren't obliged to satisfy the requests made by their slave widgets, they usually do.

The second kind of input for a geometry manager comes from the application designer and is used to control the layout algorithm. The nature of this information varies from geometry manager to geometry manager. In some cases the information is very specific. For example, with the placer an application designer can specify the precise location and dimensions for a given slave; all the placer does is to apply the given geomety to the slave window. In other cases the information is more abstract. For example, with the packer an application designer can name three slaves and request that they be arranged in a row from left to right within the master; the packer will then check the requested sizes of the slaves and position them so that they abut in a row, with each slave given just as much space as it needs.

The third kind of information used by geometry managers is the geometry of the master window. For example, the geometry manager might position a slave at the lower left corner of its master, or it might divide the space of the master among one or more slaves, or it might refuse to display a slave altogether if it doesn't fit within the area of its master.

Once it has received all of the above information, the geometry manager executes a layout algorithm to determine the dimensions and position of each of its slaves. If the size of a widget isn't what it requested then the widget must make do in the best way it can. Geometry managers usually try to give widgets the space they requested, but they may produce better layouts by giving widgets extra space in some situations. If there isn't enough space in a master for all of its slaves, then some of the slaves may get less space than they asked for. In extreme cases the geometry manager may choose not to display some slaves at all.

The controlling information for geometry management may change while an application runs. For example, a button might be reconfigured with a different font or bitmap, in which case it will change its requested dimensions. Or, the geometry manager might be told to use a different approach (e.g., arrange a collection of windows from top to bottom instead of left to right) or some of the slave windows might be deleted, or the user might interactively resize the master window. When any of these things happens the geometry manager recomputes the layout.

Some geometry managers (e.g. the packer) will set the requested size for the master window. For example, the packer computes how much space is needed in the master to accommodate all of its slaves in the fashion requested by the application designer. It then sets the requested size for the master to these dimensions, overriding any request made by the master widget itself. This approach allows for hierarchical geometry management, where each master is itself the slave of another higher-level master. Size requests pass up through the hierarchy from each slave to its master, resulting ultimately in a size request for a top-level window, which is passed to the window manager. Then actual geometry information passes down through the hierarchy, with the geometry manager at each level accepting the geometry of a master and using it to compute the geometry of one or more slaves. As a result, the entire hierarchy sizes itself to just meet the needs of the lowest-level slaves (the master windows "shrink-wrap" around their slaves).

Each widget can be managed by at most one geometry manager at a time, although it is possible to switch geometry managers during the life of a slave. A widget can act as master to any number of slaves, and it is even possible for different geometry managers to control different groups of slaves associated with the same master. A single geometry manager can simultaneously manage different groups of slaves associated with different masters.

Only internal windows may be slaves for geometry management. The techniques described here do not apply to top-level or main windows. These windows are managed by the window manager for the display; see Chapter 22 for information on how to control their geometry.

`place` *`window option value`* ?*`option value`* ...?	Same as `place configure` command described below.
`place configure` *`window option value`* ?*`option value`* ...?	Arranges for the placer to manage the geometry of *`window`*. The *`option`* and *`value`* arguments determine the dimensions and position of *`window`*.
`place dependents` *`window`*	Returns a list whose elements are the slave windows managed by the placer for which *`window`* is the master.
`place forget` *`window`*	Causes the placer to stop managing *`window`* and unmap it from the screen. Has no effect if *`window`* isn't currently managed by the placer.
`place info` *`window`*	Returns a list giving the current configuration of *`window`*. The list consists of *`option`*-*`value`* pairs in exactly the same form as might be specified to the `place configure` command. Returns an empty string if *`window`* isn't currently managed by the placer.

Table 17.1. A summary of the `place` command.

17.2 Controlling positions with the placer

The placer is a simple geometry manager that implements fixed placements. The application designer specifies the position and size of each slave relative to its master, and the placer simply implements the requested placement. The placer treats each slave independently, so changes in the placement of one slave have no effect on any other slave.

The `place` command is used to communicate with the placer; see Table 17.1 for a summary of its features. In its simplest form its arguments consist of a window name and one or more configuration options specified as name-value pairs:

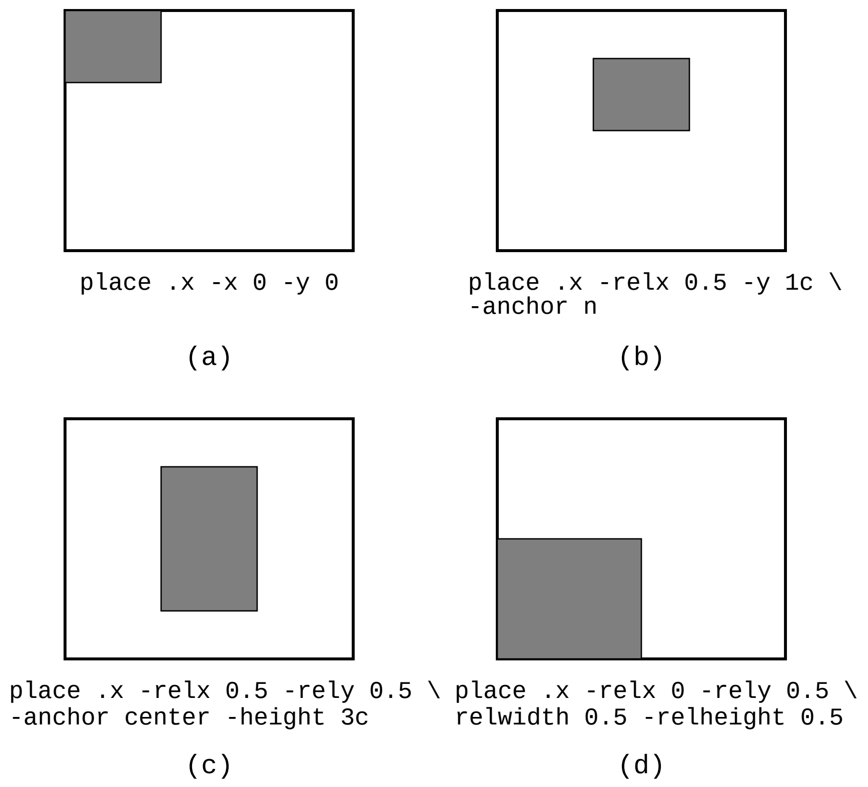
```
place .x -x 0 -y 0
```

This command positions window `.x` so that its upper-left corner appears at the upper-left corner of its master, which defaults to its parent. The placer supports about a dozen configuration options in all; Table 17.2 summarizes the options and Figure 17.2 shows some examples of using the placer.

The placer determines the position of a slave window in two steps. First, it uses the `-x`, `-y`, `-relx`, and `-rely` options to choose an anchor point, then it positions the slave relative to that anchor point using the `-anchor` option. The anchor point is specified relative to the upper left corner of the master window. If the `-x` and `-y` options are used then the position is given with absolute distances in any of the forms described in Section 16.3. If the `-relx` and `-rely` options are used then the position is specified as a fraction of the size of the master; for example, "`-relx .75`" specifies that the anchor point should lie

`-x` *distance*	Specifies the horizontal distance of the slave’s anchor point from the left edge of its master.
`-y` *distance*	Specifies the vertical distance of the slave’s anchor point from the top edge of its master.
`-relx` *fraction*	Specifies the horizontal position of the slave’s anchor point in a relative fashion as a floating-point number. If *fraction* is `0.0` it refers to the master’s left edge, and `1.0` refers to the right edge. *Fraction* need not lie between 0.0 and 1.0.
`-rely` *fraction*	Specifies the vertical position of the slave’s anchor point in a relative fashion as a floating-point number. If *fraction* is `0.0` it refers to the master’s top edge, and `1.0` refers to the bottom edge. *Fraction* need not lie between 0.0 and 1.0.
`-anchor` *anchor*	Specifies which point on the slave window is to be positioned over the anchor point.
`-width` *distance*	Specifies the width of the slave.
`-height` *distance*	Specifies the height of the slave.
`-relwidth` *fraction*	Specifies the slave’s width as a fraction of the width of its master.
`-relheight` *fraction*	Specifies the slave’s height as a fraction of the height of its master.
`-in` *window*	Specifies the master window for the slave. Must be the slave’s parent or a descendant of the parent.
`-bordermode` *mode*	Specifies how the master’s borders are to be used in placing the slave. *Mode* must be `inside`, `outside`, or `ignore`.

Table 17.2. A summary of the configuration options supported by the placer.



```
place .x -x 0 -y 0
(a)

place .x -relx 0.5 -y 1c \
-anchor n
(b)

place .x -relx 0.5 -rely 0.5 \
-anchor center -height 3c
(c)

place .x -relx 0 -rely 0.5 \
relwidth 0.5 -relheight 0.5
(d)
```

Figure 17.2. Examples of using the placer to manage a window. Each figure shows a `place` command and the layout that results. The larger window is the master and the smaller shaded window is `.x`, the slave being managed. In (a) and (b) the slave is given the size it requested. In (c) the height of the slave is specified in the `place` command, and in (d) both the width and height of the slave are specified in the `place` command.

three-fourths of the way from the left edge of the master to its right edge. These forms can be mixed for a given slave, as in Figure 17.2(b).

The `-anchor` option indicates which point on the slave window should be positioned over the anchor point. It can have any of the anchor names described in Section 16.8. For example, an anchor position of `s` positions the slave so that the center of its bottom edge lies over the anchor point.

It is possible to position a slave outside the area of its master, for example by giving a negative `-x` option or a `-rely` option greater than 1.0. However, X clips each window to the dimensions of its parent, so the portions of the slave that lie outside its parent will not appear on the screen. In the normal case where the parent is the master it probably isn't very useful to position the slave outside its master. However, if the master is a sibling or nephew of the slave then the slave can be positioned outside its master and still be visible on the screen. See Section 17.4 for information on changing the master window.

17.3 Controlling the size of a slave

By default, a slave window managed by the placer is given the size it requests. However, the `-width`, `-height`, `-relwidth`, and `-relheight` options may be used to override either or both of the slave's requested dimensions. The `-width` and `-height` options specify the dimensions in absolute terms, and `-relwidth` and `-relheight` specify the dimensions as a fraction of the size of the master. For example, the following command sets the width of `.x` to 50 pixels and the height to half the height of its master:

```
place .x -width 50 -relheight 0.5
```

17.4 Selecting the master window

In most cases the master window for a given slave will be its parent in the window hierarchy. If no master is specified, the placer uses the parent by default. However, it is sometimes useful to use a different window as the master for a slave. For example, it might be useful to attach one window to a sibling so that whenever the sibling is moved the window will follow. This can be accomplished using the `-in` configuration option. For example, the following command arranges for `.x` always to be displayed with its upper-left corner "glued" to the upper right corner of `.y`:

```
place .x -in .y -relx 1.0 -rely 0
```

In this example, `.x` won't actually be "in" `.y`; `.y` will be `.x`'s master and `.x` will be displayed outside `.y` but adjacent to it.

Note: The master for a slave must be either the parent of the slave or a descendant of the parent. The reason for this restriction has to do with X's clipping rules. Each window is clipped to the boundaries of its parent; no portion of a child that lies outside of its parent will be displayed. Tk's restriction on master windows gurantees that the slave will be visible and unclipped if its master is visible and unclipped. Suppose that the restriction were not enforced, so that window `.x.y` *could have* `.a` *as its master. Suppose also that* `.a` *and* `.x` *do not overlap at all. If you asked the placer to position* `.x.y` *at the center of* `.a`*, the placer would set* `.x.y`*'s position as requested, but this would cause* `.x.y` *to be outside the area of* `.x` *so X would not display it, even though* `.a` *is fully visible. This behavior would be confusing to application designers so Tk restricts mastership to keep it from occurring. The restriction applies to all of Tk's geometry managers.*

17.5 Border modes

The last configuration option for the placer is `-bordermode`; it determines how the masters borders are used in placing the slave, and it must have one of the values `inside`, `outside`, or `ignore`. A border mode of `inside` is typically used when placing the slave inside the master, and it is the default. In this case, the placer considers the area of the master to be its innermost area, inside any borders. The anchor point is specified relative to the upper-left corner of this area, and the `-relx`, `-rely`, `-relwidth`, and `-relheight` options use the dimensions of this inner area.

A border mode of `outside` is typically used when positioning the slave outside the area of its master. In this case the placer considers the area of the master to be its outermost area including all borders.

The final border mode, `ignore`, causes the placer to completely ignore any borders and use the master's official X area. This area includes the 3D borders drawn by widgets, which are drawn inside a window's X area, but excludes any external borders. The `ignore` option is provided for completeness but probably isn't very useful.

17.6 More on the place command

So far the `place` command has been discussed in its simplest form, where its first argument is the name of a slave window to manage. `Place` also has several other forms, where the first argument selects a particular command option. `Place configure` has the same effect as the short form that's been used so far. For example, the following two commands have the same effect:

```
place .x -x 0 -y 0
place configure .x -x 0 -y 0
```

`Place configure` (or place without a specific option) can be invoked at any time to change the configuration of a slave window. When invoked on a window already managed by the placer, unspecified options retain their previous values.

The command `place dependents` returns a list of all the slave windows managed by the placer for a given master window:

```
place dependents .
.x .y .z
```

`Place info` returns information about the current configuration of a slave window managed by the placer:

```
place info .x
-x 0 -y 0 -anchor nw
```

The return value is a list containing name-value pairs in exactly the same form that you would specify them to `place configure`. It can be used to record the placement of a window so that it can be restored later.

Lastly, `place forget` causes the placer to stop managing a given slave window:

```
place forget .x
```

As a side effect, it unmaps the window so that it no longer appears on the screen. `Place forget` is useful if you decide that a window should be managed by a different geometry manager: you can tell the placer to forget it, then ask a different geometry manager to take over. You don't need to invoke `place forget` before deleting a widget: the placer (like all geometry managers) automatically forgets about widgets when they are deleted.

17.7 Controlling the size of the master

Although it is possible for a geometry manager to set the requested size for the master windows it manages, the placer does not do this. It simply uses whatever size is provided for a given master, without attempting to influence that size at all. Thus you'll need to use some other mechanism to specify the master's size (e.g. if the master is a frame widget you can request particular dimensions with the `-width` and `-height` configuration options).

Chapter 18
The Packer

The packer is the second geometry manager provided by Tk. Although it is slightly more complicated than the placer described in Chapter 17, it is more powerful because it arranges groups of slaves together, taking into account the needs of one slave when choosing the geometry for the others. With the packer it is easy to achieve effects such as “arrange the following three windows in a row” or “put the menu bar across the top of the window, then the scrollbar across the right side, then fill the remaining space with a text widget.” Because of this, the packer is much more commonly used than the placer, and the placer tends to be used only for special purposes. The `pack` command, summarized in Table 18.1, is used to communicate with the packer.

Note: *The* `pack` *command syntax described in this chapter is what will eventually exist in a future release of Tk. No existing release supports this syntax. The current Tk release provides essentially all of the features described in this chapter but with a clumsier syntax. The only difference in features has to do with padding. Please refer to the manual entry for the* `pack` *command before writing any scripts that use it.*

18.1 Packer basics

The packer maintains a list of all the slaves for a given master window, called the *packing list*. The packer arranges the slaves by processing the packing list in order, packing one slave in each step. At the time a particular slave is processed, part of the area of the master window has already been allocated to earlier slaves on the list, leaving a rectangular unallocated area left for this and all remaining slaves, as shown in Figure 18.1(a). The slave is positioned in three steps: allocate a frame, stretch the slave, and position it in the frame.

`pack` *`window`* ?*`window`* ...? *`option value`* ?*`option value`* ...?	Same as `pack configure` command described below.
`pack configure` *`window`* ?*`window`* ...? *`option value`* ?*`option value`* ...?	Arrange for the packer to manage the geometry of the *`windows`*. The *`option`* and *`value`* arguments provide information that determines the dimensions and position of the *`windows`*.
`pack forget` *`window`*	Causes the packer to stop managing *`window`* and unmap it from the screen. Has no effect if *`window`* isn't currently managed by the packer. Returns an empty string.
`pack info` *`window`*	Returns a list giving the current configuration of *`window`*. The list consists of *`option-value`* pairs in exactly the same form as might be specified to the `pack configure` command. Returns an empty string if *`window`* isn't currently managed by the packer.
`pack slaves` *`window`*	Returns a list of the slaves on window's packing list, in order.

Table 18.1. A summary of the `pack` command.

In the first step a rectangular region called a *frame* is allocated from the available space. This is done by "slicing" off a piece along one side of the available space. For example, in Figure 18.1(b) the frame has been sliced from the right side of the available space. The packer allows you to control the width of the frame (if it is on the left or right) or the height of the frame (if it is on the top or bottom) and which side to slice it from. By default, the controllable dimension of the frame is taken from the window's requested size in that dimension.

In the second step the packer chooses the dimensions of the slave. By default the slave will get the size it requested, but you can specify instead that it should be stretched in one or both dimensions to fill the space of the frame. If the slave's requested size is larger than the frame then it is reduced to fit the size of the frame. In Figure 18.1(c) the slave has been stretched horizontally but not vertically.

The third step is to position the slave inside its frame. If the slave is smaller than the frame then you can specify an anchor position for the slave such as `n`, `s`, or `center`. In Figure 18.1(c) the slave has been positioned in the center of the frame, which is the default.

Once the slave has been positioned, a smaller rectangular region is left for the next slave to use, as shown in Figure 18.1(d). If a slave doesn't use all of the space in its frame, as in Figure 18.1, the leftover space is unused; it won't be used for later slaves. Thus each step in the packing starts with a rectangular region of available space and ends up with a smaller rectangular region.

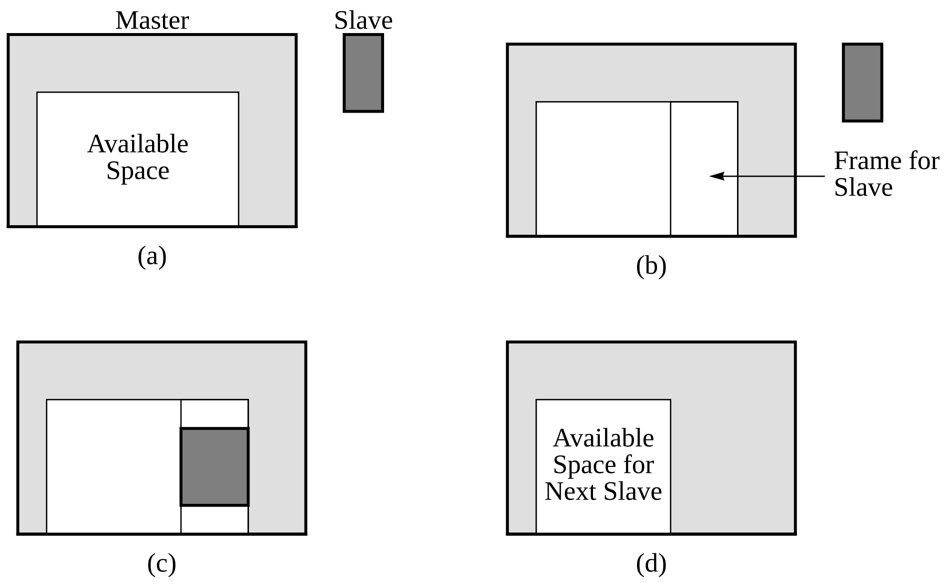


Figure 18.1. The steps taken to pack a single slave. Figure (a) shows the situation before packing a slave. Part of the master's area has already been allocated for previous slaves, and a rectangular region is left for the remaining slaves. The current slave is shown in its requested size. The packer allocates a frame for the slave along one side of the available space, as shown in (b). The packer may stretch the slave to partially or completely fill the frame, then it positions the slave over the frame as in (c). This leaves a smaller rectangular region for the next slave to use, as shown in (d).

The `pack` command is used to communicate with the packer. In its simplest form, a `pack` command takes one or more window names as arguments, followed by one or more pairs of additional arguments that indicate how to manage the windows. For example, consider the following command:

```
pack .ok .cancel .help -side left
```

This command asks the packer to manage `.ok`, `.cancel`, and `.help` as slaves and to pack them in that order. The master for the slaves defaults to their parent. The "`-side left`" option indicates that the frame for each slave should be allocated on the left side of the available space. By default, the frame for each slave is allocated just wide enough for the slave's requested width, and the slave is centered in its frame without any stretching. The result is that the slaves will be arranged in a row from left to right across the master, as shown in Figure 18.2 (b).

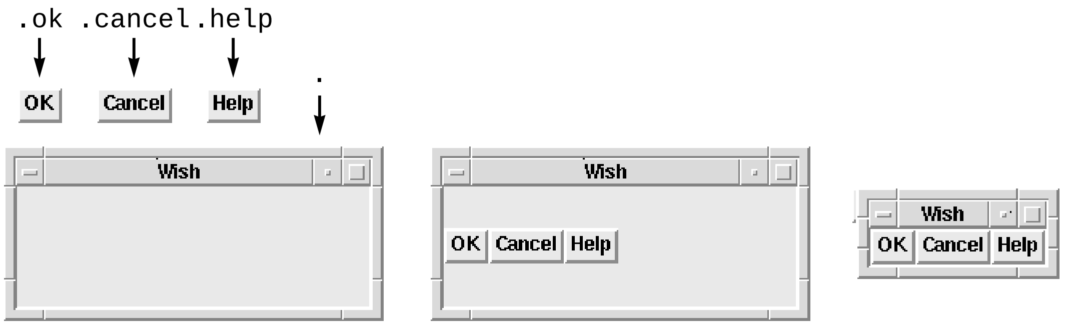


Figure 18.2. A simple example of packing. Figure (a) shows a master window and the requested sizes for three slaves. Figure (b) shows the arrangement that is produced by the command "`pack .ok .cancel .help -side left`" if the master's size is fixed. In most cases, however, the master will resize so that it just meets the needs of its slaves, producing the result in (c).

The result in Figure 18.2(b) assumes that the master window is fixed in size. However, this isn't usually the case. As part of its layout computation the packer computes the minimum dimensions the master would need so that all of its slaves just barely fit, and it sets the requested size of the master to those dimensions. In most cases the geometry manager for the master will set the master's size from those dimensions, so that the master "shrink wraps" around the slaves. For example, top-level windows resize themsleves to their requested dimensions unless other directions have been given with the `wm` command described in Chapter 22. Thus the result from the `pack` command above is more likely to be as shown in Figure 18.2(c). You can choose between the scenarios in Figure 18.2(b) and Figure 18.2(c) with the way you manage the master's geometry.

Figure 18.3 shows another simple packer example, which uses the following script to arrange three windows:

```
pack .label -side top -fill x
pack .scrollbar -side right -fill y
pack .listbox
```

The three windows are configured differently so a separate `pack` command is used for each one. The order of the `pack` commands determines the order of the windows in the packing list. The `.menubar` widget is packed first, and it occupies the top part of the master window. The "`-fill x`" option specifies that the window should be stretched horizontally so that it fills its frame. The scrollbar widget is packed next, in a similar fashion except that it is arranged against the right side of the window and stretched vertically. The widget `.listbox` is packed last. No options need to be specified for `.listbox`: it gets all the remaining space regardless of which side it is packed against.

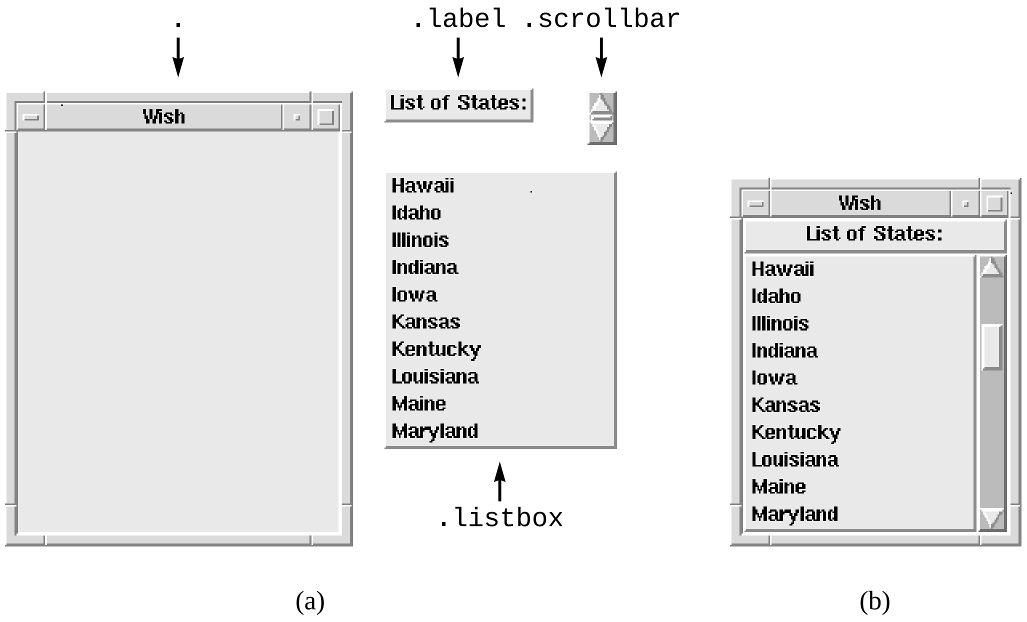


Figure 18.3. Another packer example. Figure (a) shows a master window (`.`) and the requested sizes for three slaves. Figure (b) shows the result of packing the slaves with the script

```
pack .label -side top -fill x
pack .scrollbar -side right -fill y
pack .listbox
```

under the assumption that the master window resizes to just meet the needs of its slaves.

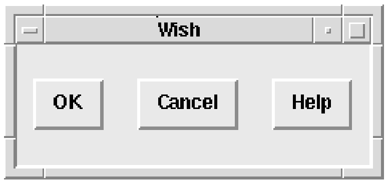
18.2 Packer configuration options

The examples in the previous section illustrated a few of the configuration options provided by the packer; Table 18.2 contains a complete listing. The options fall into three groups: those that determine the location and size of a slave's frame; those that determine the size and position of the slave within its frame; and those that select a master for the slave and determine the slave's position in the master's packing list.

The location of a slave's frame is determined by the `-side` option as already discussed. For slaves packed on the top or bottom, the width of the frame is always the width of the available space left in the master. The height of the frame is usually the requested height of the slave; however, the options `-padx`, `-ipadx`, `-pady`, and `-ipady` cause the packer to pretend that the slave's requested size is larger than what the slave specified. Slaves packed on the left and right sides are handled in an analogous fashion.

`-after` *`window`*	Use *`window`*'s master as the master for the slave and insert the slave into the packing list just after *`window`*.
`-anchor` *`position`*	If the frame is larger than the slave's final size, this option determines where in the frame the slave will be positioned.
`-before` *`window`*	Use *`window`*'s master as the master for the slave and insert the slave into the packing list just before *`window`*.
`-expand` *`boolean`*	If *`boolean`* is a true value then the slave's frame will be grown to absorb any extra space left over in the master.
`-fill` *`style`*	Specifies whether (and how) to grow the slave if its frame is larger than the slave's requested size. *`Style`* must be either `none`, `x`, `y`, or `both`.
`-in` *`window`*	Use *`window`* as the master for slave. *`Window`* must be the slave's parent or a descendant of the slave's parent. If no master is specified then it defaults to the slave's parent.
`-ipadx` *`distance`*	*`Distance`* specifies internal padding for the slave, which is extra horizontal space to allow inside the slave on each side, in addition to what the slave requests.
`-ipady` *`distance`*	*`Distance`* specifies internal padding for the slave, which is extra vertical space to allow inside the slave on each side, in addition to what the slave requests.
`-padx` *`distance`*	*`Distance`* specifies external padding for the slave, which is extra horizontal space to allow outside the slave but inside its frame on each side.
`-pady` *`distance`*	*`Distance`* specifies external padding for the slave, which is extra vertical space to allow outside the slave but inside its frame on each side.
`-side` *`side`*	*`Side`* specifies which side of the master the slave should be packed against. Must be `top`, `bottom`, `left`, or `right`.

Table 18.2. A summary of the configuration options supported by the packer.



```
pack .ok .cancel .help -side left -ipadx 3m -ipady 2m -expand 1
```

Figure 18.4. An example of the padding and `-expand` options. When the `pack` command in the figure is applied to the windows shown in Figure 18.2(a), the resulting layout is as shown in the figure, assuming that the master's size is fixed. Internal padding causes each window's size to be increased beyond what it requested, and the `-expand` option causes the extra space in the master to be distributed among the slaves' frames.

The `-expand` option allows a frame to absorb leftover space in the master. If the master ends up with more space than its slaves need (e.g. because the user has interactively stretched a top-level window), and if the `-expand` option has been set to true for one of the slaves, then that slave's frame will be expanded to use up all the extra horizontal or vertical space (for left/right and top/bottom slaves, respectively). If multiple slaves have the `-expand` option set, then the extra space is divided evenly among them. See Figure 18.4 for an example that uses `-expand` and the padding options.

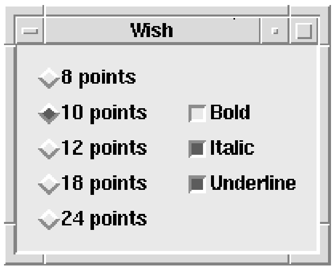
The size and location of a slave within its frame are determined by the `-fill` and `-anchor` options in conjunction with the padding options. The `-fill` option can select no filling, filling in a single direction, or filling in both directions. If internal padding has been specified for a slave (`-ipadx` or `-ipady`) then the slave will be stretched by the amount of the internal padding even if no filling has been requested in that dimension. If external padding has been specified for a slave (`-padx` or `-pady`), then the packer will leave the specified amount of space between the window and the edge of the frame even if filling is requested.

If the final size of the slave is smaller than the frame, then the `-anchor` option controls where to place the slave in the frame. This option may have any of the values described in Section 16.8, such as `nw` to indicate that the northwest (upper-left) corner of the slave should be positioned at the northwest corner of the frame. If external padding has been specified with `-padx` or `-pady`, then `nw` really refers to a point inset from the corner of the frame by the pad amounts.

The third group of options, `-in`, `-before`, and `-after`, controls the master for a slave and the position of the slave in the packing list. By default the master for a slave is its parent and the order of slaves in the packing list is determined by the order of their `pack` commands. However, the `-in` option may be used to specify a different master. As

```
pack .left -side left -padx 3m -pady 3m
pack .right -side right -padx 3m -pady 3m
pack .pts8 .pts10 .pts12 .pts18 .pts24 \
    -in .left -side top -anchor w
pack .bold .italic .underline \
    -in .right -side top -anchor w
```

(a)



(b)

Figure 18.5. Hierarchical packing. The pack commands in (a) produce the layout shown in (b). Two invisible frame widgets, `.left` and `.right`, are used to achieve the column effect.

with the placer, the master must be either the slave's parent or a descendant of the slave's parent (see page 185 for an explanation of this restriction). The `-before` and `-after` options allow you to control the order in which slaves are packed. When one of these options is used, the master for the slave is automatically set to the master for the window named in the option.

18.3 Hierarchical packing

The packer is often used in hierarchical arrangements where slave windows are also masters for other slaves. Figure 18.5 shows an example of hierarchical packing. The resulting layout has a column of radio buttons on the left and a column of check buttons on the right, with each group of buttons centered vertically in its column. To achieve this effect two extra frame widgets, `.left` and `.right`, are packed side by side in the main window, then the buttons are packed inside them. The packer sets the requested sizes for `.left` and `.right` to provide enough space for the buttons, then uses this information to set the requested size for the main window. The main window's geometry will be set to the requested size, then the packer will arrange `.left` and `.right` inside the it, and finally it will arrange the buttons inside `.left` and `.right`.

Figure 18.5 also illustrates why it is sometimes useful for a window's master to be different from its parent. It would have been possible to create the button windows as children of `.left` and `.right` (e.g. `.left.pts8` instead of `.pts8`) but it is better to create them as children of `.` and then pack them inside `.left` and `.right`.The windows `.left` and `.right` serve no purpose in the application except to help in geometry management. They are not even visible on the screen. If the buttons were children of their geometry masters then changes to the geometry management (such as adding more levels in the packing hierarchy) might require the button windows to be renamed and would break any code that used the old names (such as entries in users' `.Xdefaults` files). It is better to give windows names that reflect their logical purpose in the application, build separate frame hierarchies where needed for geometry management, and then pack the functional windows into the frames.

18.4 Other options to the pack command

So far the `pack` command has been discussed in its most common form, where the first argument is the name of a slave window and the other arguments specify configuration options. Table 18.1 shows several other forms for the `pack` command, where the first argument selects a particular command option. `Pack configure` has the same effect as the short form that's been used up until now: the remaining arguments specify windows and configuration options. If `pack configure` (or the short form with no command option) is applied to a window that is already managed by the packer, then the slave's configuration is modified; configuration options not specified in the `pack` command retain their old values.

The command `pack slaves` returns a list of all of the slaves managed by the packer for a given master window. The order of the slaves in the list reflects their order in the packing list:

```
pack slaves .left
.pts8 .pts10 .pts12 .pts18 .pts24
```

`Pack info` returns all of the configuration options for a given slave:

```
pack info .pts8
-in .left -side top -anchor w
```

The return value is a list consisting of names and values for configuration options in exactly the form you would specify them to `pack configure`. This command can be used to save the state of a slave so that it can be restored later.

Lastly, `pack forget` causes the packer to stop managing one or more slaves and forget all of its configuration state for them. It also unmaps the windows so that they no longer appear on the screen. This command can be used to transfer control of a window from one geometry manager to another, or simply to remove a window from the screen for a while. If a forgotten window is itself a master for other slaves, the information about those slaves is retained but the slaves won't be displayed on the screen until the master window becomes managed again.

Chapter 19
Bindings

You have already seen that Tcl scripts can be associated with certain widgets such as buttons or menus so that the scripts are invoked whenever certain events occur, such as clicking a mouse button over a button widget. These mechanisms are provided as specific features of specific widget classes. Tk also contains a general-purpose *binding* mechanism that can be used to create additional event handlers for widgets. A binding "binds" a Tcl script to an X event or sequence of X events in one or more windows; the script will be invoked automatically by Tk whenever the given event sequence occurs in any of the windows. You can create new bindings to extend the basic functions of a widget (e.g. with keyboard accelerators for common actions), or you can override or modify the default behaviors of widgets, since they are implemented with bindings.

This chapter assumes that you already know at least the basics about X event types, keysyms, modifiers, and the fields in event structures. More information on these topics can be found in any of several books that describe the Xlib programming interface.

19.1 An overview of the bind command

The `bind` command is used to create, modify, query, and remove bindings; Table 19.1 summarizes its syntax. This section illustrates the basic features of `bind`, and later sections go over the features in more detail.

Bindings are created with commands like the one below:

```
bind .entry <Control-d> {.entry delete insert}
```

`bind` *`windowSpec sequence script`*	Arranges for *`script`* to be executed each time the event sequence given by *`sequence`* occurs in the window(s) given by *`windowSpec`*. If a binding already exists for *`windowSpec`* and *`sequence`* then it is replaced. If *`script`* is an empty string then the binding for *`windowSpec`* and *`sequence`* is removed, if there is one.
`bind` *`windowSpec sequence +script`*	If there is already a binding for *`windowSpec`* and *`sequence`* then appends *`script`* to the script for the current binding; otherwise creates a new binding.
`bind` *`windowSpec sequence`*	If there is a binding for *`windowSpec`* and *`sequence`* then returns its script. Otherwise returns an empty string.
`bind` *`windowSpec`*	Returns a list whose entries are all of the sequences for which *`windowSpec`* has bindings.
`tkerror` *`message`*	Invoked by Tk when it encounters a Tcl error in an event handler such as a binding. *`Message`* is the error message returned by Tcl. Any result returned by `tkerror` is ignored.

Table 19.1. A summary of the `bind` and `tkerror` commands.

The first argument to the command specifies the path name of the window that the binding applies to. It can also be a widget class name, in which case the binding applies to all widgets of that class (such bindings are called *class bindings*), or it can be `all`, in which case the binding applies to all widgets. The second argument specifies a sequence of one or more X events. In this example the sequence specifies a single event, which is a key-press of the `d` character while the `Control` key is down. The third argument may be any Tcl script. The script in the example invokes `.entry`'s widget command to delete the character just after the insertion cursor.

After the command completes, the script will be invoked whenever Control-d is typed in `.entry`. The binding can trigger any number of times. It remains in effect until `.entry` is deleted or the binding is explicitly removed by invoking `bind` with an empty script:

```
bind .entry <Control-d> {}
```

Note: A binding for a keystroke will only trigger if the input focus is set to the window for the binding. See Chapter 21 for more information on the input focus.

The `bind` command can also be used to retrieve information about bindings. If `bind` is invoked with an event sequence but no script then it returns the script for the given event sequence:

```
bind .entry <Control-d>
```

```
.entry delete insert
```

If `bind` is invoked with a single argument then it returns a list of all the bound event sequences for that window or class:

```
bind .entry
<Control-Key-d>
bind Button
<ButtonRelease-1> <Button-1> <Any-Leave> <Any-Enter>
```

The first example returned the bound sequences for `.entry`, and the second example returned information about all of the class bindings for button widgets.

19.2 Event patterns

Event sequences are constructed out of basic units called *event patterns*, which Tk matches against the stream of X events received by the application. An event sequence can contain any number of patterns, but in practice most sequences only contain a single pattern.

The simplest form for an event pattern consists of a printing character such as `a` or `@`. This form of pattern matches a key-press event for that character as long as there are no modifier keys pressed. For example,

```
bind .entry a {.entry insert insert a}
```

arranges for the character `a` to be inserted into `.entry` at the point of the insertion cursor whenever it is typed.

The second form for an event pattern is longer but more flexible. It consists of one or more fields between angle brackets, with the following syntax:

```
<modifier-modifier-...-modifier-type-detail>
```

White space may be used instead of dashes to separate the various fields, and most of the fields are optional. The *type* field identifies the particular X event type, such as `KeyPress` or `Enter` (see Table 19.2 for a list of all the available types). For example, the command

```
bind .x <Enter> {puts Hello!}
```

causes “`Hello!`” to be printed on standard output whenever the mouse cursor moves into widget `.x`.

For key and button events, the event type may be followed by a *detail* field that specifies a particular button or key. For buttons, the detail is the number of the button (1-5). For keys, the detail is an X *keysym*. A keysym is a textual name that describes a particular key on the keyboard, such as `BackSpace` or `Escape` or `comma`. The keysym for alphanumeric ASCII characters such as “a” or “A” or “2” is just the character itself. Refer to your X documentation for a complete list of keysyms.

`Button, ButtonPress`	`Expose`	`Leave`
`ButtonRelease`	`FocusIn`	`Map`
`Circulate`	`FocusOut`	`Property`
`CirculateRequest`	`Gravity`	`Reparent`
`Colormap`	`Keymap`	`ResizeRequest`
`Configure`	`Key, KeyPress`	`Unmap`
`ConfigureRequest`	`KeyRelease`	`Visibility`
`Destroy`	`MapRequest`	
`Enter`	`Motion`	

Table 19.2. Names for event types. Some event types have multiple names, e.g. `Key` and `KeyPress`.

If no detail field is provided, as in `<KeyPress>`, then the pattern matches any event of the given type. If a detail field is provided, as in `<KeyPress-Escape>`, then the pattern only matches events for the specific key or button. If a detail is specified then you can omit the event type: `<Escape>` is equivalent to `<KeyPress-Escape>`.

Note: The pattern `<1>` *is equivalent to* `<Button-1>`*, not* `<KeyPress-1>`.

The event type may be preceded by any number of *modifiers*, each of which must be one of the values in Table 19.3. Most of the modifiers are X modifier names, such as `Control` or `Shift`. If one or more of these modifiers are specified then the pattern only matches events that occur when the specified modifiers are present. For example, the pattern `<Meta-Control-d>` requires that both the Meta and Control keys be held down when `d` is typed, and `<B1-Button-2>` requires that button 1 already be down when button 2 is pressed. If no modifiers are specified then none must be present: `<KeyPress-a>` will not match an event if the Control key is down.

If the `Any` modifier is specified, it means that the state of unspecified modifiers should be ignored. For example, `<Any-a>` will match a press of the “a” key even if button 1 is down or the Meta key is pressed. `<Any-B1-Motion>` will match any mouse motion event as long as button 1 is pressed; other modifiers are ignored.

The last two modifiers, `Double` and `Triple`, are used primarily for specifying double and triple mouse clicks. They match a sequence of two or three events, each of which matches the remainder of the pattern. For example, `<Double-1>` matches a double-click of mouse button 1 with no modifiers down, and `<Any-Triple-2>` matches any triple click of button 2 regardless of modifiers. For a `Double` or `Triple` pattern to match, all of the events must occur close together in time and without substantial mouse motion between them.

`Control`	`Button4, B4`	`Mod1, M2, Alt`
`Shift`	`Button5, B5`	`Mod3, M3`
`Lock`	`Any`	`Mod4, M4`
`Button1, B1`	`Double`	`Mod5, M5`
`Button2, B2`	`Triple`	
`Button3, B3`	`Mod1, M1, Meta, M`	

Table 19.3. Modifier names for event patterns. Multiple names are available for some modifiers; for example, `Mod1`, `M1`, `Meta`, and `M` are all synonyms for the same modifier.

19.3 Sequences of events

An event sequence consists of one or more event patterns optionally separated by white space. For example, the sequence `<Escape>a` contains two patterns. It triggers when the `a` key is pressed immediately after the `Escape` key.

A sequence need not necessarily match consecutive events. For example, the sequence `<Escape>a` will match an event sequence consisting of a key-press on `Escape`, a release of `Escape`, and then a press of `a`; the release of `Escape` will be ignored in determining the match. Tk ignores conflicting events in the input event stream unless they are of type `KeyPress` or `ButtonPress`. Thus if some other key is pressed between the `Escape` and the `a` then the sequence won't match. These same rules apply to double events such as `<Double-1>`.

19.4 Conflict resolution

At most one binding will trigger for any given X event. If several bindings match the event then the most specific binding is chosen and only its script is invoked. For example, suppose there are bindings for `<Button-1>` and `<Double-Button-1>` and button 1 is clicked three times. The first button-press event will match only the `<Button-1>` binding, but the second and third presses will match both bindings. Since `<Double-Button-1>` is more specific than `<Button-1>`, its script is executed on the second and third presses. Similarly, `<Escape>a` is more specific than `<a>`, `<Control-d>` is more specific than `<Any-d>` or `<d>`, and `<d>` is more specific than `<KeyPress>`.

There may also be a conflict among bindings with different window specifications. For example, there might be a binding for a specific window, plus another binding for its class, plus another for `all`. When this occurs, any window-specific binding receives preference over any class binding and any class binding receives preference over any `all` binding. For example, if there is an `<Any-KeyPress>` binding for a window and a `<Return>` binding for its class, pressing the return key will trigger the window-specific binding, not the class binding.

Note: *The default behaviors for widgets are established with class bindings created by Tk during initialization. You can modify the behavior of an individual widget by creating window-specific bindings that override the class bindings. However, you have to be careful in doing this that you don't accidentally override more behavior than you intended. For example, if you specify an* `<Any-KeyPress>` *binding for a widget, it will override a* `<Return>` *binding for the class, even though the* `<Return>` *binding appears to be more specific. The solution is to duplicate the* `<Return>` *class binding for the widget.*

19.5 Substitutions in scripts

If the script for a binding contains `%` characters then it is not executed directly. Instead, a new script is generated by replacing each `%` character and the one that follows it with information about the X event. The character following the `%` selects a specific substitution to make. About 30 different substitutions are defined; see the reference documentation for complete details. The following substitutions are the most commonly used ones:

`%x`	Substitute the x-coordinate from the event.
`%y`	Substitute the y-coordinate from the event.
`%W`	Substitute the path name of the event window.
`%A`	Substitute the 8-bit ISO character value that corresponds to a `KeyPress` or `KeyRelease` event, or an empty string if the event is for a key like Shift that doesn't have an ISO equivalent.
`%%`	Substitute the character `%`.

For example, the following bindings implement a simple mouse tracker:

```
bind all <Enter> {puts "Entering %W"}
bind all <Leave> {puts "Leaving %W"}
bind all <Motion> {puts "Mouse at (%x,%y)"}
```

Note: *When Tk makes % substitutions it treats the script as an ordinary string without any special properties. The normal quoting rules for Tcl commands are not considered, so* `%` *sequences will be substituted even if embedded in braces or preceded by backslashes. The only way to prevent a* `%` *substitution is to double the* `%` *character. The easiest way to avoid problems with complex scripts and % substitutions is to keep the binding simple, for example by putting the script in a procedure and having the binding invoke the procedure with arguments created via % substitution.*

19.6 When are events processed?

Tk only processes events at a few well-defined times. After a Tk application completes its initialization it enters an *event loop* to wait for X events and other events such as timer and file events. When an event occurs the event loop executes C or Tcl code to respond to that event. Once the response has completed, control returns to the event loop to wait for the next interesting event. Almost all events are processed from the top-level event loop. New events will not be considered while responding to the current event, so there is no danger of one binding triggering in the middle of the script for another binding. This approach applies to all event handlers, including those for bindings, those for the script options associated with widgets, and others yet to be discussed, such as window manager protocol handlers.

A few special commands such as `tkwait` and `update` reinvoke the event loop recursively, so bindings may trigger during the execution of these commands. You should only invoke these commands at times when it is safe for bindings to trigger. Commands that invoke the event loop are specially noted in their reference documentation; all other commands complete immediately without re-entering the event loop.

Note: *Event handlers are always invoked at global level (as if the command "*`uplevel #0`*" were used), even if the event loop was invoked from a* `tkwait` *or* `update` *command inside a procedure. This means that global variables are always accessible in event handlers without invoking the* `global` *command.*

19.7 Background errors: tkerror

It is possible for a Tcl error to occur while executing the script for a binding. These errors are called *background errors*; when one occurs, the default action is for Tk to print the associated error message on standard output. However, this probably isn't very useful in most cases. It is usually better to display the error message in a message window or dialog box on the screen where the user can see it. The `tkerror` command permits each application to handle background errors in the best way for that application. When a background error occurs, Tk invokes `tkerror` with a single argument consisting of the error message. The `tkerror` command is not defined by Tk; presumably each application will define its own `tkerror` procedure to report errors in a way that makes sense for that application. If `tkerror` returns normally then Tk will assume it has dealt with the error and it won't do anything else itself. If `tkerror` returns an error (e.g. because there is no `tkerror` command defined) then Tk falls back on the default approach of printing the message on standard output.

The `tkerror` procedure is invoked not just for errors in bindings, but for all other errors that are returned to Tk at times when it has no-one else to return the errors to. For example, menus and buttons call `tkerror` if an error is returned by the script for a menu entry or button; scrollbars call `tkerror` if a Tcl error occurs while communicating with the associated widget; and the window-manager interface calls `tkerror` if an error is returned by the script associated with a window manager protocol.

19.8 Other uses of bindings

The binding mechanism described in this chapter applies to widgets. However, similar mechanisms are available internally within some widgets. For example, canvas widgets allow bindings to be associated with graphical items such as rectangles or polygons, and text widgets allow bindings to be associated with ranges of characters. These bindings are created using the same syntax for event sequences and `%`-substitutions, but they are created with the widget command for the widget and refer to the widget's internal objects instead of windows. For example, the following command arranges for a message to be printed whenever mouse button 1 is clicked over item 2 in a canvas `.c`:

```
.c bind 2 <ButtonPress-1> {puts Hello!}
```

Chapter 20
The Selection

The *selection* is a mechanism for passing information between widgets and applications. The user first selects one or more objects in a widget, for example by dragging the mouse across a range of text or clicking on a graphical object. Once a selection has been made, the user can invoke commands in other widgets that cause them to retrieve information about the selection, such as the characters in the selected range or the name of the file containing the selection. The widget containing the selection and the widget requesting it can be in the same or different applications. The selection is most commonly used to copy information from one place to another, but it can be used for other purposes as well, such as setting a breakpoint at a selected line or opening a new window on a selected file.

X defines a standard mechanism for supplying and retrieving the selection and Tk provides access to this mechanism with the `selection` command. Table 20.1 summarizes the `selection` command. The rest of this chapter describes its features in more detail. For complete information on the X selection protocol, refer to the Inter-Client Communications Convention Manual (ICCCM).

20.1 Selections, retrievals, and targets

X's selection mechanism allows for multiple selections to exist at once, with names like "primary selection", "secondary selection", and so on. However, Tk supports only the primary selection; Tk applications cannot retrieve or supply selections other than the primary one and the term "selection" always refers to the primary selection in this book. At most one widget has a primary selection at any given time on a given display. When a user selects information in one widget, any selected information in any other widget is auto-

`selection clear` *window*	If there is a selection anywhere on *window*'s display, deselect it so that no window owns the selection anymore.
`selection get` ?*target*?	Retrieve the value of the primary selection using *target* as the form in which to retrieve it, and return the selection's value as result. *Target* defaults to `STRING`.
`selection handle` *window script* ?*target*? ?*format*?	Creates a handler for selection requests such that *script* will be executed whenever the primary selection is owned by *window* and someone attempts to retrieve it in the form given by *target*. *Target* defaults to `STRING`. *Format* specifies a representation for transmitting the selection to the requester; it defaults to `STRING`. When *script* is invoked, two additional numbers are appended to it, consisting of the starting offset and maximum number of bytes to retrieve. *Script* should return the requested range of the selection; if it returns an error then the selection retrieval will be rejected.
`selection own` ?*window*? ?*script*?	Claims ownership of the selection for *window*; if some other window previously owned the selection, deselects the old selection. If *script* is specified then it will be executed when *window* is deselected. If neither *window* nor *script* is specified, then the command returns the path name of the window that currently owns the selection, or an empty string if no window in this application owns the selection.

Table 20.1. A summary of the `selection` command.

matically deselected. It is possible for multiple disjoint objects to be selected simultaneously within a widget (e.g. three different items in a listbox or several different polygons in a drawing window), but usually the selection consists of a single object or a range of adjacent objects.

When you retrieve information about the selection, you can ask for any of several different kinds of information. The different kinds of information are referred to as retrieval *targets*. The most common target is `STRING`. In this case the contents of the selection are returned as a string. For example, if text is selected then a retrieval with target `STRING` will return the contents of the selected text; if graphics are selected then a retrieval with target `STRING` will return some string representation for the selected graphics. If the selection is retrieved with target `FILE_NAME` then the return value will be the name of the file associated with the selection. If target `LINE` is used then the return value will be the number of the selected line within its file. There are many targets with well-defined meanings; refer to the X ICCCM for more information.

The command `selection get` retrieves the selection. The target may be specified explicitly or it may be left unspecified, in which case it defaults to `STRING`. For example, the following commands might be invoked when the selection consists of a few words on one line of a file containing the text of Shakespeare's *Romeo and Juliet*:

```
selection get
star-crossed lovers
selection get FILE_NAME
romeoJuliet
selection get LINE
6
```

These commands could be issued in any Tk application on the display containing the selection; they need not be issued in the application containing the selection.

Not every widget supports every possible selection target. For example, if the information in a widget isn't associated with a file then the `FILE_NAME` target will not be supported. If you try to retrieve the selection with an unsupported target then an error will be returned. Fortunately, every widget is supposed to support retrievals with target `TARGETS`; such retrievals return a list of all the target forms supported by the current selection owner. You can use the result of a `TARGETS` retrieval to pick the most convenient available target. For example, the following procedure retrieves the selection as Postscript as possible, otherwise as an unformatted string:

```
proc getSelection {} {
        set targets [selection get TARGETS]
        if {[lsearch $targets POSTSCRIPT] >= 0} {
            return [selection get POSTSCRIPT]
        }
        selection get STRING
}
```

20.2 Locating and clearing the selection

Tk provides two mechanisms for retrieving information about who owns the selection. The command `selection own` (with no additional arguments) will check to see if the selection is owned by a widget in the invoking application. If so it will return the path name of that widget; if there is no selection or it is owned by some other application then `selection own` will return an empty string.

The second way to locate the selection is with the retrieval targets `APPLICATION` and `WINDOW_NAME`. These targets are both implemented by Tk and are automatically available whenever the selection is in a Tk application. The command

```
selection get APPLICATION
```

returns the name of the Tk application that owns the selection (in a form suitable for use with the `send` command, for example) and

```
selection get WINDOW_NAME
```

returns the path name of the window that owns the selection. These commands will work only if the owning application is based on Tk. If the application that owns the selection isn't based on Tk then it probably does not support the `APPLICATION` and `WINDOW_NAME` targets and the `selection get` command will return an error. These commands will also return errors if there is no selection.

The command

```
selection clear
```

will clear out any selection on the display of the invoking application. It works regardless of whether the selection is in the invoking application or some other application on the same display. The following script will clear out the selection only if it is in the invoking application:

```
if {[selection own] != ""} {
        selection clear
}
```

20.3 Supplying the selection with Tcl scripts

The sections above described Tk's facilities for retrieving the selection; this section describes how to supply the selection. The standard widgets like entries and texts already contain C code that supplies the selection, so you don't usually have to worry about it when writing Tcl scripts. However, it is possible to write Tcl scripts that implement new targets or that provide the complete supply-side protocol, and this section describes how to do it. This feature of Tk is seldom used so you may wish to skip over this material until you need it.

The protocol for supplying the selection has three parts:

1. A widget must claim ownership of the selection. This deselects any previous selection and typically redisplays the selected material in a highlighted fashion.
2. The selection owner must respond to retrieval requests by other widgets and applications.
3. The owner may request that it be notified when it is deselected. Widgets typically respond to deselection by eliminating the highlights on the display.

The paragraphs below describe two scenarios. The first scenario just adds a new target to a widget that already has selection support, so it only deals with the second part of the protocol. The second scenario implements complete selection support for a group of widgets that didn't previously have any; it deals with all three parts of the protocol.

Suppose that you wish to add a new target to those supported for a particular widget. For example, text widgets contain built-in support for the `STRING` target but they don't automatically support the `FILE_NAME` target. You could add support for `FILE_NAME` retrievals with the following script:

```
selection handle .t getFile FILE_NAME
proc getFile {offset maxBytes} {
       global fileName
       set last [expr $offset+$maxBytes-1]
       string range $fileName $offset $last
}
```

This code assumes that the text widget is named `.t` and that the name of its associated file is stored in a global variable named `fileName`. The `selection handle` command tells Tk to invoke `getFile` whenever `.t` owns the selection and someone attempts to retrieve it with target `FILE_NAME`. When such a retrieval occurs, Tk takes the specified command (`getFile` in this case) appends two additional numerical arguments, and invokes the resulting string as a Tcl command. In this example a command like

```
getFile 0 4000
```

will result. The additional arguments identify a sub-range of the selection by its first byte and maximum length, and the command must return this portion of the selection. If the requested range extends beyond the end of the selection, then the command should return everything from the given starting point up to the end of the selection. Tk takes care of returning the information to the application that requested it. In most cases the entire selection will be retrieved in one invocation of the command, but for very large selections Tk will make several separate invocations so that it can transmit the selection back to the requester in manageable pieces.

The above example simply added a new target to a widget that already provided some built-in selection support. If selection support is being added to a widget that has no built-in support at all, then additional Tcl code is needed to claim ownership of the selection and to respond to deselections. For example, suppose that there is a group of three radio buttons named `.a`, `.b`, and `.c` and that the buttons have already been configured with their `-variable` and `-value` options to store information about the selected button in a global variable named `state`. Now suppose that you want to tie the radio buttons to the selection, so that (a) whenever a button becomes selected it claims the X selection, (b) selection retrievals return the contents of `state`, and (c) when some other widget claims the selection away from the buttons then `state` is cleared and all the buttons become deselected. The following code implements these features:

```
selection handle .a getValue STRING
proc getValue {offset maxBytes} {
       global state
       set last [expr $offset+$maxBytes-1]
       string range $state $offset $last
}
foreach w {.a .b .c} {
       $w config -command {selection own .a selGone}
}
proc selGone {} {
```

```
                global state
                set state {}
        }
```

The `selection handle` command and the `getValue` procedure are similar to the previous example: they respond to `STRING` selection requests for `.a` by returning the contents of the `state` variable. The `foreach` loop specifies a `-command` option for each of the widgets. This causes the `selection own` command to be invoked whenever the user clicks on any of the radio buttons, and the `selection own` command claims ownership of the selection for widget `.a` (`.a` will own the selection regardless of which radio button gets selected and it will return `state` in response to selection requests). The `selection own` command also specifies that procedure `selGone` should be invoked whenever the selection is claimed away by some other widget. `SelGone` sets `state` to an empty string. All of the radio buttons monitor `state` for changes, so when it gets cleared the radio buttons will all deselect themselves.

Chapter 21
The Input Focus

At any given time one window of an application is designated as the *input focus window*, or *focus window* for short. All keystrokes received by the application are directed to the focus window and they are processed according to its event bindings. This chapter describes Tk's `focus` command, which is used to control the input focus. Table 21.1 summarizes the syntax of the `focus` command. The focus window only determines what happens once a keystroke event arrives at a particular application; it does not determine which of the applications on the display receives keystrokes. The selection of a focus application is made by the window manager.

21.1 Focus model: explicit vs. implicit

There are two possible ways of handling the input focus, which are known as the *implicit* and *explicit* models. In the implicit model the focus follows the mouse: keystrokes are directed to the window under the mouse pointer and the focus window changes implicitly when the mouse moves from one window to another. In the explicit model the focus window is set explicitly and doesn't change until it is explicitly reset; mouse motions do not change the focus.

Tk implements the explicit focus model, for several reasons. First, the explicit model allows you to move the mouse cursor out of the way when you're typing in a window; with the implicit model you'd have to keep the mouse in the window you're typing to. Second, and more important, the explicit model allows an application to change the focus window without the user moving the mouse. For example, when an application pops up a dialog box that requires type-in (e.g. one that prompts for a file name) it can set the input

`focus`	Returns the path name of the application’s focus window, or an empty string if there is no focus window.
`focus` *`window`*	Sets the application’s focus window to *`window`* .
`focus default` ?*`window`*?	If *`window`* is specified then it becomes the default focus window, which will receive the input focus whenever the focus window is deleted. In this case the command returns an empty string. If *`window`* is specified as `none`, then there will be no default focus window. If *`window`* is omitted then the command returns the current default focus window, or `none` if there is no default.
`focus none`	Clears the focus window.

Table 21.1. A summary of the `focus` command.

focus to the appropriate window in the dialog without you having to move the mouse, and it can move the focus back to its original window when you’re finished with the dialog box. This allows you to keep your hands on the keyboard. Similarly, when you’re typing in a form the application can move the input focus to the next entry in the form each time you type a tab, so that you can keep your hands on the keyboard and work more efficiently. Lastly, if you want an implicit focus model then you can always achieve it with event bindings that change the focus each time the mouse cursor enters a new window.

Tk applications don’t need to worry about the input focus very often because the default bindings for text-oriented widgets already take care of the most common situations. For example, when you click button 1 over an entry or text widget, the widget will automatically make itself the focus window. As application designer, you only need to set the focus in cases like those in the previous paragraph where you want to move the focus among the windows of your application to reflect the flow of work.

21.2 Setting the input focus

To set the input focus, invoke the `focus` command with a widget name as argument:

```
focus .dialog.entry
```

From this point on, all keystrokes received by the application will be directed to `.dialog.entry` and the previous focus window will no longer receive keystrokes. The new focus window will display some sort of highlight, such as a blinking insertion cursor, to indicate that it has the focus and the previous focus window will stop displaying its highlight.

Here is a script that implements tabbing among four entries in a form:

```
set tabList {.form.e1 .form.e2 .form.e3 .form.e4}
foreach w $tabList {
        bind $w <Tab> {tab $tabList}
}
proc tab list {
        set i [lsearch $list [focus]]
        incr i
        if {$i >= [llength $list]} {
            set i 0
        }
        focus [lindex $list $i]
}
```

This script assumes that the four entry windows have already been created. It uses the variable `tabList` to describe the order of traversal among the entries and arranges for the procedure `tab` to be invoked whenever a tab is typed in any of the entries. `Tab` invokes `focus` with no arguments to determine which window has the focus, finds where this window is in the list that gives the order of tabbing, and then sets the input focus to the next window in the list. The procedure `tab` could be used for many different forms just by passing it a different `list` argument for each form. The order of focussing can also be changed at any time by changing the value of the `tabList` variable.

21.3 Clearing the focus

The command `focus none` clears the input focus for the application. Once this command has been executed, keystrokes for the application will be discarded.

21.4 The default focus

When the focus window is deleted, Tk automatically sets the input focus for the application to a window called the *default focus window*. The default focus window is initially `none`, which means that there will be no focus window after the focus window is deleted and keystrokes will be discarded until the focus window is set again.

The `focus default` command can be used to specify a default focus window and to query the current default:

```
focus default
none
focus default .entry
focus default
```

```
        .entry
```

Once this script has been completed, `.entry` will receive the input focus whenever the input focus window is deleted.

21.5 Keyboard accelerators

Applications with keyboard accelerators (e.g. they allow you to type `Control+s` to save the file or `Control+q` to quit the application) require special attention to bindings and the input focus. First, the accelerator bindings must be present in every window where you want them to apply. For example, suppose that an editor has a main text window plus several entry windows for searching and replacement. You will create bindings for accelerators like `Control+q` in the main text window, but you will probably want most or all of the bindings to apply in the auxiliary windows also, so you'll have to define the accelerator bindings in each of these windows too.

In addition, an application with keyboard accelerators should never let the focus become `none`, since that will prevent any of the accelerators from being processed. If no other focus window is available, I suggest setting the focus to the main window of the application; of course, you'll have to define accelerator bindings for `.` so that they are available in this mode. In addition, I recommend setting the default focus window to `.` or some other suitable window so that the focus isn't lost when dialog boxes and other windows are deleted.

Chapter 22
Window Managers

For each display running the X Window System there is a special process called the *window manager.* The window manager is separate from the X display server and from the application processes using the display. The main function of the window manager is to control the arrangement of all the top-level windows on each screen. In this respect it is similar to the geometry managers described in Chapters 17 and 18 except that instead of managing the internal windows within an application it manages the top-level windows of all applications. The window manager allows each application to request particular locations and sizes for its top-level windows, which can be overridden interactively by users. Window managers also serve several other purposes besides geometry management: they add decorative frames around top-level windows; they allow windows to be iconified and deiconified; and they notify applications of certain events, such as user requests to destroy the window.

X allows for the existence of many different window managers that implement different styles of layout, provide different kinds of decoration and icon management, and so on. Only a single window manager runs for a display at any given time, and the user gets to choose which one. In order to allow any application to work smoothly with any window manager, X defines a protocol for the interactions between applications and window managers. The protocol is defined as part of the Inter-Client Communication Conventions Manual (ICCCM). With Tk you use the `wm` command to communicate with the window manager; Tk implements the `wm` command using the ICCCM protocols so that any Tk-based application should work with any window manger. Tables 22.1 and 22.2 summarize the `wm` command.

`wm aspect` *window* ?*xThin yThin xFat yFat*?	Set or query *window*'s aspect ratio. If an aspect ratio is specified, it constrains interactive resizes so that *window*'s width/height will be at least as great as *xThin*/*yThin* and no greater than *xFat*/*yFat*.
`wm client` *window* ?*name*?	Set or query the `WM_CLIENT_MACHINE` property for *window*, which gives the name of the machine on which *window*'s application is running.
`wm command` *window* ?*value*?	Set or query the `WM_COMMAND` property for *window*, which should contain the command line used to initiate *window*'s application.
`wm deiconify` *window*	Arrange for window to be displayed in normal fashion.
`wm focusmodel` *window* ?*model*?	Set or query the focus model for *window* . *Model* must be `active` or *passive*.
`wm geometry` *window* ?*value*?	Set or query the requested geometry for window. *Value* must have the form =*width*x*height x y* (any of =, *width*x*height*, or *x y* can be omitted).
`wm group` *window* ?*leader*?	Set or query the window group that *window* belongs to. *Leader* must be the name of a top-level window, or an empty string to remove *window* from its current group.
`wm iconbitmap` *window* ?*bitmap*?	Set or query the bitmap for *window*'s icon.
`wm iconify` *window*	Arrange for *window* to be displayed in iconic form.
`wm iconmask` *window* ?*bitmap*?	Set or query the mask bitmap for *window*'s icon.
`wm iconname window` ?`string`?	Set or query the string to be displayed in *window*'s icon.
`wm iconposition` *window* ?*x y*?	Set or query the hints about where on the screen to display *window*'s icon.
`wm iconwindow` *window* ?*icon*?	Set or query the window to use as icon for *window*. *Icon* must be the path name of a top-level window.
`wm maxsize` *window* ?*width height*?	Set or query the maximum permissible dimensions for *window* during interactive resize operations.
`wm minsize` *window* ?*width height*?	Set or query the minimum permissible dimensions for *window* during interactive resize operations.

Table 22.1. A summary of the `wm` command. In all of these commands *window* must be the name of a top-level window. Many of the commands, such as `wm aspect` or `wm group`, are used to set and query various parameters related to window management. For these commands, if the parameters are specified as null strings then the parameters are removed completely, and if the parameters are omitted then the command returns the current settings for the parameters.

`wm overrideredirect` *`window`* ?*`boolean`*?	Set or query the override-redirect flag for *`window`*.
`wm positionfrom` *`window`* ?*`whom`*?	Set or query the source of the position specification for *`window`*. *`Whom`* must be `program` or `user`.
`wm protocol` *`window`* ?*`protocol`*? ?*`script`*?	Arrange for *`script`* to be executed whenever the window manager sends a message to *`window`* with the given *`protocol`*. *`Protocol`* must be the name of an atom for a window manager protocol, such as `WM_DELETE_WINDOW`, `WM_SAVE_YOURSELF`, or `WM_TAKE_FOCUS`. If *`script`* is an empty string then the current handler for protocol is deleted. If *`script`* is omitted then the current script for *`protocol`* is returned (or an empty string if there is no handler for *`protocol`*). If both *`protocol`* and *`script`* are omitted then the command returns a list of all protocols with handlers defined for *`window`*.
`wm sizefrom` *`window`* ?*`whom`*?	Set or query the source of the size specification for *`window`*. *`Whom`* must be `program` or `user`.
`wm state` *`window`*	Returns the current state of *`window`*: `normal`, `iconic`, or `withdrawn`.
`wm title` *`window`* ?*`string`*?	Set or query the title string to display in the decorative border for *`window`*.
`wm transient` *`window`* ?*`master`*?	Set or query the transient status of *`window`*. *`Master`* must be the name of a top-level window on whose behalf *`window`* is working as a transient.
`wm withdraw` *`window`*	Arrange for *`window`* not to appear on the screen at all, either in normal or iconic form.

22.1 Window sizes

If a Tk application doesn't use the `wm` command, Tk will communicate with the window manager automatically on the application's behalf so that its top-level windows appear on the screen. By default each top-level window will appear in its "natural" size, which is the size it requested using the normal Tk mechanisms for geometry management. Tk will forward the requested size on to the window manager and most window managers will honor the request. If the requested size of a top-level window should change then Tk will forward the new size on to the window manager and the window manager will resize the window to correspond to the latest request. By default the user will not be able to resize windows interactively: window sizes will be determined solely by their requested sizes as computed internally.

If you want to allow interactive resizing then you must invoke at least one of the `wm minsize` and `wm maxsize` commands, which specify a range of acceptable sizes. For example the commands

```
wm minsize .x 100 50
wm maxsize .x 400 150
```

will allow `.x` to be resized but constrain it to be 100 to 400 pixels wide and 50 to 150 pixels high. If the command

```
wm minsize .x 1 1
```

is invoked then there will effectively be no lower limit on the size of `.x`. If you set a minimum size without a maximum size (or vice versa) then the other limit will be unconstrained. You can disable interactive resizing again by clearing all of the size bounds:

```
wm minsize .x {} {}
wm maxsize .x {} {}
```

In addition to constraining the dimensions of a window you can also constrain its aspect ratio (width divided by height) using the `wm aspect` command. For example,

```
wm aspect .x 1 3 4 1
```

will tell the window manager not to let the user resize the window to an aspect ratio less than 1/3 (window three times as tall as it is wide) or greater than 4 (four times as wide as it is tall).

If the user interactively resizes a top-level window then the window's internally requested size will be ignored from that point on. Regardless of how the internal needs of the window change, its size will remain as set by the user. A similar effect occurs if you invoke the `wm geometry` command, as in the following example:

```
wm geometry .x 300x200
```

This command forces `.x` to be 300 pixels wide and 200 pixels high just as if the user had resized the window interactively. The internally requested size for `.x` will be ignored once the command has completed, and the size specified in the `wm geometry` command overrides any size that the user might have specified interactively (but the user can resize the window again to override the size in the `wm geometry` command). The only difference between the `wm geometry` command and an interactive resize is that `wm geometry` is not subject to the constraints specified by `wm minsize`, `wm maxsize`, and `wm aspect`.

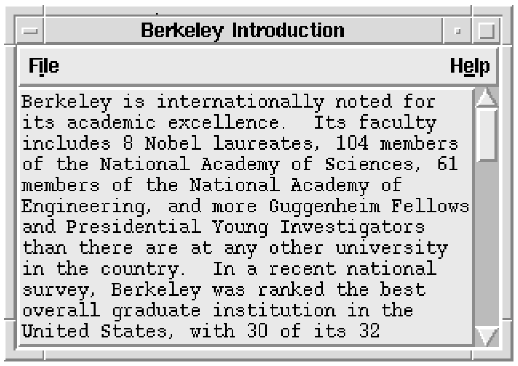
If you would like to restore a window to its natural size you can invoke `wm geometry` with an empty geometry string:

```
wm geometry .x {}
```

This causes Tk to forget any size specified by the user or by `wm geometry`, so the window will return to the size it requested internally.

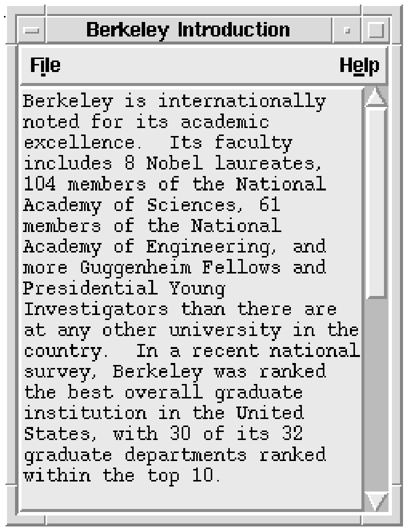
22.2 Gridded windows

In some cases it doesn't make sense to resize a window to arbitrary pixel sizes. For example, consider the application in Figure 22.1. When the user resizes the top-level window



```
Berkeley is internationally noted for
its academic excellence.  Its faculty
includes 8 Nobel laureates, 104 members
of the National Academy of Sciences, 61
members of the National Academy of
Engineering, and more Guggenheim Fellows
and Presidential Young Investigators
than there are at any other university
in the country.  In a recent national
survey, Berkeley was ranked the best
overall graduate institution in the
United States, with 30 of its 32
```

(a)



```
Berkeley is internationally
noted for its academic
excellence.  Its faculty
includes 8 Nobel laureates,
104 members of the National
Academy of Sciences, 61
members of the National
Academy of Engineering, and
more Guggenheim Fellows and
Presidential Young
Investigators than there are
at any other university in the
country.  In a recent national
survey, Berkeley was ranked
the best overall graduate
institution in the United
States, with 30 of its 32
graduate departments ranked
within the top 10.
```

(b)

Figure 22.1. An example of gridded geometry management. If the user interactively resizes the window from the dimensions in (a) to those in (b), the window manager will round off the dimensions so that the text widget holds an even number of characters in each dimension. This figure shows decorative borders as provided by the `mwm` window manager.

the text widget changes size in response. Ideally the text widget should always contain an even number of characters in each dimension, and sizes that result in partial characters should be rounded off.

Gridded geometry management accomplishes this effect. When gridding is enabled for a top-level window its dimensions will be constrained to lie on an imaginary grid. The geometry of the grid is determined by one of the widgets contained in the top-level window (e.g. the text widget in Figure 22.1) so that the widget always holds an integral number of its internal objects. Usually the widget that controls the gridding is a text-oriented widget such as an entry or listbox or text.

To enable gridding, set the `-setgrid` option to 1 in the controlling widget. The following code was used in the example in Figure 22.1, where the text widget is `.t`:

```
    .t configure -setgrid 1
```

This command has several effects. First, it automatically makes the main window resizable, even if no `wm minsize` or `wm maxsize` command has been invoked. Second, it constrains the size of the main window so that `.t` will always hold an even number of characters in its font. Third, it changes the meaning of dimensions used in Tk. These dimensions now represent grid units rather than pixels. For example, the command

```
wm geometry . 50x30
```

will set the size of the main window so that `.t` is 50 characters wide and 30 lines high, and dimensions in the `wm minsize` and `wm maxsize` commands will also be grid units. Many window managers display the dimensions of a window on the screen while it is being resized; these dimensions will given in grid units too.

Note: In order for gridding to work correctly you must have configured the internal geometry management of the application so that the controlling window stretches and shrinks in response to changes in the size of the top-level window , e.g. by packing it with the `-expand` *option set to* `1` *and* `-fill` *to* `both`.

22.3 Window positions

Controlling the position of a top-level window is simpler than controlling its size. Users can always move windows interactively, and an application can also move its own windows using the `wm geometry` command. For example, the command

```
wm geometry .x +100+200
```

will position `.x` so that its upper-left corner is at pixel (100,200) on the display. If either of the `+` characters is replaced with a `-` then the coordinates are measured from the right and bottom sides of the display. For example,

```
wm geometry .x -0-0
```

positions `.x` at the lower-right corner of the display.

22.4 Window states

At any given time each top-level window is in one of three states. In the *normal* or *de-iconified* state the window appears on the screen. In the *iconified* state the window does not appear on the screen, but a small icon is displayed instead. In the *withdrawn* state neither the window nor its icon appears on the screen and the window is ignored completely by the window manager.

New top-level windows start off in the normal state. You can use the facilities of your window manager to iconify a window interactively, or you can invoke the `wm iconify` command within the window’s application, for example

```
wm iconify .x
```

If you invoke `wm iconify` immediately, before the window first appears on the screen, then it will start off in the iconic state. The command `wm deiconify` causes a window to revert to normal state again.

The command `wm withdraw` places a window in the withdrawn state. If invoked immediately, before a window has appeared on the screen, then the window will start off withdrawn. The most common use for this command is to prevent the main window of an application from ever appearing on the screen (in some applications the main window serves no purpose: the application presents a collection of windows any of which can be deleted independently from the others; if one of these windows were the main window, deleting it would delete all the other windows too). Once a window has been withdrawn, it can be returned to the screen with either `wm deiconify` or `wm iconify`.

The `wm state` command returns the current state for a window:

```
wm iconify .x
wm state .x
iconic
```

22.5 Decorations

When a window appears on the screen in the normal state, the window manager will usually add a decorative frame around the window. The frame typically displays a title for the window and contains interactive controls for resizing the window, moving it, and so on. For example, the window in Figure 22.1 was decorated by the `mwm` window manager.

The `wm title` command allows you to set the title that's displayed a window's decorative frame. For example, the command

```
wm title . "Berkeley Introduction"
```

was used to set the title for the window in Figure 22.1.

The `wm` command provides several options for controlling what is displayed when a window is iconified. First, you can use the `wm iconname` command to specify a title to display in the icon. Second, some window managers allow you to specify a bitmap to be displayed in the icon. The `wm iconbitmap` command allows you to set this bitmap, and `wm iconmask` allows you to create non-rectangular icons by specifying that certain bits of the icon are transparent. Third, some window managers allow you to use one window as the icon for another; `wm iconwindow` will set up such an arrangement if your window manager supports it. Finally, you can specify a position on the screen for the icon with the `wm iconposition` command.

Note: *Almost all window managers support* `wm iconname` *and* `wm iconposition` *but fewer support* `wm iconbitmap` *and almost no window managers support* `wm iconwindow` *very well. Don't assume that these features work until you've tried them with your own window manager.*

22.6 Window manager protocols

There are times when the window manager needs to inform an application that an important event has occurred or is about to occur so that the application can do something to deal with the event. In X terminology, these events are called *window manager protocols*.

The window manager passes an identifier for the event to the application and the application can do what it likes in response (including nothing). The two most useful protocols are `WM_DELETE_WINDOW` and `WM_SAVE_YOURSELF`. The window manager invokes the `WM_DELETE_WINDOW` protocol when it wants the application to destroy the window (e.g. because the user asked the window manager to kill the window). The `WM_SAVE_YOURSELF` protocol is invoked when the X server is about to be shut down or the window is about to be lost for some other reason. It gives the application a chance to save its state on disk before its X connection disappears. For information about other protocols, refer to ICCCM documentation.

The `wm protocol` command arranges for a script to be invoked whenever a particular protocol is triggered. For example, the command

```
wm protocol . WM_DELETE_WINDOW {
        puts stdout "I don’t wish to die"
}
```

will arrange for a message to be printed on standard output whenever the window manager asks the application to kill its main window. In this case, the window will not actually be destroyed. If you don’t specify a handler for `WM_DELETE_WINDOW` then Tk will destroy the window automatically. `WM_DELETE_WINDOW` is the only protocol where Tk takes default action on your behalf; for other protocols, like `WM_SAVE_YOURSELF`, nothing will happen unless you specify an explicit handler.

22.7 Special handling: transients, groups, and override-redirect

The window manager protocols allow you to request three kinds of special treatment for windows. First, you can mark a top-level window as *transient* with a command like the following:

```
wm transient .x .
```

This indicates to the window manager that `.x` is a short-lived window, such as a dialog box, working on behalf of the application’s main window. The last argument to `wm transient` (“`.`” in the example) is referred to as the *master* for the transient window. The window manager may treat transient windows differently e.g. by providing less decoration or by iconifying and deiconifying them whenever their master is iconified or deiconified.

In situations where a group of long-lived windows works together you can use the `wm group` command to tell the window manager about the group. The following script tells the window manager that the windows `.top1`, `.top2`, `.top3`, and `.top4` are working together as a group, and `.top1` is the group *leader*:

```
foreach i {.top2 .top3 .top4} {
        wm group $i .top1
}
```

The window manager can then treat the group as a unit, and it may give special treatment to the leader. For example, when the group leader is iconified, all the other windows in the group might be removed from the display without displaying icons for them: the leader's icon would represent the whole group. When the leader's icon is deiconfied again, all the windows in the group might return to the display also. The exact treatment of groups is up to the window manager, and different window managers may handle them differently. The leader for a group need not actually appear on the screen (e.g. it could be withdrawn).

In some extreme cases it is important for a top-level window to be completely ignored by the window manager: no decorations, no interactive manipulation of the window via the window manager, no iconifying, and so on. The best example of such a window is a pop-up menu. In these cases, the windows should be marked as *override-redirect* using a command like the following:

```
wm overrideredirect .popup
```

This command must be invoked before the window has actually appeared on the screen.

22.8 Session management

The `wm` command provides two options for communicating with session managers: `wm client` and `wm command`. These commands pass information to the session manager about the application running in the window; they are typically used by the session manager to display information to the user and to save the state of the session so that it can be recreated in the future. `Wm client` identifies the machine on which the application is running, and `wm command` identifies the shell command used to invoke the application. For example,

```
wm client . sprite.berkeley.edu
wm application . {browse /usr/local/bin}
```

indicates that the application is running on the machine `sprite.berkeley.edu` and was invoked with the shell command "`browse /usr/local/bin`".

22.9 A warning about window managers

Although the desired behavior of window managers is supposedly described in the X ICCCM document, the ICCCM is not always clear and no window manager that I am aware of implements everything exactly as described in the ICCCM. For example, the `mwm` window manager doesn't always deal properly with changes in the minimum and maximum sizes for windows after they've appeared on the screen, and the `twm` window manager treats the aspect ratio backwards; neither window manager positions windows on the screen in exactly the places they request. Tk tries to compensate for some of the deficiencies of window managers (e.g. it checks to see where the window manager puts a window and if it's the wrong place then Tk repositions it again to compensate for the window manager's error), but it can't compensate for all the problems.

One of the main sources of trouble is Tk's dynamic nature, which allows you to change anything anytime. Almost all applications (except those based on Tk) set all the information about a window before it appears on the screen and they never change it after that. Because of this, window manager code to handle dynamic changes hasn't been debugged very well. You can avoid problems by setting as much of the information as possible before the window first appears on the screen and avoiding changes.

Chapter 23
The Send Command

The selection mechanism described in Chapter 20 provides a simple way for one application to retrieve data from another application. This chapter describes the `send` command, which provides a more powerful form of communication between applications. With `send`, any Tk application can invoke arbitrary Tcl scripts in any other Tk application on the display; these commands can not only retrieve information but also take actions that modify the state of the target application. Table 23.1 summarizes `send` and a few other commands that are useful in conjunction with it.

23.1 Basics

To use `send`, all you have to do is give the name of an application and a Tcl script to execute in the application. For example, consider the following command:

```
send tgdb {break tkButton.c 200}
```

The first argument to `send` is the name of the target application (see Section 23.3 below for more on application names) and the second argument is a Tcl script to execute in that application. Tk locates the named application (an imaginary Tcl-based version of the `gdb` debugger in this case), forwards the script to that application, and arranges for the script to be executed in the application's interpreter. In this example the script sets a breakpoint at a particular line in a particular file. The result or error generated by the script is passed back to the originating application and returned by the `send` command.

`Send` is synchronous: it doesn't complete until the script has been executed in the remote application and the result has been returned. While waiting for the remote applica-

`send appName arg ?arg ...?`	Concatenates all the *arg*'s with spaces as separators, then executes the resulting script in the interpreter of the application given by *appName*. The result of that execution is returned as the result of the `send` command.
`winfo interps`	Returns a list whose elements are the names of all the applications available on the display containing the application's main window.
`winfo name .`	Returns the name of the current application, suitable for use in `send` commands issued by other applications.

Table 23.1. A summary of `send` and related commands.

tion to respond, `send` will defer the processing of X events, so the application will not respond to its user interface during this time. Once the `send` command completes and the application returns to normal event processing, any deferred events will be processed. A sending application *will* respond to `send` requests from other applications while waiting for its own `send` to complete. This means, for example, that the target of the `send` can send a command back to the initiator while processing the script, if that is useful.

23.2 Hypertools

I hope that `send` will enable a new kind of small re-usable application that I call *hypertools*. Many of today's windowing applications are monoliths that bundle several different packages into a single program. For example, debuggers often contain editors to display the source files being debugged, and spreadsheets often contain charting packages or communication packages or even databases. Unfortunately, each of these packages can only be used from within the monolithic program that contains it.

With `send` each of these packages can be built as a separate stand-alone program. Related programs can communicate by sending commands to each other. For example, a debugger can send a command to an editor to highlight the current line of execution, or a spreadsheet can send a script to a charting package to chart a dataset derived from the spreadsheet, or a mail reader can send a command to a multi-media application to play a video clip associated with the mail. With this approach it should be possible to re-use existing programs in many unforeseen ways. For example, once a Tk-based audio-video application becomes available, any existing Tk application can become a multi-media application just by extending with scripts that send commands to the audio-video application. The term "hypertools" reflects this ability to connect applications together in interesting ways and to re-use them in ways not foreseen by their original designers.

When designing Tk applications, I encourage you to focus on doing one or a few things well; don't try to bundle everything in one program. Instead, provide different functions in different hypertools that can be controlled via `send` and re-used independently.

23.3 Application names

In order to send to an application you have to know its name. Each application on the display has a unique name, which it can choose in any way it pleases as long as it is unique. In many cases the application name is just the name of the program that created the application. For example, `wish` will use the application name `wish` by default; or, if it is running under the control of a script file then it will use the name of the script file as its application name. In programs like editors that are typically associated with a disk file, the application name typically has two parts: the name of the application and the name of the file or object on which it is operating. For example, if an editor named `mx` is displaying a file named `tk.h`, then the application's name is likely to be "`mx tk.h`".

If an application requests a name that is already in use then Tk adds an extra number to the end of the new name to keep it from conflicting with the existing name. For example, if you start up `wish` twice on the same display the first instance will have the name `wish` and the second instance will have the name "`wish #2`". Similarly, if you open a second editor window on the same file it will end up with a name like "`mx tk.h #2`".

Tk provides two commands that return information about the names of applications. First, the command

```
winfo name .
wish #2
```

will return the name of the invoking application (this command is admittedly obscure; implement "`tk appname`" before the book is published!!). Second, the command

```
winfo interps
wish {wish #2} {mx tk.h}
```

will return a list whose elements are the names of all the applications defined on the display.

23.4 Security issues

The `send` command is potentially a major security loophole. Any application that uses your display can `send` scripts to any Tk application on that display, and the scripts can use the full power of Tcl to read and write your files or invoke subprocesses with the authority of your account. Ultimately this security problem must be solved in the X display server, since even applications that don't use Tk can be tricked into abusing your account by sufficiently sophisticated applications on the same display. However without Tk it is relatively difficult to create invasive applications; with Tk and `send` it is trivial.

You can protect yourself fairly well if you employ a key-based protection scheme for your display like `xauth` instead of a host-based scheme like `xhost`. Unfortunately, many people use the `xhost` program for protection: it specifies a set of machine names to the server and any process running on any of those machines can establish connections with the server. Anyone with an account on any of the listed machines can connect to your server, send to your Tk applications, and misuse your account.

If you currently use `xhost` for protection, you should learn about `xauth` and switch to it as soon as possible. `Xauth` generates an obscure authorization string and tells the server not to allow an application to use the display unless it can produce the string. Typically the string is stored in a file that can only be read by a particular user, so this restricts use of the display to the one user. If you want to allow other users to access your display then you can give them a copy of your authorization file, or you can change the protection on your authorization file so that it is group-readable. Of course, you should be aware that in doing so you are effectively giving these other users full use of your account.

Chapter 24
Modal Interactions

Usually the user of a Tk application has complete flexibility to determine what to do next. The application offers a variety of panels and controls and the user selects between them. However, there are times when it's useful to restrict the user's range of choices or force the user to do things in a certain order; these are called *modal interactions*. The best example of a modal interaction is a dialog box: the application is carrying out some function requested by the user (e.g. writing information to a file) when it discovers that it needs additional input from the user (e.g. the name of the file to write). It displays a dialog box and forces the user to respond to the dialog box (e.g. type in a file name). Once the user responds, the application completes the operation and returns to its normal mode of operation where the user can do anything he or she pleases.

Tk provides two mechanisms for use in modal interactions. First, the `grab` command allows you to temporarily restrict the user so that he or she can only interact with certain of the application's windows (e.g. only the dialog box). Second, the `tkwait` command allows you to suspend the evaluation of a script (e.g. saving a file) until a particular event has occurred (e.g. the user responded to the dialog box), and then continue the script once this has happened. These commands are summarized in Table 24.1.

24.1 Grabs

Mouse events such as button presses and mouse motion are normally delivered to the window under the mouse cursor. However, it is possible for a window to claim ownership of the mouse so that mouse events are only delivered to that window and its descendants in the Tk window hierarchy. This is called a *grab*. When the mouse is over one of the win-

`grab ?-global? `*`window`*	Same as `grab set` command described below.
`grab current ?`*`window`*`?`	Returns the name of the current grab window for *`window`*'s display, or an empty string if there is no grab for that display. If *`window`* is omitted, returns a list of all windows grabbed by this application for all displays.
`grab release `*`window`*	Releases the grab on *`window`*, if there is one.
`grab set ?-global? `*`window`*	Sets a grab on *`window`*, releasing any previous grab on *`window`*'s display. If `-global` is specified then the grab is global; otherwise it is local.
`grab status `*`window`*	Returns `none` if no grab is currently set on *`window`*, `local` if a local grab is set, and `global` if a global grab is set.
`tkwait variable `*`varName`*	Waits until variable *`varName`* changes value, then returns.
`tkwait visibility `*`window`*	Waits until the visibility state of *`window`* changes, then returns.
`tkwait window `*`window`*	Waits until *`window`* is destroyed, then returns.

Table 24.1. A summary of the `grab` and `tkwait` commands.

dows in the grab sub-tree, mouse events are delivered and processed just as if no grab were in effect. When the mouse is outside the grab sub-tree, button presses and releases and mouse motion events are delivered to the grab window instead of the window under the mouse, and window entry and exit events are discarded. Thus a grab prevents the user from interacting with windows outside the grab sub-tree.

The `grab` command sets and releases grabs. For example, if you've created a dialog box named `.dlg` and you want to restrict interactions to `.dlg` and its subwindows, you can invoke the command

```
grab set .dlg
```

Once the user has responded to the dialog box you can release the grab with the command

```
grab release .dlg
```

If the dialog box is destroyed after the user has responded to it then there's no need to invoke `grab release`: Tk releases the grab automatically when the grab window is destroyed.

Tk provides two forms of grab, local and global. A local grab affects only the grabbing application: if the user moves the mouse into some other application on the display then he or she can interact with the other application as usual. You should normally use local grabs, and they are the default in the `grab set` command. A global grab takes over the entire display so that you cannot interact with any application except the one that set the grab. To request a global grab, specify the `-global` switch to `grab set` as in the following command:

```
grab set -global .dlg
```

Global grabs are rarely needed and they are tricky to use (if you forget to release the grab your display will become unusable). One place where they are used is for pull-down menus.

Note: X will not let you set a global grab on a window unless it is visible. Section 24.3 describes how to use the `tkwait visibility` *command to wait for a window to become visible. Local grabs are not subject to the visibility restriction.*

The most common way to use grabs is to set a grab on a top-level window so that only a single panel or dialog box is active during the grab. However, it is possible for the grab sub-tree to contain additional top-level windows; when this happens then all of the panels or dialogs corresponding to those top-level windows will be active during the grab.

24.2 Keyboard handling during grabs

Local grabs have no effect on the way the keyboard is handled: keystrokes received anywhere in the application will be forwarded to the focus window as usual. Most likely you will set the focus to a window in the grab sub-tree when you set the grab. Windows outside the grab sub-tree can’t receive any mouse events so they are unlikely to claim the focus away from the grab sub-tree. Thus the grab is likely to have the effect of restricting the keyboard focus to the grab sub-tree; however, you are free to move the focus anywhere you wish. If you move the mouse to another application then the focus will move to that other application just as if there had been no grab.

During global grabs Tk also sets a grab on the keyboard so that keyboard events go to the grabbing application even if the mouse is over some other application. This means that you cannot use the keyboard to interact with any other application. Once keyboard events arrive at the grabbing application they are forwarded to the focus window in the usual fashion.

24.3 Waiting: the tkwait command

The second aspect of a modal interaction is waiting. Typically you will want to suspend a script during a modal interaction, then resume it when the interaction is complete. For example, if you display a file selection dialog during a file write operation, you will probably want to wait for the user to respond to the dialog, then complete the file write using the name supplied in the dialog interaction. Or, when you start up an application you might wish to display an introductory panel that describes the application and keep this panel visible while the application initializes itself; before going off to do the main initialization you'll want to be sure that the panel is on the screen. The `tkwait` command can be used to wait in situations like these.

`Tkwait` has three forms, each of which waits for a different event to occur. The first form is used to wait for a window to be destroyed, as in the following command:

```
tkwait window .dlg
```

This command will not return until `.dlg` has been destroyed. You might invoke this command after creating a dialog box and setting a grab on it; the command won't return until after the user has interacted with the dialog in a way that causes it to be destroyed. While `tkwait` is waiting the application responds to events so the user can interact with the application's windows. In the dialog box example you should have set up bindings that destroy the dialog once the user's response is complete (e.g. the user clicks on the `OK` button). The bindings for the dialog box might also save additional information in variables (such as the name of a file, or an identifier for the button that was pressed). This information can be used once `tkwait` returns.

The script below creates a panel with two buttons labelled `OK` and `Cancel`, waits for the user to click on one of the buttons, and then deletes the panel:

```
toplevel .panel
button .panel.ok -text OK -command {
       set label OK
       destroy .panel
}
button .panel.cancel -text Cancel -command {
       set label Cancel
       destroy .panel
}
pack .panel.ok -side left
pack .panel.cancel -side right
grab set .panel
tkwait window panel
```

When the `tkwait` command returns the variable `label` will contain the label of the button that was clicked upon.

The second form for `tkwait` waits for the visibility state of a window to change. For example, the command

```
tkwait visibility .intro
```

will not return until the visibility state of `.intro` has changed. Typically this command is invoked just after a new window has been created, in which case it won't return until the window has become visible on the screen. `Tkwait visibility` can be used to wait for a window to become visible before setting a global grab on it, or to make sure that an introductory panel is on the screen before invoking a lengthy initialization script. Like all forms of `tkwait`, `tkwait visibility` will respond to events while waiting.

The third form of `tkwait` provides a general mechanism for implementing other forms of waiting. In this form, the command doesn't return until a given variable has been modified. For example, the command

```
tkwait variable x
```

will not return until variable `x` has been modified. This form of `tkwait` is typically used in conjunction with event bindings that modify the variable. For example, the following procedure uses `tkwait variable` to implement something analogous to `tkwait window` except that you can specify more than one window and it will return as soon as any of the named windows has been deleted (it returns the name of the window that was deleted):

```
proc waitWindows args {
       global dead
       foreach w $args {
          bind $w <Destroy> "set dead $w"
       }
       tkwait variable dead
       return $dead
}
```

Chapter 25
Odds and Ends

This chapter describes five additional Tk commands: `destroy`, which deletes widgets; `after`, which delays execution or schedules a script for execution later; `update`, which forces operations that are normally delayed, such as screen updates, to be done immediately; `winfo`, which provides a variety of information about windows, such as their dimensions and children; and `tk`, which provides access to various internals of the Tk toolkit. Table 25.1 summarizes these commands. This chapter also describes several global variables that are read or written by Tk and may be useful to Tk applications.

25.1 Destroying windows

The `destroy` command is used to delete windows. It takes any number of window names as arguments, for example:

```
destroy .dlg1 .dlg2
```

This command will destroy `.dlg1` and `.dlg2`, including all of their widget state and the widget commands named after the windows. It also recursively destroys all of their children. The command “`destroy .`” will destroy all of the windows in the application; when this happens most Tk applications (e.g. `wish`) will exit.

Command	Description
`after` *`ms`*	Delays for *`ms`* milliseconds.
`after` *`ms arg`* ?*`arg arg`* ...?	Concatenates all the *`arg`* values (with spaces as separators) and arranges for the resulting script to be executed after *`ms`* milliseconds have elapsed. Returns without waiting for the script to be executed.
`destroy` *`window`* ?*`window window`* ...?	Deletes each of the `window`s, plus all of the windows descended from them. The corresponding widget commands (and all widget state) are also deleted.
`tk colormodel` *`window`* ?*`value`*?	Sets the color model for *`window`*'s screen to value, which must be either `color` or `monochrome`. If *`value`* isn't specified, returns the current color model for *`window`*'s screen.
`update ?idletasks?`	Brings display up to date and processes all pending events. If `idletasks` is specified then no events are processed except those in the idle task queue (delayed updates).
`winfo` *`option`* ?*`arg arg`* ...?	Returns various pieces of information about windows, depending on *`option`* argument. See reference documentation for details.

Table 25.1. A summary of the commands discussed in this chapter.

25.2 Time delays

The `after` command allows you to incorporate timing into your Tk applications. It has two forms. If you invoke `after` with a single argument, then the argument specifies a delay in milliseconds, and the command delays for that number of milliseconds before returning. For example,

```
after 500
```

will delay for 500 milliseconds before returning. If you specify additional arguments, as in the command

```
after 5000 {puts "Time’s up!"}
```

then the after command returns immediately without any delay. However, it concatenates all of the additional arguments (with spaces between them) and arranges for the resulting script to be evaluated after the specified delay. The script will be evaluated at global level as an event handler, just like the scripts for bindings. In the example above, a message will be printed on standard output after five seconds. The script below uses `after` to build a general-purpose blinking utility:

```
proc blink {w option value1 value2 interval} {
        $w config $option $value1
        after $interval [list blink $w $option \
            $value2 $value1 $interval]
}
blink .b -bg red black 500
```

The `blink` procedure takes five arguments, which are the name of a widget, the name of an option for that widget, two values for that option, and a blink interval in milliseconds. The procedure arranges for the option to switch back and forth between the two values at the given blink interval. It does this by immediately setting the option to the first value and then arranging for itself to be invoked again at the end of the next interval with the two option values reversed, so that option is set to the other value. The procedure reschedules itself each time it is called, so it executes periodically forever. `Blink` runs "in background": it always returns immediately, then gets reinvoked by Tk's timer code after the next interval expires.

25.3 The update command

Tk normally delays operations such as screen updates until the application is idle. For example, if you invoke a widget command to change the text in a button, the button will not redisplay itself immediately. Instead, it will schedule the redisplay to be done later and return immediately. When the application becomes idle (i.e. the current event handler has completed, plus all events have been processed, so that the application has nothing to do but wait for the next event) then it carries out all the delayed operations. Tk delays redisplays because it saves work in situations where a script changes the same window several different times: with delayed redisplay the window only gets redrawn once at the end. Tk also delays many other operations, such as geometry recalculations and window creation.

For the most part the delays are invisible. Tk rarely does very much work at a time, so it becomes idle again very quickly and updates the screen before the user can perceive any delay. However, there are times when the delays are inconvenient. For example, if a script is going to execute for a long time then you may wish to bring the screen up to date at certain times during the execution of the script. The `update` command allows you to do this. If you invoke the command

```
update idletasks
```

then all of the delayed operations like redisplays will be carried out immediately; the command will not return until they have finished.

The following procedure uses `update` to flash a widget synchronously:

```
proc flash {w option value1 value2 interval count} {
        for {set i 0} {$i < $count} {incr i} {
            $w config $option $value1
```

```
                update idletasks
                after $interval
                $w config $option $value2
                update idletasks
                after $interval
            }
    }
```

This procedure is similar to `blink` except that it runs in foreground instead of background: it flashes the option a given number of times and doesn't return until the flashing is complete. Tk never becomes idle during the execution of this procedure so the `update` commands are needed to force the widget to be redisplayed. Without the `update` commands no changes would appear on the screen until the script completed, at which point the widget's option would change to `value2`.

If you invoke `update` without the `idletasks` argument, then all pending events will be processed too. You might do this in the middle of a long calculation to allow the application to respond to user interactions (e.g. the user might invoke a "cancel" button to abort the calculation).

25.4 Information about windows

The `winfo` command provides information about windows. It has more than 40 different forms for retrieving different kinds of information. For example,

```
winfo exists .x
```

returns a `0` or `1` value to indicate whether there exists a window `.x`,

```
winfo children .menu
```

returns a list whose elements are all of the children of `.menu`,

```
winfo screenmmheight .dialog
```

returns the height of `.dialog`'s screen in millimeters, and

```
winfo class .x
```

returns the class of widget `.x` (e.g. `button`, `text`, etc.). Refer to the Tk reference documentation for details on all of the options provided by `winfo`.

25.5 The tk command: color models

The `tk` command provides access to various aspects of Tk's internal state. At present only one aspect is accessible: the *color model*. At any given time, Tk treats each screen as being either a color or monochrome screen; this is the screen's color model. When creating widgets, Tk will use different defaults for configuration options depending on the color model of the screen. If you specify a color other than black or white for a screen whose color model is monochrome, then Tk will round the color to either black or white.

By default Tk picks a color model for a screen based on the number of bits per pixel for that screen: if the screen has only a few bits per pixel (currently four or fewer) then Tk uses a monochrome color model; if the screen has many bits per pixel then Tk treats the screen as color. You can invoke the `tk` command to change Tk's color model from the default. For example, the following command sets the color model for the main window's screen to monochrome:

```
tk colormodel . monochrome
```

If the color model for a screen is color and Tk finds itself unable to allocate a color for a window on that screen (e.g. because the colormap is full) then Tk generates an error that is processed using the standard `tkerror` mechanism described in Section 19.7. Tk then changes the color model to monochrome and retries the allocation so the application can continue in monochrome mode. If the application finds a way to free up more colors, it can reset the color model back to color again.

25.6 Variables managed by Tk

Several global variables are significant to Tk, either because it sets them or because it reads them and adjusts its behavior accordingly. You may find the following variables useful:

`tk_version`	Set by Tk to its current version number. Has a form like 3.2, where 3 is the major version number and 2 is a minor version number. Changes in the major version number imply incompatible changes in Tk.
`tk_library`	Set by Tk to hold the path name of the directory containing a library of standard Tk scripts and demonstrations. This variable is set from the `TK_LIBRARY` environment variable, if it exists, or from a compiled-in default otherwise.
`tk_strictMotif`	If set to 1 by the application, then Tk goes out of its way to observe strict Motif compliance. Otherwise Tk deviates slightly from Motif (e.g. by highlighting active elements when the mouse cursor passes over them).

In addition to these variables, which may be useful to the application, Tk also uses the associative array `tk_priv` to store information for its private use. Applications should not use or modify any of the values in `tk_priv`.

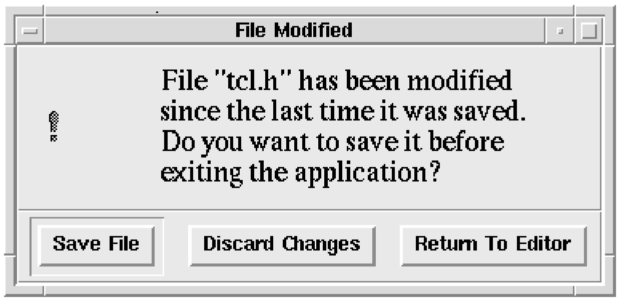
Chapter 26
Examples

This chapter presents two relatively complete examples that illustrate many of the features of Tk. The first example is a procedure that generates dialog boxes, waits for the user to respond, and returns the user's response. The second example is an application that allows you to "remote-control" any other Tk application on the display: it connects itself to that application so that you can type commands to the other application and see the results.

26.1 A procedure that generates dialog boxes

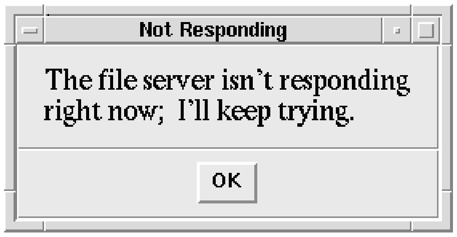
The first example is a Tcl procedure named `dialog` that creates dialog boxes like those shown in Figure 26.1. Each dialog contains a text message at the top plus an optional bitmap to the left of the text. At the bottom of the dialog box is a row of any number of buttons. One of the buttons may be specified as the default button, in which case it is displayed in a sunken frame. `Dialog` creates a dialog box of this form, then waits for the user to respond by clicking on a button. Once the user has responded, `dialog` destroys the dialog box and returns the index of the button that was invoked. If the user types a return and a default button was specified, then the index of the default button is returned. `Dialog` sets a grab so that the user must respond to the dialog box before interacting with the application in any other way.

Figures 26.2 and 26.3 show the Tcl code for `dialog`. It takes six or more arguments. The first argument, `w`, gives the name to use for the dialog's top-level window. The second argument, `title`, gives a title for the window manager to display in the dialog's decorative frame. The third argument, `text`, gives a message to display on the right side of the dialog. The fourth argument, `bitmap`, gives the name of a bitmap to display on the left



File "tcl.h" has been modified since the last time it was saved. Do you want to save it before exiting the application?

```
dialog .d {File Modified} {File "tkInt.h" has been modified since the last
time it was saved. Do you want to save it before exiting the application?}
warning 0 {Save File} {Discard Changes} {Return To Editor}
```



The file server isn't responding right now; I'll keep trying.

```
dialog .d {Not Responding} {The file server isn’t responding right
now; I’ll keep trying.} {} -1 OK
```

Figure 26.1. Two examples of dialog boxes created by the `dialog` procedure. Underneath each dialog box is the command that created it.

side of the dialog; if it is specified as an empty string then no bitmap is displayed.The fifth argument, `default`, gives the index of a default button, or -1 if there is to be no default button. The sixth and additional arguments contain the strings to display in the buttons.

The code for `dialog` divides into five major parts, each headed by a comment. The first part of the procedure creates the dialog’s top-level window. It sets up information for the window manager, such as the title for the window’s frame and the text to display in the dialog’s icon. Then it creates two frames, one for the bitmap and message at the top of the dialog, and the other for the row of buttons at the bottom.

The second part of `dialog` creates a message widget to hold the dialog’s text string and a label widget to hold its bitmap, if any. The widgets are arranged on the right and left sides of the top frame, respectively, using the packer.

```
proc dialog {w title text bitmap default args} {
    global button

    # 1. Create the top-level window and divide it into top
    # and bottom parts.

    toplevel $w -class Dialog
    wm title $w $title
    wm iconname $w Dialog
    frame $w.top -relief raised -bd 1
    pack $w.top -side top -fill both
    frame $w.bot -relief raised -bd 1
    pack $w.bot -side bottom -fill both

    # 2. Fill the top part with the bitmap and message.

    message $w.top.msg -width 3i -text $text \
        -font -Adobe-Times-Medium-R-Normal-*-180-*
    pack $w.top.msg -side right -expand 1 -fill both \
        -padx 5m -pady 5m
    if {$bitmap != ""} {
        label $w.top.bitmap -bitmap $bitmap
        pack $w.top.bitmap -side left -padx 5m -pady 5m
    }

    # 3. Create a row of buttons at the bottom of the dialog.

    set i 0
    foreach but $args {
        button $w.bot.button$i -text $but -command \
            "set button $i"
        if {$i == $default} {
            frame $w.bot.default -relief sunken -bd 1
            pack $w.bot.default -side left -expand 1\
                -padx 5m -pady 2m
            pack $w.bot.button$i -in $w.bot.default -side left
\
                -padx 3m -pady 3m -ipadx 2m -ipady 1m
        } else {
            pack $w.bot.button$i -side left -expand 1 \
                -padx 5m -pady 5m -ipadx 2m -ipady 1m
        }
        incr i
    }
```

Figure 26.2. A Tcl procedure that generates dialog boxes with a text message, optional bitmap, and any number of buttons. Continued in Figure 26.3.

```
    # 4. Set up a binding for <Return>, if there’s a default,
    # set a grab, and claim the focus too.

    if {$default > 0} {
        bind $w <Return> "$w.bot.button$default flash; \
            set button $default"
    }
    set oldFocus [focus]
    grab $w
    focus $w

    # 5. Wait for the user to respond, then restore the focus
    # and return the index of the selected button.

    tkwait variable button
    destroy $w
    focus $oldFocus
    return $button
}
```

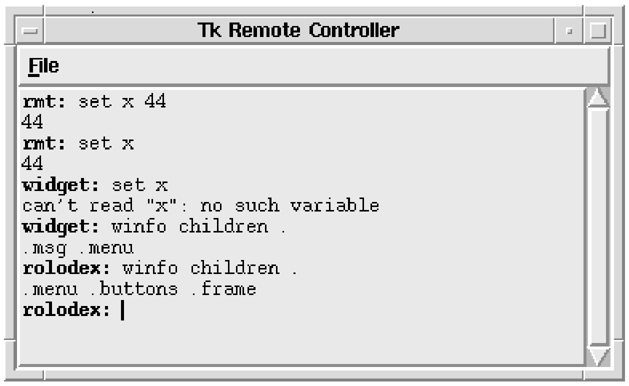
Figure 26.3. Procedure to generate dialog boxes, cont’d.

The third part of the procedure creates the row of buttons. Since `args` was used as the name of the last argument to `dialog`, the procedure can take any number of arguments greater than or equal to five; `args` will be a list whose elements are all the additional arguments after `default`. For each of these arguments, `dialog` creates a button that displays the argument value as its text. The default button, if any, is packed in a special sunken ring (`$w.bot.default`). The buttons are packed with the `-expand` option so that they spread themselves evenly across the width of the dialog box; if there is only a single button then it will be centered. Each button is configured so that when the user clicks on it the global variable `button` will be set to the index of that button.

Note: It’s important that the value of the `-command` *option is specified in quotes, not curly braces, so that* `$i` *(the button’s index) is substituted into the command immediately. If the value were surrounded by braces, then the value of* `$i` *wouldn’t be substituted until the command is actually executed; this would use the value of global variable* `i`*, not the variable* `i` *from the* `dialog` *procedure.*

The fourth part of `dialog` sets up a binding so that typing a return to the dialog box will flash the default button and set the `button` variable just as if the button had been invoked. It also sets the input focus to the dialog box and sets a local grab on the dialog box to give it control over both the keyboard and the mouse.

The last part of the procedure waits for the user to interact with the dialog. It does this by waiting for the `button` variable to change value, which will happen when the user



```
rmt: set x 44
44
rmt: set x
44
widget: set x
can't read "x": no such variable
widget: winfo children .
.msg .menu
rolodex: winfo children .
.menu .buttons .frame
rolodex: |
```

Figure 26.4. The `rmt` application allows users to type interactively to any Tk application on the display. It contains a menu for selecting an application plus a text widget for typing commands and displaying results. In this example the user has issued commands to three different applications: first the `rmt` application itself, then an application named `widget`, and finally one named `rolodex` (the prompt on each command line indicates the name of the application that executed the command).

clicks on a button in the dialog box or types a return. When the `tkwait` command returns, the `button` variable contains the index of the selected button. `Dialog` then destroys the dialog box (which also releases its grab), restores the input focus to its old window, and returns.

26.2 A remote-control application

The second example is an application called `rmt`, which allows you to type Tcl commands interactively to any Tk application on the display. Figure 26.4 shows what `rmt` looks like on the screen. It contains a menu that can be used to select an application plus a text widget and scrollbar. At any given time `rmt` is “connected” to one application; lines that you type in the text widget are forwarded to the current application using `send` and the results are displayed in the text widget. `Rmt` displays the name of the current application in the prompt at the beginning of each command line. You can change the current application by selecting an entry in the menu, in which case the prompt will change to display the new application’s name. You can also type commands to the `rmt` application itself by selecting `rmt` as the current application. When `rmt` starts up it connects to itself.

The script that creates `rmt` is shown in Figures 26.5-26.9. The script is designed to be placed into a file and executed directly. The first line of the script,

```
#!/usr/local/bin/wish -f

# 1. Create basic application structure:  menu bar on top of
# text widget, scrollbar on right.

frame .menu -relief raised -bd 2
pack .menu -side top -fill x
scrollbar .s -relief flat -command ".t yview"
pack .s -side right -fill y
text .t -relief raised -bd 2 -yscrollcommand ".s set" \
    -setgrid true
.t tag configure bold -font *-Courier-Bold-R-Normal-*-120-*
pack .t -side left -fill both -expand 1
wm title . "Tk Remote Controller"
wm iconname . "Tk Remote"
wm minsize . 1 1

# 2. Create menu button and menus.

menubutton .menu.file -text "File" -underline 0 -menu
.menu.file.m
menu .menu.file.m
.menu.file.m add cascade -label "Select Application" \
    -underline 0 -accelerator => -menu .menu.file.m.apps
.menu.file.m add command -label "Quit" -underline 0 \
    -command "destroy ."
menu .menu.file.m.apps -postcommand fillAppsMenu
pack .menu.file -side left
tk_menuBar .menu .menu.file
proc fillAppsMenu {} {
    catch {.menu.file.m.apps delete 0 last}
    foreach i [lsort [winfo interps]] {
        .menu.file.m.apps add command -label $i \
            -command [list newApp $i]
    }
}
```

Figure 26.5. A script that generates `rmt`, an application for remotely controlloing other Tk applications. This figure contains basic window set-up code. The script continues in Figures 26.6-26.9

```
#!/usr/local/bin/wish -f
```

is similar to the first line of a shell script: if you invoke the script file directly from a shell then the operating system will invoke `wish` instead, passing it two arguments: `-f` and the name of the script file. `Wish` will then execute the contents of the file as a Tcl script.

```
# 3. Create bindings for text widget to allow commands to
# be entered and information to be selected.  New characters
# can only be added at the end of the text (can't ever move
# insertion point).

bind .t <1> {
    set tk_priv(selectMode) char
    .t mark set anchor @%x,%y
    if {[lindex [%W config -state] 4] == "normal"} {focus %W}
}
bind .t <Double-1> {
    set tk_priv(selectMode) word
    tk_textSelectTo .t @%x,%y
}
bind .t <Triple-1> {
    set tk_priv(selectMode) line
    tk_textSelectTo .t @%x,%y
}
bind .t <Return> {.t insert insert \n; invoke}
bind .t <BackSpace> backspace
bind .t <Control-h> backspace
bind .t <Delete> backspace
bind .t <Control-v> {
    .t insert insert [selection get]
    .t yview -pickplace insert
    if [string match *.0 [.t index insert]] {
        invoke
    }
}
```

Figure 26.6. Bindings for the `rmt` application. These are modified versions of the default Tk bindings, so they use existing Tk facilities such as the variable `tk_priv` and the procedure `tk_textSelectTo`

The `rmt` script contains about 100 lines of Tcl code in all, which divide into seven major parts. It makes extensive use of the facilities of text widgets, including marks and tags; you may wish to review the reference documentation for texts as you read through the code for `rmt`.

The first part of the `rmt` script sets up the overall window structure, consisting of a menu bar, a text widget, and a scrollbar. It also passes information to the window manager, such as titles to appear in the window's decorative frame and icon. The command "`wm minsize . 1 1`" enables interactive resizing by the user as described in Section 22.1. Since the text widget has been packed with the `-expand` option set to 1, it will receive any extra space; since it is last in the packing order, it will also shrink if the user resizes

```
# 4. Procedure to backspace over one character, as long as
# the character isn't part of the prompt.

proc backspace {} {
    if {[.t index promptEnd] != [.t index {insert - 1 char}]}
{
        .t delete {insert - 1 char} insert
        .t yview -pickplace insert
    }
}
```

Figure 26.7. Procedure that implements backspacing for `rmt`.

the application to a smaller size than it initially requested. The `-setgrid` option for the text widget enables gridding as described in Section 22.2: interactive resizing will always leave the text widget with dimensions that are an integral number of characters.

The command

```
.t tag configure bold -font \
          *-Courier-Bold-R-Normal-*-120-*
```

creates a *tag* named `bold` for the text widget and associates a bold font with that tag. The script will apply this tag to the characters in the prompts so that they appear in boldface, whereas the commands and results appear in a normal font.

The second part of the script fills in the menu with two entries. The top entry displays a cascaded submenu with the names of all applications, and the bottom entry is a command entry that causes `rmt` to exit (it executes the script “`destroy .`”, which destroys all of the application’s windows; when `wish` discovers that it no longer has any windows left then it exits). The cascaded submenu is named `.menu.file.m.apps`; its `-postcommand` option causes the script “`fillAppsMenu`” to be executed each time the submenu is posted on the screen. `FillAppsMenu` is a Tcl procedure defined at the bottom of Figure 26.5; it deletes any existing entries in the submenu, extracts the names of all applications on the display with “`winfo interps`”, and creates one entry in the menu for each application name. When one of these entries is invoked by the user, the procedure `newApp` will be invoked with the application’s name as argument.

Note: The command “`[list newApp $i]`*” creates a Tcl list with two elements. As described in Section XXX, when a list is executed as a command each element of the list becomes one word for the command. Thus this form guarantees that newApp will be invoked with a single argument consisting of the value of* `$i` *at the time the menu entry is created, even if* `$i` *contains spaces or other special characters.*

The third part of the `rmt` script, shown in Figure 26.6, creates event bindings for the text widget. Tk defines several default bindings for texts, which handle mouse clicks,

```
# 5. Procedure that's invoked when return is typed:  if
# there’s not yet a complete command (e.g. braces are open)
# then do nothing.  Otherwise, execute command (locally or
# remotely), output the result or error message, and issue
# a new prompt.

proc invoke {} {
    global app
    set cmd [.t get {promptEnd + 1 char} insert]
    if [info complete $cmd] {
        if {$app == [winfo name .]} {
            catch [list uplevel #0 $cmd] msg
        } else {
            catch [list send $app $cmd] msg
        }
        if {$msg != ""} {
            .t insert insert $msg\n
        }
        prompt
    }
    .t yview -pickplace insert
}

proc prompt {} {
    global app
    .t insert insert "$app: "
    .t mark set promptEnd {insert - 1 char}
    .t tag add bold {insert linestart} promptEnd
}
```

Figure 26.8. Procedures that execute commands and output prompts for `rmt`.

character insertion, and common editing keystrokes such as backspace. However, `rmt`’s text widget has special behavior that is inconsistent with the default bindings, so the code in Figure 26.6 overrides many of the defaults. You don’t need to understand the details of the bindings; they have been copied from the defaults in Tk’s startup script and modified so that (a) the user can’t move the insertion cursor (it always has to be at the end of the text), (b) the procedure `backspace` is invoked instead of Tk’s normal text backspace procedure, and (c) the procedure `invoke` is called whenever the user types a return or copies in text that ends with a newline.

The fourth part of the `rmt` script is a procedure called `backspace`. It implements backspacing in a way that disallows backspacing over the prompt (see Figure 26.7). `Backspace` checks to see if the character just before the insertion cursor is the last character of the most recent prompt. If not, then it deletes the character; if so, then it does noth-

```
# 6. Procedure to select a new application.  Also changes
# the prompt on the current command line to reflect the new
# name.

proc newApp appName {
    global app
    set app $appName
    .t delete {promptEnd linestart} promptEnd
    .t insert promptEnd "$appName:"
    .t tag add bold {promptEnd linestart} promptEnd
}

# 7. Miscellaneous initialization.

set app [winfo name .]
prompt
focus .t
```

Figure 26.9. Code to select a new application for rmt, plus miscellaneous initialization code.

ing, so that the prompt never gets erased. To keep track of the most recent prompt, `rmt` sets a *mark* named `promptEnd` at the position of the last character in the most recent prompt (see the `prompt` procedure below for the code that sets `promptEnd`).

The fifth part of the `rmt` script handles command invocation; it consists of two procedures, `invoke` and `prompt` (see Figure 26.8). The `invoke` procedure is called whenever a newline character has been added to the text widget, either because the user typed a return or because the selection was copied into the widget and it ended with a newline. Invoke extracts the command from the text widget (everything from the end of the prompt to the current insertion point) and then invokes `info complete` to make sure that the command is complete. If the command contains unmatched braces or unmatched quotes then `invoke` returns without executing the command so the user can enter the rest of the command; after each return is typed `invoke` will check again, and once the command is complete it will be invoked. The command is invoked by executing it locally or sending it to the appropriate application. If the command returns a non-empty string (either as a normal reult or as an error message) then the string is added to the end of the text widget. Finally, `invoke` outputs a new prompt and scrolls the view in the text to keep the insertion cursor visible.

The `prompt` procedure is responsible for outputting prompts. It just adds characters to the text widget, sets the `promptEnd` mark to the last character in the prompt, and then applies the `bold` tag to all the characters in the prompt so that they'll appear in a bold font.

The sixth part of the `rmt` script consists of the `newApp` procedure in Figure 26.9. `NewApp` is invoked to change the current application. It sets the global variable `app`, which identifies the current application, then overwrites the most recent prompt to display the new application's name.

The last part of `rmt` consists of miscellaneous initialization (see Figure 26.9). It connects the application to itself initially, outputs the initial prompt, and sets the input focus to the text window.

Part III:

Writing Tcl Applications in C

Chapter 27
Philosophy

This part of the book describes how to write C applications based on Tcl. Since the Tcl interpreter is implemented as a C library package, it can be linked into any C or C++ program. The enclosing application invokes procedures in the Tcl library to create interpreters, evaluate Tcl scripts, and extend the built-in command set with new application-specific commands. Tcl also provides a number of utility procedures for use in implementing new commands; these procedures can be used to access Tcl variables, parse arguments, manipulate Tcl lists, evaluate Tcl expressions, and so on. This chapter discusses several high-level issues to consider when designing a Tcl application, such as what new Tcl commands to implement, how to name objects, and what form to use for command results. The following chapters present the specific C interfaces provided by the Tcl library.

Note: *The interfaces described in Part III are those that will be available in Tcl 7.0, which had not been released at the timex this draft was prepared. Thus there may some differences between what you read here and what you can do with your current version of Tcl. There are almost no differences in functionality; the differences mostly have to do with the interfaces. Be sure to consult your manual entries when you actually write C code.*

27.1 C vs. Tcl: primitives

In order to make a Tcl application as flexible and powerful as possible, you should organize its C code as a set of new Tcl commands that provide a clean set of *primitive operations*. You need not implement every imaginable feature in C, since new features can always be implemented later as Tcl scripts. The purpose of the C code is to provide basic operations that make it easy to implement a wide variety of useful scripts. If your C code lumps several functions together into a single command then it won't be possible to write scripts that use the functions separately and your application won't be very flexible or extensible. Instead, each command should provide a single function, and you should combine them together with Tcl scripts. You'll probably find that many of your application's essential features are implemented as scripts.

Given a choice between implementing a particular piece of functionality as a Tcl script or as C code, it's generally better to implement it as a script. Scripts are usually easier to write, they can be modified dynamically, and you can debug them more quickly because you don't have to recompile after each bug fix. However, there are three reasons why it is sometimes better to implement a new function in C. First, you may need to access low-level machine facilities that aren't accessible in Tcl scripts. For example, the Tcl built-in commands don't provide access to network sockets, so if you want to use the network you'll have to write C code to do it. Second, you may be concerned about efficiency. For example, if you need to carry out intensive numerical calculations, or if you need to operate on large arrays of data, you'll be able to do it more efficiently in C than in Tcl. The third reason for implementing in C is complexity. If you are manipulating complex data structures, or if you're writing a large amount of code, the task will probably be more manageable in C than in Tcl. Tcl provides very little structure; this makes it easy to connect different things together but hard to manage large complex scripts. C provides more structure, which is cumbersome when you're implementing small things but indispensable when you're implementing big complicated things.

As an example, consider a program to manipulate weather reports. Suppose that information about current weather is available for a large number of measurement stations from one or more network sites using a well-defined network protocol, and you want to write a Tcl application to manipulate this data. Users of your application might wish to answer questions like:

- What is the complete weather situation at station X?
- What is the current temperature at station X?
- Which station in the country has the highest current temperature?
- At which stations is it currently raining?

You'll need to write some C code for this application in order to retrieve weather reports over the network. What form should these new commands take?

One approach is to implement each of the above functions in C as a separate Tcl command. For example, you might provide a command that retrieves the weather report from a station, formats it into prose, and prints it on standard output. Unfortunately this command can only be used for one purpose; you'd have to provide a second command for situations where you want to retrieve a report without printing it out (e.g. to find all the station where it is raining).

Instead, I'd suggest providing just two commands in C: a `wthr_stations` command that returns a list of all the stations for which weather reports are available, and a `wthr_report` command that returns a complete weather report for a particular station. These commands don't implement any of the above features directly, but they make it easy to implement all of the features. For example, Tcl already has a `puts` command that can be used to print information on standard output, so the first feature (printing a weather report for a station) can be implemented with a script that calls `wthr_report`, formats the report, and prints it with `puts`. The second feature (printing just the temperature) can be implemented by extracing the temperature from the result of `wthr_report` and then printing it alone. The third and fourth features (finding the hottest station and finding all stations where it is raining) can be implemented with scripts that invoke `wthr_report` for each station and extract and print relevant information. Many other features could also be implemented, such as printing a sorted list of the ten stations with the highest temperatures.

The preceding paragraph suggests that lower-level commands are better than higher-level ones. However, if you make the commands too low level then Tcl scripts will become unnecessarily complicated and you may lose opportunities for efficient implementation. For example, instead of providing a single command that retrieves a weather report, you might provide separate Tcl commands for each step of the protocol that retrieves a report: one command to connect to a server, one command to select a particular station, one command to request a report for the selected station, and so on. Although this results in more primitive commands, it is probably a mistake. The extra commands don't provide any additional functionality and they make it more tedious to write Tcl scripts. Furthermore, suppose that network communication delays are high, so that it takes a long time to get a response from a weather server, but the server allows you to request reports for several stations at once and get them all back in about the same time as a single report. In this situation you might want an even higher level interface, perhaps a Tcl command that takes any number of stations as arguments and retrieves reports for all of them at once. This would allow the C code to amortize the communication delays across several report retrievals and it might permit a much more efficient implementation of operations such as finding the station with the highest temperature.

To summarize, you should pick commands that are primitive enough so that all of the application's key functions are available individually through Tcl commands. On the other hand, you should pick commands that are high-level enough to hide unimportant details and capitalize on opportunities for efficient implementation.

27.2 Object names

The easiest way to think about your C code is in terms of *objects*. The C code in a Tcl application typically implements a few new kinds of objects, which are manipulated by the application's new Tcl commands. In the C code of your application you'll probably refer to the objects using pointers to the C structures that represent the objects, but you can't use pointers in Tcl scripts. Strings of some sort will have to be used in the Tcl scripts, and the C code that implements your commands will have to translate from those strings to internal pointers. For example, the objects in the weather application are weather stations; the `wthr_stations` command returns a list of station names, and the `wthr_report` command takes a station name as an argument.

A simple but dangerous way to name objects is to use their internal addresses. For example, in the weather application you could name each station with a hexadecimal string giving the internal address of the C structure for that station: the command that returns a list of stations would return a list of hexadecimal strings, and the command to retrieve a weather report would take one of these hexadecimal strings as argument. When the C code receives one of these strings, it could produce a pointer by converting the string to a binary number. I don't recommend using this approach in practice because it is hard to verify that a hexadecimal string refers to a valid object. If a user specifies a bad address it might cause the C code to make wild memory accesses, which could cause the application to crash. In addition, hexadecimal strings don't convey any meaningful information to the user.

Instead, I recommend using names that can be verified and that convey meaningful information. One simple approach is to keep a hash table in your C code that maps from a string name to the internal pointer for the object; a name is only valid if it appears in the hash table. The Tcl library implements flexible hash tables to make it easy for you to use this approach (see Chapter 33). If you use a hash table then you can use any strings whatsoever for names, so you might as well pick ones that convey information. For example, Tk uses hierarchical path names like `.menu.help` for windows in order to indicate the window's position in the window hierarchy. Tcl uses names like `file3` or `file4` for open files; these names don't convey a lot of information, but they at least include the letters "`file`" to suggest that they're used for file access, and the number is the POSIX file descriptor number for the open file. For the weather application I'd recommend using station names such as the city where the station is located. Or, if the U.S. Weather Service has well-defined names for its stations then I'd suggest using those names.

27.3 Commands: action-oriented vs. object-oriented

There are two approaches you can use when defining commands in your application, which I call *action-oriented* and *object-oriented*. In the action-oriented approach there is one command for each action that can be taken on an object, and the command takes an object name as an argument. The weather application is action-oriented: the `wthr_report` command corresponds to an action (retrieve weather report) and it takes a weather station name as an argument. Tcl's file commands are also action-oriented: there are separate commands for opening files, reading, writing, closing, etc.

In the object-oriented approach there is one command for each object, and the name of the command is the name of the object. When the command is invoked its first argument specifies the operation to perform on the object. Tk's widgets work this way: if there is a button widget `.b` then there is also a command named `.b`; you can invoke "`.b flash`" to flash the widget or "`.b invoke`" to invoke its action.

The action-oriented approach is best when there are a great many objects or the objects are unpredictable or short-lived. For example, it wouldn't make sense to implement string operations using an object-oriented approach because there would have to be one command for each string, and in practice Tcl applications have large numbers of strings that are created and deleted on a command-by-command basis. The weather application uses the action-oriented approach because there are only a few actions and and potentially a large number of stations. In addition, the application probably doesn't need to keep around state for each station all the time; it just uses the station name to look up weather information when requested.

The object-oriented approach works well when the number of objects isn't too great (e.g. a few tens or hundreds) and the objects are well-defined and exist for at least moderate amounts of time. Tk's widgets fit this description. The object-oriented approach has the advantage that it doesn't pollute the command name space with lots of commands for individual actions. For example in the action-oriented approach the command "delete" might be defined for one kind of object, thereby preventing its use for any other kind of object. In the object-oriented approach you only have to make sure that your object names don't conflict with existing commands or other object names. For example, Tk claims all command names starting with "." for its widget commands. The object-oriented approach also makes it possible for different objects to implement the same action in different ways. For example, if `.t` is a text widget and `.l` is a listbox widget in Tk, the `commands` "`.t yview 0`" and "`.l yview 0`" are implemented in very different ways even though they produce the same logical effect (adjust the view to make the topmost line visible at the top of the window).

Note: *Although Tk's file commands are implemented using the action-oriented approach, in retrospect I wish that I had used the object-oriented fashion, since open files fit the object-oriented model nicely.*

27.4 Application prefixes

If you use the action-oriented approach, I strongly recommend that you add a unique prefix to each of your command names. For example, I used the prefix "`wthr_`" for the weather commands. This guarantees that your commands won't conflict with other commands as long as your prefix is unique, and it makes it possible to merge different applications together without name conflicts. I also recommend using prefixes for Tcl procedures that you define and for global variables, again so that multiple packages can be used together.

27.5 Representing information

The information passed into and out of your Tcl commands should be formatted for easy processing by Tcl scripts, not necessarily for maximum human readability. For example, the command that retrieves a weather report shouldn't return English prose describing the weather. Instead, it should return the information in a structured form that makes it easy to extract the different components under the control of a Tcl script. You might return the report as a list consisting of pairs of elements, where the first element of each pair is a keyword and the second element is a value associated with that keyword, such as:

```
temp 53 hi 68 lo 37 precip .02 sky part
```

This indicates that the current temperature at the station is 53 degrees, the high and low for the last 24 hours were 68 and 37 degrees, .02 inches of rain has fallen in the last 24 hours, and the sky is partly cloudy. Or, the command might store the report in an associative array where each keyword is used as the name of an array element and the corresponding value is stored in that element. Either of these approaches would make it easy to extract components of the report. You can always reformat the information to make it more readable just before displaying it to the user.

Although machine readability is more important than human readability, you need not gratuitously sacrifice readability. For example, the above list could have been encoded as

```
18 53 7 68 9 37 5 .02 17 4
```

where `18` is a keyword for current temperature, `7` for 24-hour high, and so on. This is unnecessarily confusing and will not make your scripts any more efficient, since Tcl handles strings at least as efficiently as numbers.

Chapter 28
Interpreters and Script Evaluation

This chapter describes how to create and delete interpreters and how to use them to evaluate Tcl scripts. Table 28.1 summarizes the library procedures that are discussed in the chapter.

28.1 Interpreters

The central data structure manipulated by the Tcl library is a C structure of type `Tcl_Interp`. I'll refer to these structures (or pointers to them) as *interpreters*. Almost all of the Tcl library procedures take a pointer to a `Tcl_Interp` structure as an argument. An interpreter embodies the execution state of a Tcl script, including commands implemented in C, Tcl procedures, variables, and an execution stack that reflects partially-evaluated commands and Tcl procedures. Most Tcl applications use only a single interpreter but it is possible for a single process to manage several independent interpreters.

28.2 A simple Tcl application

The program below illustrates how to create and use an interpreter. It is a simple but complete Tcl application that evaluates a Tcl script stored in a file and prints the result or error message, if any.

```
#include <stdio.h>
#include <tcl.h>
```

`Tcl_Interp *Tcl_CreateInterp(void)`	Create a new interpreter and return a token for it.
`Tcl_DeleteInterp(Tcl_Interp *interp)`	Delete an interpreter.
`int Tcl_Eval(Tcl_Interp *interp, char *script)`	Evaluate `script` in `interp` and return its completion code. The result or error string will be in `interp->result`.
`int Tcl_EvalFile(Tcl_Interp *interp, char *fileName)`	Evaluate the contents of file `fileName` in `interp` and return its completion code. The result or error string will be in `interp->result`.
`int Tcl_GlobalEval(Tcl_Interp *interp, char *script)`	Evaluate `script` in `interp` at global level and return its completion code. The result or error string will be in `interp->result`.
`int Tcl_VarEval(Tcl_Interp *interp, char *string, char *string, ... (char *) NULL)`	Concatenate all of the `string` arguments into a single string, evaluate the resulting script in `interp`, and return its completion code. The result or error string will be in `interp->result`.
`int Tcl_RecordAndEval(Tcl_Interp *interp, char *script, int flags)`	Records `script` as an event in `interp`'s history list and evaluates it if `eval` is non-zero (`TCL_NO_EVAL` means don't evaluate the script). Returns a completion code such as `TCL_OK` and leaves result or error message in `interp->result`.

Table 28.1. Tcl library procedures for creating and deleting interpreters and for evaluating Tcl

```
main(int argc, char *argv[]) {
    Tcl_Interp *interp;
    int code;

    if (argc != 2) {
        fprintf(stderr, "Wrong # arguments: ");
        fprintf("should be \"%s fileName\"\n",
                argv[0]);
        exit(1);
    }

    interp = Tcl_CreateInterp();
    code = Tcl_EvalFile(interp, argv[1]);
    if (*interp->result != 0) {
        printf("%s\n", interp->result);
    }
    if (code != TCL_OK) {
            exit(1);
        }
        exit(0);
    }
```

If Tcl has been installed properly at your site you can copy the C code into a file named `simple.c` and compile it with the following shell command:

```
cc simple.c -ltcl -lm
```

Once you've compiled the program you can evaluate a script file `test.tcl` by typing the following command to your shell:

```
a.out test.tcl
```

The code for `simple.c` starts out with `#include` statements for `stdio.h` and `tcl.h`. You'll need to include `tcl.h` in every file that uses Tcl structures or procedures, since it defines structures like `Tcl_Interp` and declares the Tcl library procedures.

After checking to be sure that a file name was specified on the command line, the program invokes `Tcl_CreateInterp` to create a new interpreter. The new interpreter will contain all of the built-in commands described in Part I but no Tcl procedures or variables. It will have an empty execution stack. `Tcl_CreateInterp` returns a pointer to the `Tcl_Interp` structure for the interpreter, which is used as a token for the interpreter when calling other Tcl procedures. Most of the fields of the `Tcl_Interp` structure are hidden so that they cannot be accessed outside the Tcl library. The only accessible fields are those that describe the result of the last script evaluation; they'll be discussed later.

Next `simple.c` calls `Tcl_EvalFile` with the interpreter and the name of the script file as arguments. `Tcl_EvalFile` reads the file and evaluates its contents as a Tcl script, just as if you had invoked the Tcl `source` command with the file name as an argument. When `Tcl_EvalFile` returns the execution stack for the interpreter will once again be empty.

`Tcl_EvalFile` returns two pieces of information: an integer *completion code* and a string. The completion code is returned as the result of the procedure. It will be either `TCL_OK`, which means that the script completed normally, or `TCL_ERROR`, which means that an error of some sort occurred (e.g. the script file couldn't be read or the script aborted with an error). The second piece of information returned by `Tcl_EvalFile` is a string, a pointer to which is returned in `interp->result`. If the completion code is `TCL_OK` then `interp->result` points to the script's result; if the completion code is `TCL_ERROR` then `interp->result` points to a message describing the error.

Note: *The result string belongs to Tcl. It may or may not be dynamically allocated. You can read it and copy it, but you should not modify it and you should not save pointers to it. Tcl may overwrite the string or reallocate its memory during the next call to* `Tcl_EvalFile` *or any of the other procedures that evaluate scripts. Chapter 29 discusses the result string in more detail.*

If the result string is non-empty then `simple.c` prints it, regardless of whether it is an error message or a normal result. Then the program exits. It follows the UNIX style of exiting with a status of 1 if an error occurred and 0 if it completed successfully.

When the script file is evaluated only the built-in Tcl commands are available: no Tk commands will be available in this application and no application-specific commands have been defined.

28.3 Other evaluation procedures

Tcl provides three other procedures besides `Tcl_EvalFile` for evaluating scripts. Each of these procedures takes an interpreter as its first argument and each returns a completion code and string, just like `Tcl_EvalFile`. `Tcl_Eval` is similar to `Tcl_EvalFile` except that its second argument is a Tcl script rather than a file name:

```
code = Tcl_Eval(interp, "set a 44");
```

`Tcl_VarEval` takes a variable number of string arguments terminated with a `NULL` argument. It concatenates the strings and evaluates the result as a Tcl script. For example, the statement below has the same effect as the one above:

```
code = Tcl_VarEval(interp, "set a ", "44",
        (char *) NULL);
```

`Tcl_GlobalEval` is similar to `Tcl_Eval` except that it evaluates the script at global variable context (as if the execution stack were empty) even when procedures are active. It is used in special cases such as the `uplevel` command and Tk's event bindings.

If you want a script to be recorded on the Tcl history list, call `Tcl_RecordAndEval` instead of `Tcl_Eval`:

```
char *script;
int code;
...
code = Tcl_RecordAndEval(interp, script, 0);
```

`Tcl_RecordAndEval` is identical to `Tcl_Eval` except that it records the script as a new entry on the history list before invoking it. Tcl only records the scripts passed to `Tcl_RecordAndEval`, so you can select which ones to record. Typically you'll record only commands that were typed interactively. The last argument to `Tcl_RecordAndEval` is normally `0`; if you specify `TCL_NO_EVAL` instead, then Tcl will record the script without actually evaluating it.

28.4 Deleting interpreters

The procedure `Tcl_DeleteInterp` may be called to destroy an interpreter and all its associated state. It is invoked with an interpreter as argument:

```
    Tcl_DeleteInterp(interp);
```

Once `Tcl_DeleteInterp` returns you should never use the interpreter again. In applications like `simple.c`, which use a single interpreter throughout their lifetime, there's no need to delete the interpreter.

Chapter 29
Creating New Tcl Commands

Each Tcl command is represented by a *command procedure* written in C. When the command is invoked during script evaluation, Tcl calls its command procedure to carry out the command. This chapter provides basic information on how to write command procedures, how to register command procedures in an interpreter , and how to manage the interpreter's result string. Table 29.1 summarizes the Tcl library procedures that are discussed in the chapter.

29.1 Command procedures

The interface to a command procedure is defined by the `Tcl_CmdProc` procedure prototype:

```
typedef int Tcl_CmdProc(ClientData clientData,
        Tcl_Interp *interp, int argc,
        char *argv[]);
```

Each command procedure takes four arguments. The first, `clientData`, will be discussed in Section 29.5 below. The second, `interp`, is the interpreter in which the command was invoked. The third and fourth arguments have the same meaning as the `argc` and `argv` arguments to a C main program: `argc` specifies the total number of words in the Tcl command and `argv` is an array of pointers to the values of the words. Tcl processes all the special characters such as `$` and `[]` before invoking command procedures, so the values in `argc` reflect any substitutions that were specified for the command. The command name is included in `argc` and `argv`, and `argv[argc]` is `NULL`. A command

`Tcl_CreateCommand(Tcl_Interp *interp, char *cmdName, Tcl_CmdProc *cmdProc, ClientData clientData, Tcl_CmdDeleteProc *deleteProc)`	Defines a new command in `interp` with name `cmdName`. When the command is invoked `cmdProc` will be called; if the command is ever deleted then `deleteProc` will be called.
`int Tcl_DeleteCommand(Tcl_Interp *interp, char *cmdName)`	If `cmdName` is a command or procedure in `interp` then deletes it and returns 0. Otherwise returns -1.
`Tcl_SetResult(Tcl_Interp *interp, char *string,Tcl_FreeProc *freeProc)`	Arrange for `string` (or a copy of it) to become the result for `interp`. `FreeProc` identifies a procedure to call to eventually free the result, or it may be `TCL_STATIC`, `TCL_DYNAMIC`, or `TCL_VOLATILE`.
`Tcl_AppendResult(Tcl_Interp *interp, char *string, char *string, ... (char *) NULL)`	Appends each of the `string` arguments to the result string in `interp`.
`Tcl_AppendElement(Tcl_Interp *interp, char *string)`	Formats `string` as a Tcl list element and appends it to the result string in `interp`, with a preceding separator space if needed.
`Tcl_ResetResult(Tcl_Interp *interp)`	Resets `interp`'s result to the default empty state, freeing up any dynamically-allocated memory associated with it.

Table 29.1. Tcl library procedures for creating and deleting commands and for manipulating the

procedure returns two values just like `Tcl_Eval` and `Tcl_EvalFile`. It returns an integer completion code as its result (e.g. `TCL_OK` or `TCL_ERROR`) and it leaves a result string or error message in `interp->result`.

Here is the command procedure for a new command called `eq` that compares its two arguments for equality:

```
int EqCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    if (argc != 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (strcmp(argv[1], argv[2]) == 0) {
        interp->result = "1";
    } else {
        interp->result = "0";
    }
```

```
        return TCL_OK;
    }
```

EqCmd checks to see that was called with exactly two arguments (three words, including the command name), and if not it stores an error message in interp->result and returns TCL_ERROR. Otherwise it compares its two argument strings and stores a string in interp->result to indicate whether or not they were equal; then it returns TCL_OK to indicate that the command completed normally.

29.2 Registering commands

In order for a command procedure to be invoked by Tcl, you must register it by calling Tcl_CreateCommand. For example, EqCmd could be registered with the following statement:

```
Tcl_CreateCommand(interp, "eq", EqCmd,
        (ClientData *) NULL,
        (Tcl_CmdDeleteProc *) NULL);
```

The first argument to Tcl_CreateCommand identifies the interpreter in which the command will be used. The second argument specifies the name for the command and the third argument specifies its command procedure. The fourth and fifth arguments are discussed in Section 29.5 below; they can be specified as NULL for simple commands like this one. Tcl_CreateCommand will create a new command for interp named eq; if there already existed a command by that name then it is deleted. Whenever eq is invoked in interp Tcl will call EqCmd to carry out its function.

After the above call to Tcl_CreateCommand, eq can be used in scripts just like any other command:

```
eq abc def
0
eq 1 1
1
set w .dlg
set w2 .dlg.ok
eq $w.ok $w2
1
```

When processing scripts, Tcl carries out all of the command-line substitutions before calling the command procedure, so when EqCmd is called for the last eq command above both argv[1] and argv[2] are ".dlg.ok".

Tcl_CreateCommand is usually called by applications during initialization to register application-specific commands. However, new commands can also be created at any time while an application is running. For example, the proc command creates a new command for each Tcl procedure that is defined, and Tk creates a widget command for each new widget. In Section 29.5 you'll see an example where the command procedure for one command creates a new command.

Commands created by `Tcl_CreateCommand` are indistinguishable from Tcl's built-in commands. Each built-in command has a command procedure with the same form as EqCmd, and you can redefine a built-in command by calling `Tcl_CreateCommand` with the name of the command and a new command procedure.

29.3 The result protocol

The `EqCmd` procedure returns a result by setting `interp->result` to point to one of several static strings. However, the result string can also be managed in several other ways. Tcl defines a protocol for setting and using the result, which allows for dynamically-allocated results and provides a small static area to avoid memory-allocation overheads in simple cases.

The full definition of the `Tcl_Interp` structure, as visible outside the Tcl library, is as follows:

```
typedef struct Tcl_Interp {
    char *result;
    Tcl_FreeProc *freeProc;
    int errorLine;
} Tcl_Interp;
```

The first field, `result`, points to the interpreter's current result. The second field, `freeProc`, is used when freeing dynamically-allocated results; it will be discussed below. The third field, `errorLine`, is related to error handling and is described in Section XXX.

When Tcl invokes a command procedure the `result` and `freeProc` fields always have well-defined values. `Interp->result` points to a small character array that is part of the interpreter structure and the array has been initialized to hold an empty string (the first character of the array is zero). `Interp->freeProc` is always zero. This state is referred to as the *initialized state* for the result. Not only is this the state of the result when command procedures are invoked, but many Tcl library procedures also expect the interpreter's result to be in the initialized state when they are invoked. If a command procedure wishes to return an empty string as its result, it simply returns without modifying `interp->result` or `interp->freeProc`.

There are three ways that a command procedure can specify a non-empty result. First, it can modify `interp->result` to point to a static string as in `EqCmd`. A string can be considered to be static as long as its value will not change before the next Tcl command procedure is invoked. For example, Tk stores the name of each widget in a dynamically-allocated record associated with the widget, and it returns widget names by setting `interp->result` to the name string in the widget record. This string is dynamically allocated, but widgets are deleted by Tcl commands so the string is guaranteed not to be recycled before the next Tcl command executes. If a string is stored in automatic storage associated with a procedure it cannot be treated as static, since its value will change as soon as some other procedure re-uses the stack space.

The second way to set a result is to use the pre-allocated space in the `Tcl_Interp` structure. In its initialized state `interp->result` points to this space. If a command procedure wishes to return a small result it can copy it to the location pointed to by `interp->result`. For example, the procedure below implements a command `numwords` that returns a decimal string giving a count of its arguments:

```
int NumwordsCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    sprintf(interp->result, "%d", argc);
    return TCL_OK;
}
```

The size of the pre-allocated space is guaranteed to be at least 200 bytes; you can retrieve the exact size with the symbol `TCL_RESULT_SIZE` defined by `tcl.h`. It's generally safe to use this area for printing a few numbers and/or short strings, but it is *not* safe to copy strings of unbounded length to the pre-allocated space.

The third way to set a result is to allocate memory with a storage allocator such as `malloc`, store the result string there, and set `interp->result` to the address of the memory. In order to ensure that the memory is eventually freed, you must also set `interp->freeProc` to the address of a procedure that Tcl can call to free the memory, such as `free`. In this case the dynamically-allocated memory becomes the property of Tcl. Once Tcl has finished using the result it will free it by invoking the procedure specified by `interp->freeProc`. This procedure must match the following procedure prototype:

```
typedef void Tcl_FreeProc(char *blockPtr);
```

The procedure will be invoked with a single argument containing the address that you stored in `interp->result`. In most cases you'll use `malloc` for dynamic allocation and thus set `interp->freeProc` to `free`, but the mechanism is general enough to support other storage allocators too.

29.4 Procedures for managing the result

Tcl provides several library procedures for manipulating the result. These procedures all obey the protocol described in the previous section, and you may find them more convenient than setting `interp->result` and `interp->freeProc` directly. The first procedure is `Tcl_SetResult`, which simply implements the protocol described above. For example, `EqCmd` could have replaced the statement

```
interp->result = "wrong # args";
```

with a call to Tcl_SetResult as follows:

```
Tcl_SetResult(interp, "wrong # args", TCL_STATIC);
```

The first argument to Tcl_SetResult is an interpreter. The second argument is a string to use as result, and the third argument gives additional information about the string. TCL_STATIC means that the string is static, so Tcl_SetResult just stores its address into interp->result. A value of TCL_VOLATILE for the third argument means that the string is about to change (e.g. it's stored in the procedure's stack frame) so a copy must be made for the result. Tcl_SetResult will copy the string into the pre-allocated space if it fits, otherwise it will allocate new memory to use for the result and copy the string there (setting interp->freeProc appropriately). If the third argument is TCL_DYNAMIC it means that the string was allocated with malloc and is now the property of Tcl: Tcl_SetResult will set interp->freeProc to free as described above. Finally, the third argument may be the address of a procedure suitable for use in interp->freeProc; in this case the string is dynamically-allocated and Tcl will eventually call the specified procedure to free it.

Tcl_AppendResult makes it easy to build up results in pieces. It takes any number of strings as arguments and appends them to the interpreter's result in order. As the result grows in length Tcl_AppendResult allocates new memory for it. Tcl_AppendResult may be called repeatedly to build up long results incrementally, and it does this efficiently even if the result becomes very large (e.g. it allocates extra memory so that it doesn't have to copy the existing result into a larger area on each call). Here is an implementation of the concat command that uses Tcl_AppendResult:

```
int ConcatCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    int i;
    if (argc == 1) {
        return TCL_OK;
    }
    Tcl_AppendResult(interp, argv[1], (char *) NULL);
    for (i = 2; i < argc; i++) {
        Tcl_AppendResult(interp, " ", argv[i],
            (char *) NULL);
    }
    return TCL_OK;
}
```

The NULL argument in each call to Tcl_AppendResult marks the end of the strings to append. Since the result is initially empty, the first call to Tcl_AppendResult just sets the result to argv[1]; each additional call appends one more argument preceded by a separator space.

Tcl_AppendElement is similar to Tcl_AppendResult except that it only adds one string to the result at a time and it appends it as a list element instead of a raw string. It's useful for creating lists. For example, here is a simple implementation of the `list` command:

```
int ListCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char **argv) {
    int i;
    for (i = 1; i < argc; i++) {
        Tcl_AppendElement(interp, argv[i]);
    }
    return TCL_OK;
}
```

Each call to `Tcl_AppendElement` adds one argument to the result. The argument is converted to a proper list element before appending it to the result (e.g. it is enclosed in braces if it contains space characters). `Tcl_AppendElement` also adds a separator space if it's needed before the new element (no space is added if the result is currently empty or if its characters are " `{`", which means that the new element will be the first element of a sub-list). For example, if `ListCmd` is invoked with four arguments, "`list`", "`abc`", "`x y`", and "`}`", it produces the following result:

```
abc {x y} \}
```

Like `Tcl_AppendResult`, `Tcl_AppendElement` grows the result space if needed and does it in a way that is efficient even for large results and repeated calls.

If you set the result for an interpreter and then decide that you want to discard it (e.g. because an error has occurred and you want to replace the current result with an error message), you should call the procedure `Tcl_ResetResult`. It will invoke `interp->freeProc` if needed and then restore the interpreter's result to its initialized state. You can then store a new value in the result in any of the usual ways. You need not call `Tcl_ResetResult` if you're going to use `Tcl_SetResult` to store the new result, since `Tcl_SetResult` takes care of freeing any existing result.

29.5 ClientData and deletion callbacks

The fourth and fifth arguments to `Tcl_CreateCommand`, `clientData` and `deleteProc`, were not discussed in Section 29.2 but they are useful when commands are associated with objects. The `clientData` argument is used to pass a one-word value to a command procedure. Tcl saves the `clientData` value that is passed to `Tcl_CreateCommand` and uses it as the first argument to the command procedure. The type `ClientData` is large enough to hold either an integer or a pointer value. It is usually the address of a C data structure for the command to manipulate.

Tcl and Tk use *callback procedures* in many places. A callback is a procedure whose address is passed to a library procedure and saved in a data structure. Later, at some significant time, the address is used to invoke the procedure ("call it back"). A command procedure is an example of a callback: Tcl associates the procedure address with a Tcl command name and calls the procedure whenever the command is invoked. When a callback is specified in Tcl or Tk a `ClientData` argument is usually provided along with the procedure address and the `ClientData` value is passed to the callback as its first argument.

The `deleteProc` argument to `Tcl_CreateCommand` specifies a deletion callback. If its value isn't `NULL` then it is the address of a procedure for Tcl to invoke when the command is deleted. The procedure must match the following prototype:

```
typedef void Tcl_CmdDeleteProc(ClientData clientData);
```

The deletion callback takes a single argument, which is the ClientData value specified when the command was created. Deletion callbacks are used for purposes such as freeing the object associated with a command.

Figure 29.1 shows how `clientData` and `deleteProc` can be used to implement counter objects. The application containing this code must register `CounterCmd` as a Tcl command using the following call:

```
Tcl_CreateCommand(interp, "counter", CounterCmd,
        (ClientData) NULL, (Tcl_CmdDeleteProc) NULL);
```

New counters can then be created by invoking the `counter` Tcl command; each invocation creates a new object and returns a name for that object:

```
counter
ctr0
counter
ctr1
```

`CounterCmd` is the command procedure for `counter`. It allocates a structure for the new counter and initializes its value to zero. Then it creates a name for the counter using the static variable `id`, arranges for that name to be returned as the command's result, and increments `id` so that the next new counter will get a different name.

This example uses the object-oriented style described in Section 27.3, where there is one command for each counter object. As part of creating a new counter `CounterCmd` creates a new Tcl command named after the counter. It uses the address of the `Counter` structure as the `ClientData` for the command and specifies `DeleteCounter` as the deletion callback for the new command.

Counters can be manipulated by invoking the commands named after them. Each counter supports two options to its command: `get`, which returns the current value of the counter, and `next`, which increments the counter's value. Once `ctr0` and `ctr1` were created above, the following Tcl commands could be invoked:

```
ctr0 next; ctr0 next; ctr0 get
2
ctr1 get
0
```

```
typedef struct {
    int value;
} Counter;

int CounterCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    Counter *counterPtr;
    static int id = 0;
    if (argc != 1) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    counterPtr = (Counter *) malloc(sizeof(Counter));
    counterPtr->value = 0;
    sprintf(interp->result, "ctr%d", id);
    id++;
    Tcl_CreateCommand(interp, interp->result, ObjectCmd,
            (ClientData) counterPtr, DeleteCounter);
    return TCL_OK;
}

int ObjectCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    CounterPtr *counterPtr = (Counter *) clientData;
    if (argc != 2) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (strcmp(argv[1], "get") == 0) {
        sprintf(interp->result, "%d", counterPtr->value);
    } else if (strcmp(argv[1], "next") == 0) {
        counterPtr->value++;
    } else {
        Tcl_AppendResult(interp, "bad counter command \"",
                argv[1], "\": should be get or next",
                (char *) NULL);
        return TCL_ERROR;
    }
    return TCL_OK;
}

void DeleteCounter(ClientData clientData) {
    free((char *) clientData);
}
```

Figure 29.1. An implementation of counter objects.

```
ctr0 clear
bad counter command "clear": should be get or next
```

The procedure `ObjectCmd` implements the Tcl commands for all existing counters. It is passed a different `ClientData` argument for each counter, which it casts back to a value of type `Counter *`. `ObjectCmd` then checks `argv[1]` to see which command option was invoked. If it was `get` then it returns the counter's value as a decimal string; if it was `next` then it increments the counter's value and leaves `interp->result` untouched so that the result is an empty string. If an unknown command was invoked then `ObjectCmd` calls `Tcl_AppendResult` to create a useful error message.

Note: It is not safe to create the error message with a statement like

```
sprintf(interp->result, "bad counter command \"%s\": "
    "should be get or next", argv[1]);
```

This is unsafe because `argv[1]` *has unknown length. It could be so long that* `sprintf` *overflows the space allocated in the interpreter and corrupts memory .* `Tcl_AppendResult` *is safe because it checks the lengths of its arguments and allocates as much space as needed for the result.*

To destroy a counter you can delete its Tcl command, for example:

```
rename ctr0 {}
```

As part of deleting the command Tcl will invoke `DeleteProc`, which frees up the memory associated with the counter.

This object-oriented implementation of counter objects is similar to Tk's implementation of widgets: there is one Tcl command to create new instances of each counter or widget, and one Tcl command for each existing counter or widget. A single command procedure implements all of the counter or widget commands for a particular type of object, receiving a ClientData argument that identifies a specific counter or widget. A different mechanism is used to delete Tk widgets than for counters above, but in both cases the command corresponding to the object is deleted at the same time as the object.

29.6 Deleting commands

Tcl commands can be removed from an interpreter by calling `Tcl_DeleteCommand`. For example, the statement below will delete the `ctr0` command in the same way as the `rename` command above:

```
Tcl_DeleteCommand(interp, "ctr0");
```

If the command has a deletion callback then it will be invoked before the command is removed. Any command may be deleted, including built-in commands, application-specific commands, and Tcl procedures.

Chapter 30
Parsing

This chapter describes Tcl library procedures for parsing and evaluating strings in various forms such as integers, expressions and lists. These procedures are typically used by command procedures to process the words of Tcl commands. See Table 30.1 for a summary of the procedures.

30.1 Numbers and booleans

Tcl provides three procedures for parsing numbers and boolean values: `Tcl_GetInt`, `Tcl_GetDouble`, and `Tcl_GetBoolean`. Each of these procedures takes three arguments: an interpreter, a string, and a pointer to a place to store the value of the string. Each of the procedures returns `TCL_OK` or `TCL_ERROR` to indicate whether the string was parsed successfully. For example, the command procedure below uses `Tcl_GetInt` to implement a `sum` command:

```
int SumCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    int num1, num2;
    if (argc != 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (Tcl_GetInt(interp, argv[1], &num1) != TCL_OK) {
        return TCL_ERROR;
    }
```

`int Tcl_GetInt(Tcl_Interp *interp, char *string, int *intPtr)`
Parses `string` as an integer, stores value at `*intPtr`, and returns `TCL_OK`. If an error occurs while parsing, returns `TCL_ERROR` and stores an error message in `interp->result`.

`int Tcl_GetDouble(Tcl_Interp *interp, char *string, double *doublePtr)`
Same as `Tcl_GetInt` except parses `string` as a floating-point value and stores value at `*doublePtr`.

`int Tcl_GetBoolean(Tcl_Interp *interp, char *string, int *intPtr)`
Same as `Tcl_GetInt` except parses `string` as a boolean and stores 0/1 value at `*intPtr`. See Table 30.2 for legal values for `string`.

`int Tcl_ExprString(Tcl_Interp *interp, char *string)`
Evaluates `string` as an expression, stores value as string in `interp->result`, and returns `TCL_OK`. If an error occurs during evaluation, returns `TCL_ERROR` and stores an error message in `interp->result`.

`int Tcl_ExprLong(Tcl_Interp *interp, char *string, long *longPtr)`
Same as `Tcl_ExprString` except stores value as a long integer at `*longPtr`. An error occurs if the value can't be converted to an integer.

`int Tcl_ExprDouble(Tcl_Interp *interp, char *string, double *doublePtr)`
Same as `Tcl_ExprString` except stores value as double-precision floating-point value at `*doublePtr`. An error occurs if the value can't be converted to a floating-point number.

`int Tcl_ExprBoolean(Tcl_Interp *interp, char *string, int *intPtr)`
Same as `Tcl_ExprString` except stores value as 0/1 integer at `*intPtr`. An error occurs if the value can't be converted to a boolean value.

`int Tcl_SplitList(Tcl_Interp *interp, char *list, int *argcPtr, char ***argvPtr)`
Parses `list` as a Tcl list and creates an array of strings whose values are the elements of list. Stores count of number of list elements at `*argcPtr` and pointer to array at `*argvPtr`. Returns `TCL_OK`. If an error occurs while parsing `list`, returns `TCL_ERROR` and stores an error message in `interp->result`. Space for string array is dynamically allocated; caller must eventually pass `*argvPtr` to `free`.

`char *Tcl_Merge(int argc, char **argv)`
Inverse of `Tcl_SplitList`. Returns pointer to Tcl list whose elements are the members of `argv`. Result is dynamically-allocated; caller must eventually pass it to `free`.

```
if (Tcl_GetInt(interp, argv[2], &num2) != TCL_OK) {
    return TCL_ERROR;
}
sprintf(interp->result, "%d", num1+num2);
```

```
        return TCL_OK;
    }
```

`SumCmd` expects each of the command's two arguments to be an integer. It calls `Tcl_GetInt` to convert them from strings to integers, then it sums the values and converts the result back to a decimal string in `interp->result`. `Tcl_GetInt` accepts strings in decimal (e.g. "`492`"), hexadecimal (e.g. "`0x1ae`") or octal (e.g. "`017`"), and allows them to be signed and preceded by white space. If the string is in one of these formats then `Tcl_GetInt` returns `TCL_OK` and stores the value of the string in the location pointed to by its last argument. If the string can't be parsed correctly then `Tcl_GetInt` stores an error message in `interp->result` and returns `TCL_ERROR`; `SumCmd` then returns `TCL_ERROR` to its caller with `interp->result` still pointing to the error message from `Tcl_GetInt`.

Here are some examples of invoking the `sum` command in Tcl scripts:

```
sum 2 3
5
sum 011 0x14
29
sum 3 6z
expected integer but got "6z"
```

`Tcl_GetDouble` is similar to `Tcl_GetInt` except that it expects the string to consist of a floating-point number such as "`-2.2`" or "`3.0e-6`" or "`7`". It stores the double-precision value of the number at the location given by its last argument or returns an error in the same way as `Tcl_GetInt`. `Tcl_GetBoolean` is similar except that it converts the string to a 0 or 1 integer value, which it stores at the location given by its last argument. Any of the true values listed in Table 30.2 converts to 1 and any of the false values converts to 0.

True Values	False Values
1	0
true	false
on	off
yes	no

Table 30.2. Legal values for boolean strings parsed by `Tcl_GetBoolean`. Any of the values may be abbreviated or capitalized.

Many other Tcl and Tk library procedures are similar to Tcl_GetInt in the way they use an interp argument for error reporting. These procedures all expect the interpreter's result to be in its initialized state when they are called. If they complete successfully then they usually leave the result in that state; if an error occurs then they put an error message in the result. The procedures' return values indicate whether they succeeded, usually as a TCL_OK or TCL_ERROR completion code but sometimes in other forms such as a NULL string pointer. When an error occurs, all the caller needs to do is to return a failure itself, leaving the error message in the interpreter's result.

30.2 Expression evaluation

Tcl provides four library procedures that evaluate expressions of the form described in Chapter XXX: Tcl_ExprString, Tcl_ExprLong, Tcl_ExprDouble, and Tcl_ExprBoolean. These procedures are similar except that they return the result of the expression in different forms as indicated by their names. Here is a slightly simplified implementation of the expr command, which uses Tcl_ExprString:

```
int ExprCmd(ClientData clientData, TclInterp *interp,
        int argc, char *argv[]) {
    if (argc != 2) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    return Tcl_ExprString(interp, argv[1]);
}
```

All ExprCmd does is to check its argument count and then call Tcl_ExprString. Tcl_ExprString evaluates its second argument as a Tcl expression and returns the value as a string in interp->result. Like Tcl_GetInt, it returns TCL_OK if it evaluated the expression successfully; if an error occurs it leaves an error message in interp->result and returns TCL_ERROR.

Tcl_ExprLong, Tcl_ExprDouble, and Tcl_ExprBoolean are similar to Tcl_ExprString except that they return the expression's result as a long integer, double-precision floating-point number, or 0/1 integer, respectively. Each of the procedures takes an additional argument that points to a place to store the result. For these procedures the result must be convertible to the requested type. For example, if "abc" is passed to Tcl_ExprLong then it will return an error because "abc" has no integer value. If the string "40" is passed to Tcl_ExprBoolean it will succeed and store 1 in the value word (any non-zero integer is considered to be true).

30.3 Manipulating lists

Tcl provides several procedures for manipulating lists, of which the most useful are Tcl_SplitList and Tcl_Merge. Given a string in the form of a Tcl list, Tcl_SplitList extracts the elements and returns them as an array of string pointers. For example, here is an implementation of Tcl's lindex command that uses Tcl_SplitList:

```
int LindexCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    int index, listArgc;
    char **listArgv;
    if (argc != 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (Tcl_GetInt(interp, argv[2], &index) != TCL_OK) {
        return TCL_ERROR;
    }
    if (Tcl_SplitList(interp, argv[1], &listArgc,
            &listArgv) != TCL_OK) {
        return TCL_ERROR;
    }
    if ((index >= 0) && (index < listArgc)) {
        Tcl_SetResult(interp, listArgv[index],
                TCL_VOLATILE);
    }
    free((char *) listArgv);
    return TCL_OK;
}
```

LindexCmd checks its argument count, calls Tcl_GetInt to convert argv[2] (the index) into an integer, then calls Tcl_SplitList to parse the list. Tcl_SplitList returns a count of the number of elements in the list to listArgc. It also creates an array of pointers to the values of the elements and stores a pointer to that array in listArgv. If Tcl_SplitList encounters an error in parsing the list (e.g. unmatched braces) then it returns TCL_ERROR and leaves an error message in interp->result; otherwise it returns TCL_OK.

Tcl_SplitList calls malloc to allocate space for the array of pointers and for the string values of the elements; the caller must free up this space by passing listArgv to free. The space for both pointers and strings is allocated in a single block of memory so only a single call to free is needed. LindexCmd calls Tcl_SetResult to copy the desired element into the interpreter's result. It specifies TCL_VOLATILE to indicate that the string value is about to be destroyed (its memory will be freed); Tcl_SetResult will make a copy of the listArgv[index] for interp's result. If the specified index is outside the range of elements in the list then LindexCmd leaves interp->result in its initialized state, which returns an empty string.

Tcl_Merge is the inverse of Tcl_SplitList. Given argc and argv information describing the elements of a list, it returns a malloc'ed string containing the list. Tcl_Merge always succeeds so it doesn't need an interp argument for error reporting. Here's another implementation of the list command, which uses Tcl_Merge:

```
int ListCmd2(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    interp->result = Tcl_Merge(argc-1, argv+1);
    interp->freeProc = (Tcl_FreeProc *) free;
    return TCL_OK;
}
```

ListCmd2 takes the result from Tcl_Merge and stores it in the interpreter's result. Since the list string is dynamically allocated ListCmd2 sets interp->freeProc to free so that Tcl will call free to release the storage for the list when it is no longer needed.

Chapter 31
Exceptions

Many Tcl commands, such as `if` and `while`, have arguments that are Tcl scripts. The command procedures for these commands invoke `Tcl_Eval` recursively to evaluate the scripts. If `Tcl_Eval` returns a completion code other than `TCL_OK` then an *exception* is said to have occurred. Exceptions include `TCL_ERROR`, which was described in Chapter 31, plus several others that have not been mentioned before. This chapter introduces the full set of exceptions and describes how to unwind nested evaluations and leave useful information in the `errorInfo` and `errorCode` variables. See Table 31.1 for a summary of procedures related to exception handling.

31.1 Completion codes.

Table 31.2 lists the full set of Tcl completion codes that may be returned by command procedures. If a command procedure returns anything other than `TCL_OK` then Tcl aborts the evaluation of the script containing the command and returns the same completion code as the result of `Tcl_Eval` (or `Tcl_EvalFile`, etc). `TCL_OK` and `TCL_ERROR` have already been discussed; they are used for normal returns and errors, respectively. The completion codes `TCL_BREAK` or `TCL_CONTINUE` occur if `break` or `continue` commands are invoked by a script; in both of these cases the interpreter's result will be an empty string. The `TCL_RETURN` completion code occurs if `return` is invoked; in this case the interpreter's result will be the intended result of the enclosing procedure.

As an example of how to generate a `TCL_BREAK` completion code, here is the command procedure for the `break` command:

`Tcl_AddErrorInfo(Tcl_Interp *interp, char *message)`	Adds `message` to stack trace being formed in `the errorInfo` variable.
`Tcl_SetErrorCode(Tcl_Interp *interp, char *field, char *field, ... (char *) NULL)`	Creates a list whose elements are the `field` arguments, and sets the `errorCode` variable to the contents of the list.

Table 31.1. A summary of Tcl library procedures for setting `errorInfo` and `errorCode`.

Completion Code	Meaning
TCL_OK	Command completed normally.
TCL_ERROR	Unrecoverable error occurred.
TCL_BREAK	`Break` command was invoked.
TCL_CONTINUE	`Continue` command was invoked.
TCL_RETURN	`Return` command was invoked.

Table 31.2. Completion codes that may be returned by command procedures and procedures that evaluate scripts, such as `Tcl_Eval`.

```
int BreakCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    if (argc != 2) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    return TCL_BREAK;
}
```

`TCL_BREAK`, `TCL_CONTINUE`, and `TCL_RETURN` are used to unwind nested script evaluations back to an enclosing looping command or procedure invocation. Under most circumstances, any procedure that receives a completion code other than `TCL_OK` from `Tcl_Eval` should immediately return that same completion code to its caller without modifying the interpreter's result. However, a few commands process some of the special completion codes without returning them upward. For example, here is an implementation of the `while` command:

```
int WhileCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    int bool;
    int code;
    if (argc != 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    while (1) {
        Tcl_ResetResult(interp);
        if (Tcl_ExprBoolean(interp, argv[1], &bool)
                != TCL_OK) {
            return TCL_ERROR;
        }
        if (bool == 0) {
            return TCL_OK;
        }
        code = Tcl_Eval(interp, argv[2]);
        if (code == TCL_CONTINUE) {
            continue;
        } else if (code == TCL_BREAK) {
            return TCL_OK;
        } else if (code != TCL_OK) {
            return code;
        }
    }
}
```

After checking its argument count, `WhileCmd` enters a loop where each iteration evaluates the command's first argument as an expression and its second argument as a script. If an error occurs while evaluating the expression then `WhileCmd` returns the error. If the expression evaluates successfully but its value is 0, then the command terminates with a normal return. Otherwise it evaluates the script argument. If the completion code is `TCL_CONTINUE` then `WhileCmd` goes on to the next loop iteration. If the code is `TCL_BREAK` then `WhileCmd` ends the execution of the command and returns `TCL_OK` to its caller. If `Tcl_Eval` returns any other completion code besides `TCL_OK` then `WhileCmd` simply reflects that code upwards. This causes the proper unwinding to occur on `TCL_ERROR` or `TCL_RETURN` codes, and it will also unwind if any new completion codes are added in the future.

If an exceptional return unwinds all the way through the outermost script being evaluated then Tcl checks the completion code to be sure it is either `TCL_OK` or `TCL_ERROR`. If not then Tcl turns the return into an error with an appropriate error message. Furthermore, if a `TCL_BREAK` or `TCL_CONTINUE` exception unwinds all the way out of a procedure then Tcl also turns it into an error. For example:

```
break
invoked "break" outside of a loop
proc badbreak {} {break}
badbreak
invoked "break" outside of a loop
```

Thus applications need not worry about completion codes other then `TCL_OK` and `TCL_ERROR` when they evaluate scripts from the outermost level.

31.2 Augmenting the stack trace in errorInfo

When an error occurs, Tcl modifies the `errorInfo` global variable to hold a stack trace of the commands that were being evaluated at the time of the error. It does this by calling the procedure `Tcl_AddErrorInfo`, which has the following prototype:

```
void Tcl_AddErrorInfo(Tcl_Interp *interp,
        char *message)
```

The first call to `Tcl_AddErrorInfo` after an error sets `errorInfo` to the error message stored in `interp->result` and then appends `message`. Each subsubsequent call for the same error appends `message` to `errorInfo`'s current value. Whenever a command procedure returns `TCL_ERROR` `Tcl_Eval` calls `Tcl_AddErrorInfo` to log information about the command that was being executed. If there are nested calls to `Tcl_Eval` then each one adds information about its command as it unwinds, so that a stack trace forms in `errorInfo`.

Command procedures can call `Tcl_AddErrorInfo` themselves to provide additional information about the context of the error. This is particularly useful for command procedures tha invoke `Tcl_Eval` recursively. For example, consider the following Tcl procedure, which is a buggy attempt to find the length of the longest element in a list:

```
proc longest list {
    set i [llength $list]
    while {$i >= 0} {
        set length [string length [lindex $list $i]]
        if {$length > $max} {
            set max $length
        }
        incr i
    }
    return $max
}
```

This procedure is buggy because it never initializes the variable `max`, so an error will occur when the `if` command attempts to read it. If the procedure is invoked with the command “`longest {a 12345 xyz}`”, then the following stack trace will be stored in `errorInfo` after the error:

```
can’t read "max": no such variable
    while executing
"if {$length > $max} {
            set max $length
        }"
    ("while" body line 3)
    invoked from within
"while {$i >= 0} {
        set length [string length [lindex $list $i]]
        if {$length > $max} {
            set max $length
        }
        incr i
    }"
    (procedure "longest" line 3)
    invoked from within
"longest {a 12345 xyz}"
```

All of the information is provided by `Tcl_Eval` except for the two lines with comments in parentheses. The first of these lines was generated by the command procedure for `while`, and the second was generated by the Tcl code that evaluates procedure bodies. If you used the implementation of `while` on page 287 instead of the built-in Tcl implementation then the first parenthesized message would be missing. The C code below is a replacement for the last `else` clause in `WhileCmd`; it uses `Tcl_AppendResult` to add the parenthetical remark.

```
...
} else if (code != TCL_OK) {
    if (code == TCL_ERROR) {
        char msg[50];
        sprintf(msg, "\n    (\"while\" body line %d)",
                interp->errorLine);
        Tcl_AddErrorInfo(interp, msg);
    }
    return code;
}
...
```

The `errorLine` field of `interp` is set by `Tcl_Eval` whenever a command procedure returns an error; it gives the line number of the command that produced the error, within the script being executed. A line number of 1 corresponds to the first line, which is the line containing the open brace in this example; the `if` command that generated the error is on line 3.

For simple Tcl commands you shouldn't need to invoke `Tcl_AddErrorInfo`: the information provided by `Tcl_Eval` will be sufficient. However, if you write code that calls `Tcl_Eval` then I recommend calling `Tcl_AddErrorInfo` whenever `Tcl_Eval` returns an error, to provide information about why `Tcl_Eval` was invoked and also to include the line number of the error.

Note: You must call `Tcl_AddErrorInfo` *rather than trying to set the* `errorInfo` *variable directly, because* `Tcl_AddErrorInfo` *contains special code to detect the first call after an error and clear out the old contents of* `errorInfo`*.*

31.3 Setting errorCode

The last piece of information set after an error is the `errorCode` variable, which provides information about the error in a form that's easy to process with Tcl scripts. It's intended for use in situations where a script is likely to catch the error, determine exactly what went wrong, and attempt to recover from it if possible. If a command procedure returns an error to Tcl without setting `errorCode` then Tcl sets it to `NONE`. If a command procedure wishes to provide information in `errorCode` then it should invoke `Tcl_SetErrorCode` before returning `TCL_ERROR`.

`Tcl_SetErrorCode` takes as arguments an interpreter and any number of string arguments ending with a null pointer. It forms the strings into a list and stores the list as the value of `errorCode`. For example, suppose that you have written several commands to implement gizmo objects, and that there are several errors that could occur in commands that manipulate the objects, such as an attempt to use a non-existent object. If one of your command procedures detects a non-existent object error, it might set `errorCode` as follows:

```
Tcl_SetErrorCode(interp, "GIZMO", "EXIST",
        "no object by that name", (char *) NULL);
```

This will leave the value "`GIZMO EXIST {no object by that name}`" in `errorCode`. `GIZMO` identifies a general class of errors (those associated with gizmo objects), `EXIST` is the symbolic name for the particular error that occurred, and the last element of the list is a human-readable error message. You can store whatever you want in `errorCode` as long as the first list element doesn't conflict with other values already in use, but the overall idea is to provide symbolic information that can easily be processed by a Tcl script. For example, a script that accesses gizmos might catch errors and if the error is a non-existent gizmo it might automatically create a new gizmo.

Note: It's important to call `Tcl_SetErrorCode` *rather than setting* `errorCode` *directly with* `Tcl_SetVar`*. This is because* `Tcl_SetErrrorCode` *also sets other information in the interpreter so that* `errorCode` *isn't later set to its default value; if you set* `errorCode` *directly, then Tcl will override your value with the default value* `NONE`*.*

Chapter 32
Accessing Tcl Variables

This chapter describes how you can access Tcl variables from C code. Tcl provides library procedures to set variables, read their values, and unset them. It also provides a tracing mechanism that you can use to monitor and restrict variable accesses. Table 32.1 summarizes the library procedures that are discussed in the chapter.

32.1 Naming variables

The procedures related to variables come in pairs such as `Tcl_SetVar` and `Tcl_SetVar2`. The two procedures in each pair differ only in the way they name a Tcl variable. In the first procedure of each pair, such as `Tcl_SetVar`, the variable is named with a single string argument, `varName`. This form is typically used when a variable name has been specified as an argument to a Tcl command. The string can name a scalar variable, e.g. "`x`" or "`fieldName`", or it can name an element of an array, e.g. "`a(42)`" or "`area(South America)`". No substitutions or modifications are performed on the name. For example, if `varName` is "`a($i)`" Tcl will not use the value of variable `i` as the element name within array `a`; it will use the string "`$i`" literally as the element name.

The second procedure of each pair has a name ending in "`2`", e.g. `Tcl_SetVar2`. In these procedures the variable name is separated into two arguments: `name1` and `name2`. If the variable is a scalar then `name1` is the name of the variable and `name2` is `NULL`. If the variable is an array element then `name1` is the name of the array and `name2` is the name of the element within the array. This form of procedure is less commonly used but it is slightly faster than the first form (procedures like `Tcl_SetVar` are implemented by calling procedures like `Tcl_SetVar2`).

```
char *Tcl_SetVar(Tcl_Interp *interp, char *varName,
    char *newValue, int flags)
char *Tcl_SetVar2(Tcl_Interp *interp, char *name1, char *name2,
    char *newValue, int flags)
```

Sets the value of the variable to `newValue`, creating the variable if it didn't already exist. Returns the new value of the variable or `NULL` in case of error.

```
char *Tcl_GetVar(Tcl_Interp *interp, char *varName,
    int flags)
char *Tcl_GetVar2(Tcl_Interp *interp, char *name1, char *name2,
    int flags)
```

Returns the current value of the variable, or `NULL` in case of error.

```
int Tcl_UnsetVar(Tcl_Interp *interp, char *varName,
    int flags)
int Tcl_UnsetVar2(Tcl_Interp *interp, char *name1, char *name2,
    int flags)
```

Removes the variable from `interp` and returns `TCL_OK`. If the variable doesn't exist or has an active trace then it can't be removed and `TCL_ERROR` is returned.

```
int Tcl_TraceVar(Tcl_Interp *interp, char *varName,
    int flags, Tcl_VarTraceProc *proc, ClientData clientData)
int Tcl_TraceVar2(Tcl_Interp *interp, char *name1, char *name2,
    int flags, Tcl_VarTraceProc *proc, ClientData clientData)
```

Arrange for `proc` to be invoked whenever one of the operations specified by `flags` is performed on the variable. Returns `TCL_OK` or `TCL_ERROR`.

```
Tcl_UntraceVar(Tcl_Interp *interp, char *varName,
    int flags, Tcl_VarTraceProc *proc, ClientData clientData)
Tcl_UntraceVar2(Tcl_Interp *interp, char *name1, char *name2,
    int flags, Tcl_VarTraceProc *proc, ClientData clientData)
```

Removes the trace on the variable that matches `proc`, `clientData`, and `flags`, if there is one.

```
ClientData Tcl_VarTraceInfo(Tcl_Interp *interp, char *varName,
    int flags, Tcl_VarTraceProc *proc, ClientData prevClientData)
ClientData Tcl_VarTraceInfo2(Tcl_Interp *interp, char *name1,
    char *name2, int flags, Tcl_VarTraceProc *proc,
    ClientData prevclientData)
```

If `prevClientData` is `NULL`, returns the ClientData associated with the first trace on the variable that matches `flags` and `proc` (only the `TCL_GLOBAL_ONLY` bit of `flags` is used); otherwise returns the `ClientData` for the next trace matching `flags` and `proc` after the one whose `ClientData` is `prevClientData`. Returns `NULL` if there are no (more) matching traces.

Table 32.1. Tcl library procedures for manipulating variables. The procedures come in pairs; in one procedure the variable is named with a single string (which may specify either a scalar or an array element) and in the other procedure the variable is named with separate array and element names (`name1` and `name2`, respectively). If `name2` is `NULL` then the variable must be a scalar.

Flag Name	Meaning
TCL_GLOBAL_ONLY	Reference global variable, regardless of current execution context.
TCL_LEAVE_ERR_MSG	If operation fails, leave error message in `interp->result`.
TCL_APPEND_VALUE	Append new value to existing value instead of overwriting.
TCL_LIST_ELEMENT	Convert new value to a list element before setting or appending.

Table 32.2. Values that may be OR'ed together in the flags arguments to `Tcl_SetVar` and `Tcl_SetVar2`. Other procedures use a subset of these flags.

32.2 Setting variable values

`Tcl_SetVar` and `Tcl_SetVar2` are used to set the value of a variable. For example,

```
Tcl_SetVar(interp, "a", "44", 0);
```

will set the value of variable `a` in `interp` to the string "`44`". If there does not yet exist a variable named `a` then a new one will be created. The variable is set in the current execution context: if a Tcl procedure is currently being executed, the variable will be a local one for that procedure; if no procedure is currently being executed then the variable will be a global variable. If the operation completed successfully then the return value from `Tcl_SetVar` is a pointer to the variable's new value as stored in the variable table (this value is static enough to be used as an interpreter's result). If an error occurred, such as specifying the name of an array without also specifying an element name, then `NULL` is returned.

The last argument to `Tcl_SetVar` or `Tcl_SetVar2` consists of an OR'ed combination of flag bits. Table 32.2 lists the symbolic values for the flags. If the `TCL_GLOBAL_ONLY` flag is specified then the operation always applies to a global variable, even if a Tcl procedure is currently being executed. `TCL_LEAVE_ERR_MSG` controls how errors are reported. Normally, `Tcl_SetVar` and `Tcl_SetVar2` just return `NULL` if an error occurs. However, if `TCL_LEAVE_ERR_MSG` has been specified then the procedures will also store an error message in the interpreter's result. This last form is useful when the procedure is invoked from a command procedure that plans to abort if the variable access fails.

The flag `TCL_APPEND_VALUE` means that the new value should be appended to the variable's current value instead of replacing it. Tcl implements the append operation in a way that is relatively efficient, even in the face of repeated appends to the same variable. If the variable doesn't yet exist then `TCL_APPEND_VALUE` has no effect.

The last flag, `TCL_LIST_ELEMENT`, means that the new value should be converted to a proper list element (e.g. by enclosing in braces if necessary) before setting or appending. If both `TCL_LIST_ELEMENT` and `TCL_APPEND_VALUE` are specified then a separator space is also added before the new element if it's needed.

Here is an implementation of the `lappend` command that uses `Tcl_SetVar`:

```
int LappendCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    int i;
    char *newValue;
    if (argc < 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    for (i = 2; i < argc; i++) {
        newValue = Tcl_SetVar(interp, argv[1], argv[i],
                TCL_LIST_ELEMENT|TCL_APPEND_VALUE
                |TCL_LEAVE_ERR_MSG);
        if (newValue == NULL) {
            return TCL_ERROR;
        }
    }
    interp->result = newValue;
    return TCL_OK;
}
```

It simply calls `Tcl_SetVar` once for each argument and lets `Tcl_SetVar` do all the work of converting the argument to a list value and appending it to the variable. If an error occurs then `Tcl_SetVar` leaves an error message in `interp->result` and `LappendCmd` returns the message back to Tcl. If the command completes successfully then it returns the variable's final value as its result. For example, suppose the following Tcl command is invoked:

```
set a 44
lappend a x {b c}
44 x {b c}
```

When `LappendCmd` is invoked `argc` will be 4. `Argv[2]` will be "`x`" and `argv[3]` will be "`b c`" (the braces are removed by the Tcl parser). `LappendCmd` makes two calls to `Tcl_SetVar`; during the first call no conversion is necessary to produce a proper list element, but during the second call `Tcl_SetVar` adds braces back around "`b c`" before appending it the variable.

32.3 Reading variables

The procedures `Tcl_GetVar` and `Tcl_GetVar2` may be used to retrieve variable values. For example,

```
char *value;
...
value = Tcl_GetVar(interp, "a", 0);
```

will store in `value` a pointer to the current value of variable `a`. If the variable doesn't exist or some other error occurs then `NULL` is returned. `Tcl_GetVar` and `Tcl_GetVar2` support the `TCL_GLOBAL_ONLY` and `TCL_LEAVE_ERR_MSG` flags in the same way as `Tcl_SetVar`. The following command procedure uses `Tcl_GetVar` and `Tcl_SetVar` to implement the `incr` command:

```
int IncrCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    int value, inc;
    char *string;
    if ((argc != 2) && (argc != 3)) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (argc == 2) {
        inc = 1;
    } else if (Tcl_GetInt(interp, argv[2], &inc)
            != TCL_OK) {
        return TCL_ERROR;
    }
    string = Tcl_GetVar(interp, argv[1],
            TCL_LEAVE_ERR_MSG);
    if (string == NULL) {
        return TCL_ERROR;
    }
    if (Tcl_GetInt(interp, string, &value) != TCL_OK) {
        return TCL_ERROR;
    }
    sprintf(interp->result, "%d", value + inc);
    if (Tcl_SetVar(interp, argv[1], interp->result,
            TCL_LEAVE_ERR_MSG) == NULL) {
        return TCL_ERROR;
    }
    return TCL_OK;
}
```

`IncrCmd` does very little work itself. It just calls library procedures and aborts if errors occur. The first call to `Tcl_GetInt` converts the increment from text to binary.

Tcl_GetVar retrieves the original value of the variable, and another call to Tcl_GetInt converts that value to binary. IncrCmd then adds the increment to the variable's value and calls sprintf to convert the result back to text. Tcl_SetVar stores this value in the variable, and IncrCmd then returns the new value as its result.

32.4 Unsetting variables

To remove a variable, call Tcl_UnsetVar or Tcl_UnsetVar2. For example,

```
Tcl_UnsetVar2(interp, "population", "Michigan", 0);
```

will remove the element Michigan from the array population. This statement has the same effect as the Tcl command

```
unset population(Michigan)
```

Tcl_UnsetVar and Tcl_UnsetVar2 return TCL_OK if the variable was successfully removed and TCL_ERROR if the variable didn't exist or couldn't be removed for some other reason. TCL_GLOBAL_ONLY and TCL_LEAVE_ERR_MSG may be specified as flags to these procedures. If an array name is given without an element name then the entire array is removed.

32.5 Setting and unsetting variable traces

Variable traces allow you to specify a C procedure to be invoked whenever a variable is read, written, or unset. Traces can be used for many purposes. For example, in Tk you can configure a button widget so that it displays the value of a variable and updates itself automatically when the variable is modified. This feature is implemented with variable traces. You can also use traces for debugging, to create read-only variables, and for many other purposes.

The procedures Tcl_TraceVar and Tcl_TraceVar2 create variable traces, as in the following example:

```
Tcl_TraceVar(interp, "x", TCL_TRACE_WRITES, WriteProc,
        (ClientData) NULL);
```

This creates a write trace on variable x in interp: WriteProc will be invoked whenever x is modified. The third argument to Tcl_TraceVar is an OR'ed combination of flag bits that select the operations to trace: TCL_TRACE_READS for reads, TCL_TRACE_WRITES for writes, and TCL_TRACE_UNSETS for unsets. In addition, the flag TCL_GLOBAL_ONLY may be specified to force the variable name to be interpreted as global. Tcl_TraceVar and Tcl_TraceVar2 normally return TCL_OK; if an error occurs then they leave an error message in interp->result and return TCL_ERROR.

The library procedures `Tcl_UntraceVar` and `Tcl_UntraceVar2` remove variable traces. For example, the following call will remove the trace set above:

```
Tcl_UntraceVar(interp, "x", TCL_TRACE_WRITES,
        WriteProc, (ClientData) NULL);
```

`Tcl_UntraceVar` finds the specified variable, looks for a trace that matches the flags, trace procedure, and ClientData specified by its arguments, and removes the trace if it exists. If no matching trace exists then `Tcl_UntraceVar` does nothing. `Tcl_UntraceVar` and `Tcl_UntraceVar2` accept the same flag bits as `Tcl_TraceVar`.

32.6 Trace callbacks

Trace callback procedures such as `WriteProc` in the previous section must match the following prototype:

```
typedef char *Tcl_VarTraceProc(ClientData clientData,
        Tcl_Interp *interp, char *name1, char *name2,
        int flags);
```

The `clientData` and `interp` arguments will be the same as the corresponding arguments passed to `Tcl_TraceVar` or `Tcl_TraceVar2`. `ClientData` typically points to a structure containing information needed by the trace callback. `Name1` and `name2` give the name of the variable in the same form as the arguments to `Tcl_SetVar2`. `Flags` consists of an OR'ed combination of bits. One of `TCL_TRACE_READS`, `TCL_TRACE_WRITES`, or `TCL_TRACE_UNSETS` is set to indicate which operation triggered the trace, and `TCL_GLOBAL_ONLY` is set if the variable is a global variable that isn't accessible from the current execution context; the trace callback must pass this flag back into procedures like `Tcl_GetVar2` if it wishes to access the variable. The bits `TCL_TRACE_DESTROYED` and `TCL_INTERP_DESTROYED` are set in special circumstances described below.

For read traces, the callback is invoked just before `Tcl_GetVar` or `Tcl_GetVar2` returns the variable's value to whomever requested it; if the callback modifies the value of the variable then the modified value will be returned. For write traces the callback is invoked after the variable's value has been changed. The callback can modify the variable to override the change, and this modified value will be returned as the result of `Tcl_SetVar` or `Tcl_SetVar2`. For unset traces the callback is invoked after the variable has been unset, so the callback cannot access the variable. Unset callbacks can occur when a variable is explicitly unset, when a procedure returns (thereby deleting all of its local variables) or when an interpreter is destroyed (thereby deleting all of the variables in the interpreter).

A trace callback procedure can invoke `Tcl_GetVar2` and `Tcl_SetVar2` to read and write the value of the traced variable. All traces on the variable are temporarily disabled while the callback executes so calls to `Tcl_GetVar2` and `Tcl_SetVar2` will not trigger additional trace callbacks. As mentioned above, unset traces aren't invoked until after the variable has been deleted, so attempts to read the variable during unset callbacks will fail. However, it is possible for an unset callback procedure to write the variable, in which case a new variable will be created.

The code below sets a write trace that prints out the new value of variable `x` each time it is modified:

```
Tcl_TraceVar(interp, "x", TCL_TRACE_WRITES, Print,
        (ClientData) NULL);
...
char *Print(ClientData clientData,
        Tcl_Interp *interp, char *name1, char *name2,
        int flags) {
    char *value;
    value = Tcl_GetVar2(interp, name1, name2,
            flags & TCL_GLOBAL_ONLY);
    if (value != NULL) {
        printf("new value is %s\n", value);
    }
    return NULL;
}
```

`PrintProc` must pass the `TCL_GLOBAL_ONLY` bit of its `flags` argument on to `Tcl_GetVar2` in order to make sure that the variable can be accessed properly. `Tcl_GetVar2` should never return an error, but `PrintProc` checks for one anyway and doesn't try to print the variable's value if an error occurs.

Trace callbacks normally return `NULL` values; a non-`NULL` value signals an error. In this case the return value must be a pointer to a static string containing an error message. The traced access will abort and the error message will be returned to whomever initiated that access. For example, if the access was invoked by a `set` command or `$`-substitution then a Tcl error will result; if the access was invoked via `Tcl_GetVar`, `Tcl_GetVar` will return `NULL` and also leave the error message in `interp->result` if the `TCL_LEAVE_ERR_MSG` flag was specified.

The code below uses a trace to make variable `x` read-only with value `192`:

```
Tcl_TraceVar(interp, "x", TCL_TRACE_WRITES, Reject,
        (ClientData) "192");
char *Reject(ClientData clientData, Tcl_Interp *interp,
        char *name1, char *name2, int flags) {
    char *correct = (char *) ClientData;
    Tcl_SetVar2(interp, name1, name2, correct,
                flags & TCL_GLOBAL_ONLY);
    return "variable is read-only";
};
```

`Reject` is a trace callback that's invoked whenever `x` is written. It returns an error message to abort the write access. Since `x` has already been modified before `Reject` is invoked, Reject must undo the write by restoring the variable's correct value. The correct value is passed to the trace callback using its clientData argument. This implementation allows the same procedure to be used as the write callback for many different read-only variables; a different correct value can be passed to Reject for each variable.

32.7 Whole-array traces

You can create a trace on an entire array by specifying an array name to Tcl_TraceVar or Tcl_TraceVar2 without an element name. This creates a whole-array trace: the callback procedure will be invoked whenever any of the specified operations is invoked on any element of the array. If the entire array is unset then the callback will be invoked just once, with name1 containing the array name and name2 NULL.

32.8 Multiple traces

Multiple traces can exist for the same variable. When this happens, each of the relevant callbacks is invoked on each variable access. The callbacks are invoked in order from most-recently-created to oldest. If there are both whole-array traces and individual element traces, then the whole-array callbacks are invoked before element callbacks. If an error is returned by one of the callbacks then no subsequent callbacks are invoked.

32.9 Unset callbacks

Unset callbacks are different from read and write callbacks in several ways. First of all, unset callbacks cannot return an error condition; they must always succeed. Second, two extra flags are defined for unset callbacks: TCL_TRACE_DELETED and TCL_INTERP_DESTROYED. When a variable is unset all of its traces are deleted; unset traces on the variable will still be invoked, but they will be passed the TCL_TRACE_DELETED flag to indicate that the trace has now been deleted and won't be invoked anymore. If an array element is unset and there is a whole-array unset trace for the element's array, then the unset trace is not deleted and the callback will be invoked without the TCL_TRACE_DELETED flag set.

If the TCL_INTERP_DESTROYED flag is set during an unset callback it means that the interpreter containing the variable has been destroyed. In this case the callback must be careful not to use the interpreter at all, since the interpreter's state is in the process of being deleted. All that the callback should do is to clean up its own internal data structures.

32.10 Non-existent variables

It is legal to set a trace on a variable that does not yet exist. The variable will continue to appear not to exist (e.g. attempts to read it will fail), but the trace's callback will be invoked during operations on the variable. For example, you can set a read trace on an undefined variable and then, on the first access to the variable, assign it a default value.

32.11 Querying trace information

The procedures `Tcl_VarTraceInfo` and `Tcl_VarTraceInfo2` can be used to find out if a particular kind of trace has been set on a variable and if so to retrieve its Client-Data value. For example, consider the following code:

```
ClientData clientData;
...
clientData = Tcl_VarTraceInfo(interp, "x", 0, Reject,
        (ClientData) NULL);
```

`Tcl_VarTraceInfo` will see if there is a trace on variable `x` that has `Reject` as its trace callback. If so, it will return the ClientData value associated with the first (most recently created) such trace; if not it will return `NULL`. Given the code in Section 32.6 above, this call will tell whether `x` is read-only; if so, it will return the variable's read-only value. If there are multiple traces on a variable with the same callback, you can step through them all in order by making multiple calls to `Tcl_VarTraceInfo`, as in the following code:

```
ClientData clientData;
...
clientData = NULL;
while (1) {
    clientData = Tcl_VarTraceInfo(interp, "x", 0,
            Reject, clientData);
    if (clientData == NULL) {
        break;
    }
    ... process trace ...
}
```

In each call to `Tcl_VarTraceInfo` after the first, the previous ClientData value is passed in as the last argument. `Tcl_VarTraceInfo` finds the trace with this value, then returns the ClientData for the next trace. When it reaches the last trace it returns `NULL`.

Chapter 33
Hash Tables

A *hash table* is a collection of *entries*, where each entry consists of a *key* and a *value*. No two entries have the same key. Given a key, a hash table can very quickly locate its entry and hence the associated value. Tcl contains a general-purpose hash table package that it uses in several places internally. For example, all of the commands in an interpreter are stored in a hash table where the key for each entry is a command name and the value is a pointer to information about the command. All of the global variables are stored in another hash table where the key for each entry is the name of a variable and the value is a pointer to information about the variable.

Tcl exports its hash table facilities through a set of library procedures so that applications can use them too (see Table 33.1 for a summary). The most common use for hash tables is to associate names with objects. In order for an application to implement a new kind of object it must give the objects textual names for use in Tcl commands. When a command procedure receives an object name as an argument it must locate the C data structure for the object. Typically there will be one hash table for each type of object, where the key for an entry is an object name and the value is a pointer to the C data structure that represents the object. When a command procedure needs to find an object it looks up its name in the hash table. If there is no entry for the name then the command procedure returns an error.

For the examples in this chapter I'll use a hypothetical application that implements objects called "gizmos". Each gizmo is represented internally with a structure declared like this:

```
typedef struct Gizmo {
    ... fields of gizmo object ...
} Gizmo;
```

`Tcl_InitHashTable(Tcl_HashTable *tablePtr, int keyType)`	Creates a new hash table and stores information about the table at `*tablePtr`. `KeyType` is either `TCL_STRING_KEYS`, `TCL_ONE_WORD_KEYS`, or an integer greater than 1.
`Tcl_DeleteHashTable(Tcl_HashTable *tablePtr)`	Deletes all the entries in the hash table and frees up related storage.
`Tcl_HashEntry *Tcl_CreateHashEntry(Tcl_HashTable *tablePtr, char *key, int *newPtr)`	Returns a pointer to the entry in `tablePtr` whose key is `key`, creating a new entry if needed. `*NewPtr` is set to 1 if a new entry was created or 0 if the entry already existed.
`Tcl_HashEntry *Tcl_FindHashEntry(Tcl_HashTable *tablePtr, char *key)`	Returns a pointer to the entry in `tablePtr` whose key is `key`, or `NULL` if no such entry exists.
`Tcl_DeleteHashEntry(Tcl_HashEntry *entryPtr)`	Deletes an entry from its hash table.
`ClientData Tcl_GetHashValue(Tcl_HashEntry *entryPtr)`	Returns the value associated with a hash table entry.
`Tcl_SetHashValue(Tcl_HashEntry *entryPtr, ClientData value)`	Sets the value associated with a hash table entry.
`char *Tcl_GetHashKey(Tcl_HashEntry *entryPtr)`	Returns the key associated with a hash table entry.
`Tcl_HashEntry *Tcl_FirstHashEntry(Tcl_HashTable *tablePtr, Tcl_HashSearch *searchPtr)`	Starts a search through all the elements of a hash table. Stores information about the search at `*searchPtr` and returns the hash table's first entry or `NULL` if it has no entries.
`Tcl_HashEntry *Tcl_NextHashEntry(Tcl_HashSearch *searchPtr)`	Returns the next entry in the search identified by `searchPtr` or `NULL` if all entries in the table have been returned.
`char *Tcl_HashStats(Tcl_HashTable *tablePtr)`	Returns a string giving usage statistics for `tablePtr`. The string is dynamically allocated and must be freed by the caller.

The application uses names like "`gizmo42`" to refer to gizmos in Tcl commands, where each gizmo has a different number at the end of its name. The application follows the action-oriented approach described in Section 27.3 by providing a collection of Tcl commands to manipulate the objects, such as `gcreate` to create a new gizmo, `gdelete` to delete an existing gizmo, `gsearch` to find gizmos with certain characteristics, and so on.

33.1 Keys and values

Tcl hash tables support three different kinds of keys. All of the entries in a single hash table must use the same kind of key, but different tables may use different kinds. The most common form of key is a string. In this case each key is a `NULL`-terminated string of arbitrary length, such as "`gizmo18`" or "`Waste not want not`". Different entries in a table may have keys of different length. The gizmo implementation uses strings as keys.

The second form of key is a one-word value. In this case each key may be any value that fits in a single word, such as an integer. One-word keys are passed into Tcl using values of type "`char *`" so the keys are limited to the size of a character pointer.

The last form of key is an array. In this case each key is an array of integers (C `int` type). All keys in the table must be the same size.

The values for hash table entries are items of type `ClientData`, which are large enough to hold either an integer or a pointer. In most applications, such as the gizmo example, hash table values are pointers to records for objects. These pointers are cast into `ClientData` items when storing them in hash table entries, and they are cast back from `ClientData` to object pointers when retrieved from the hash table.

33.2 Creating and deleting hash tables

Each hash table is represented by a C structure of type `Tcl_HashTable`. Space for this structure is allocated by the client, not by Tcl; typically these structures are global variables or elements of other structures. When calling hash table procedures you pass in a pointer to a `Tcl_HashTable` structure as a token for the hash table. You should never use or modify any of the fields of a `Tcl_HashTable` directly. Use the Tcl library procedures and macros for this.

Here is how a hash table might be created for the gizmo application:

```
Tcl_HashTable gizmoTable;
...
Tcl_InitHashTable(&gizmoTable, TCL_STRING_KEYS);
```

The first argument to `Tcl_InitHashTable` is a `Tcl_HashTable` pointer and the second argument is an integer that specifies the sort of keys that will be used for the table. `TCL_STRING_KEYS` means that strings will be used in the table; `TCL_ONE_WORD_VALUES` specifies one-word keys; and an integer value greater than one means that keys are arrays with the given number of int's in each array. `Tcl_InitHashTable` ignores the current contents of the table it is passed and re-initializes the structure to refer to an empty hash table with keys as specified.

`Tcl_DeleteHashTable` removes all the entries from a hash table and frees up any memory that was allocated for the table (except space for the `Tcl_HashTable` structure itself, which is the property of the client). For example, the following statement could be used to delete the hash table initialized above:

```
Tcl_DeleteHashTable(&gizmoTable);
```

33.3 Creating entries

The procedure `Tcl_CreateHashEntry` creates an entry with a given key and `Tcl_SetHashValue` sets the value associated with the entry. For example, the code below might be used to implement the `gcreate` command, which makes a new gizmo object:

```
int GcreateCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    static int id = 1;
    int new;
    Tcl_HashEntry *entryPtr;
    Gizmo *gizmoPtr;
    ... check argc, etc ...
    do {
        sprintf(interp->result, "gizmo%d", id);
        id++;
        entryPtr = Tcl_CreateHashEntry(&gizmoTable,
                interp->result, &new);
    } while (!new);
    gizmoPtr = (Gizmo *) malloc(sizeof(Gizmo));
    Tcl_SetHashValue(entryPtr, gizmoPtr);
    ... initialize *gizmoPtr, etc ...
    return TCL_OK;
}
```

This code creates a name for the object by concatenating “`gizmo`” with the value of the static variable `id`. It stores the name in `interp->result` so that the command’s result will be the name of the new object. `GcreateCmd` then increments `id` so that each new object will have a unique name. `Tcl_CreateHashEntry` is called to create a new entry with a key equal to the object’s name; it returns a token for the entry. Under normal conditions there will not already exist an entry with the given key, in which case `Tcl_CreateHashEntry` sets `new` to 1 to indicate that it created a new entry. However, it is possible for `Tcl_CreateHashEntry` to be called with a key that already exists in the table. In `GcreateCmd` this can only happen if a very large number of objects are created, so that `id` wraps around to zero again. If this happens then `Tcl_CreateHashEntry` sets new to 0; `GcreateCmd` will try again with the next larger `id` until it eventually finds a name that isn’t already in use.

After creating the hash table entry `GcreateCmd` allocates memory for the object's record and invokes `Tcl_SetHashValue` to store the record address as the value of the hash table entry. `Tcl_SetHashValue` is actually a macro, not a procedure; its first argument is a token for a hash table entry and its second argument, the new value for the entry, can be anything that fits in the space of a `ClientData` value. After setting the value of the hash table entry `GcreateCmd` initializes the new object's record.

Note: *Tcl's hash tables restructure themselves as you add entries. A table won't use much memory for the hash buckets when it has only a small number of entries, but it will increase the size of the bucket array as the number of entries increases. Tcl's hash tables should operate efficiently even with very large numbers of entries.*

33.4 Finding existing entries

The procedure `Tcl_FindHashEntry` locates an existing entry in a hash table. It is similar to `Tcl_CreateHashEntry` except that it won't create a new entry if the key doesn't already exist in the hash table. `Tcl_FindHashEntry` is typically used to find an object given its name. For example, the gizmo implementation might contain a utility procedure called `GetGizmo`, which is something like `Tcl_GetInt` except that it translates its string argument to a `Gizmo` pointer instead of an integer:

```
Gizmo *GetGizmo(Tcl_Interp *interp, char *string) {
    Tcl_HashEntry *entryPtr;
    entryPtr = Tcl_FindHashEntry(&gizmoTable, string);
    if (entryPtr == NULL) {
        Tcl_AppendResult(interp, "no gizmo named \"",
                string, "\", (char *) NULL);
        return TCL_ERROR;
    }
    return (Gizmo *) Tcl_GetHashValue(entryPtr);
}
```

`GetGizmo` looks up a gizmo name in the gizmo hash table. If the name exists then `GetGizmo` extracts the value from the entry using the macro `Tcl_GetHashValue`, converts it to a `Gizmo` pointer, and returns it. If the name doesn't exist then `GetGizmo` stores an error message in `interp->result` and returns `NULL`.

`GetGizmo` can be invoked from any command procedure that needs to look up a gizmo object. For example, suppose there is a command `gtwist` that performs a "twist" operation on gizmos, and that it takes a gizmo name as its first argument. The command might be implemented like this:

```
int GtwistCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    Gizmo *gizmoPtr;
    ... check argc, etc ...
    gizmoPtr = GetGizmo(interp, argv[1]);
    if (gizmoPtr == NULL) {
        return TCL_ERROR;
    }
    ... perform twist operation ...
}
```

33.5 Searching

Tcl provides two procedures that you can use to search through all of the entries in a hash table. `Tcl_FirstHashEntry` starts a search and returns the first entry, and `Tcl_NextHashEntry` returns successive entries until the search is complete. For example, suppose that there is a `gsearch` command that searches through all existing gizmos and returns a list of the names of the gizmos that meet a certain set of criteria. This command might be implemented as follows:

```
int GsearchCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    Tcl_HashEntry *entryPtr;
    Tcl_HashSearch search;
    Gizmo *gizmoPtr;
    ... process arguments to choose search criteria ...
    for (entryPtr = Tcl_FirstHashEntry(&gizmoTable,
            &search); entryPtr != NULL;
            entryPtr = Tcl_NextHashEntry(&search)) {
        gizmoPtr = (Gizmo *) Tcl_GetHashValue(entryPtr);
        if (...object satisfies search criteria...) {
            Tcl_AppendElement(interp,
                    Tcl_GetHashKey(entryPtr));
        }
    }
    return TCL_OK;
}
```

A structure of type `Tcl_HashSearch` is used to keep track of the search. `Tcl_FirstHashEntry` initializes this structure and `Tcl_NextHashEntry` uses the information in the structure to step through successive entries in the table. It's possible to have multiple searches underway simultaneously on the same hash table by using a different `Tcl_HashSearch` structure for each search. `Tcl_FirstHashEntry` returns a token for the first entry in the table (or `NULL` if the table is empty) and `Tcl_NextHashEntry` returns pointers to successive entries, eventually returning `NULL` when the end of the table is reached. For each entry `GsearchCmd` extracts the value from the entry, converts it to a `Gizmo` pointer, and sees if that object meets the criteria specified in the command's arguments. If so, then `GsearchCmd` uses the `Tcl_GetHashKey` macro to get the name of the object (i.e. the entry's key) and invokes `Tcl_AppendElement` to append the name to the interpreter's result as a list element.

Note: It is not safe to modify the structure of a hash table during a search. If you create or delete entries then you should terminate any searches in progress.

33.6 Deleting entries

The procedure `Tcl_DeleteHashEntry` will delete an entry from a hash table. For example, the following procedure uses `Tcl_DeleteHashEntry` to implement a `gdelete` command, which takes any number of arguments and deletes the gizmo objects they name:

```
int GdeleteCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    Tcl_HashEntry *entryPtr;
    Gizmo *gizmoPtr;
    int i;
    for (i = 1; i < argc; i++) {
        entryPtr = Tcl_FindHashEntry(&gizmoTable,
                argv[i]);
        if (entryPtr == NULL) {
            continue;
        }
        gizmoPtr = (Gizmo *) Tcl_HashGetValue(entryPtr);
        Tcl_DeleteHashEntry(entryPtr);
        ... clean up *gizmoPtr ...
        free((char *) gizmoPtr);
    }
    return TCL_OK;
}
```

`GdeleteCmd` checks each of its arguments to see if it is the name of a gizmo object. If not, then the argument is ignored. Otherwise `GdeleteCmd` extracts a gizmo pointer from the hash table entry and then calls `Tcl_DeleteHashEntry` to remove the entry from the hash table. Then it performs internal cleanup on the gizmo object if needed and frees the object's record.

33.7 Statistics

The procedure `Tcl_HashStats` returns a string containing various statistics about the structure of a hash table. For example, it might be used to implement a `gstat` command for gizmos:

```
int GstatCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    if (argc != 1) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    interp->result = Tcl_HashStats(&gizmoTable);
    interp->freeProc = free;
    return TCL_OK;
}
```

The string returned by `Tcl_HashStats` is dynamically allocated and must be passed to free; `GstatCmd` uses this string as the command's result, and then sets `interp->freeProc` so that Tcl will free the string.

The string returned by `Tcl_HashStats` contains information like the following:

```
1416 entries in table, 1024 buckets
number of buckets with 0 entries: 60
number of buckets with 1 entries: 591
number of buckets with 2 entries: 302
number of buckets with 3 entries: 67
number of buckets with 4 entries: 5
number of buckets with 5 entries: 0
number of buckets with 6 entries: 0
number of buckets with 7 entries: 0
number of buckets with 8 entries: 0
number of buckets with 9 entries: 0
number of buckets with more than 10 entries: 0
average search distance for entry: 1.4
```

You can use this information to see how efficiently the entries are stored in the hash table. For example, the last line indicates the average number of entries that Tcl will have to check during hash table lookups, assuming that all entries are accessed with equal probability.

Chapter 34
String Utilities

This chapter describes Tcl's library procedures for manipulating strings, including a dynamic string mechanism that allows you to build up arbitrarily long strings, a procedure for testing whether a command is complete, and a procedure for doing simple string matching. Table 34.1 summarizes these procedures.

Note: *None of the dynamic string facilities are available in versions of Tcl earlier than 7.0.*

34.1 Dynamic strings

A *dynamic string* is a string that can be appended to without bound. As you append information to a dynamic string, Tcl automatically grows the memory area allocated for it. If the string is short then Tcl avoids dynamic memory allocation altogether by using a small static buffer to hold the string. Tcl provides five procedures for manipulating dynamic strings:

`Tcl_DStringInit` creates a new empty string;

`Tcl_DStringAppend` adds characters to a dynamic string;

`Tcl_DStringAppendElement` adds a new list element to a dynamic string;

`Tcl_DStringFree` releases any storage allocated for a dynamic string and reinitializes the string;

and `Tcl_DStringResult` moves the value of a dynamic string to the result string for an interpreter and reinitializes the dynamic string.

`Tcl_DStringInit(Tcl_DString *dsPtr)`
: Initializes `*dsPtr` to an empty string (previous contents of `*dsPtr` are discarded without cleanup).

`char *Tcl_DStringAppend(Tcl_DString *dsPtr, char *string, int length)`
: Appends `length` bytes from `string` to `dsPtr`'s value and returns new value of `dsPtr`. If `length` is less than zero, appends all of `string` up to terminating `NULL` character.

`char *Tcl_DStringAppendElement(Tcl_DString *dsPtr, char *string)`
: Converts `string` to proper list element and appends to `dsPtr`'s value (with separator space if needed). Returns new value of `dsPtr`.

`Tcl_DStringFree(Tcl_DString *dsPtr)`
: Frees up any memory allocated for `dsPtr` and reinitializes `*dsPtr` to an empty string.

`Tcl_DStringResult(Tcl_Interp *interp, Tcl_DString *dsPtr)`
: Moves the value of `dsPtr` to `interp->result` and reinitializes `dsPtr`'s value to an empty string.

`int Tcl_CommandComplete(char *cmd)`
: Returns `1` if `cmd` holds one or more complete commands, `0` if the last command in `cmd` is incomplete due to open braces etc.

`int Tcl_StringMatch(char *string, char *pattern)`
: Returns `1` if `string` matches `pattern` using glob-style rules for pattern matching, `0` otherwise.

The code below uses all of these procedures to implement a `map` command, which takes a list and generates a new list by applying some operation to each element of the original list. `Map` takes two arguments: a list and a Tcl command. For each element in the list, it executes the given command with the list element appended as an additional argument. It takes the results of all the commands and generates a new list out of them, and then returns this list as its result. Here are some exmples of how you might use the `map` command:

```
proc inc x {expr $x+1}
map {4 18 16 19 -7} inc
5 19 17 20 -6
proc addz x {return "$x z"}
map {a b {a b c}} addz
{a z} {b z} {a b c z}
```

Here is the command procedure that implements `map`:

```
int MapCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
```

```
        Tcl_DString command, newList;
        int listArgc, i, result;
        char **listArgv;
        if (argc != 3) {
            interp->result = "wrong # args";
            return TCL_ERROR;
        }
        if (Tcl_SplitList(interp, argv[1], &listArgc,
                &listArgv) != TCL_OK) {
            return TCL_ERROR;
        }
        Tcl_DStringInit(&newList);
        Tcl_DStringInit(&command);
        for (i = 0; i < listArgc; i++) {
            Tcl_DStringAppend(&command, argv[2], -1);
            Tcl_DStringAppendElement(&command,
                    listArgv[i]);
            result = Tcl_Eval(interp, command.string);
            Tcl_DStringFree(&command);
            if (result != TCL_OK) {
                Tcl_DStringFree(&newList);
                free((char *) listArgv);
                return result;
            }
            Tcl_DStringAppendElement(&newList,
                    interp->result);
        }
        Tcl_DStringResult(interp, &newList);
        free((char *) listArgv);
        return TCL_OK;
    }
```

`MapCmd` uses two dynamic strings. One holds the result list and the other holds the command to execute in each step. The first dynamic string is needed because the length of the command is unpredictable, and the second one is needed to store the result list as it builds up (this information can't be placed immediately in `interp->result` because the interpreter's result will be overwritten by the command that's evaluated to process the next list element). Each dynamic string is represented by a structure of type `Tcl_DString`. The structure holds information about the string such as a pointer to its current value, a small array to use for small strings, and a length. The only field that you should ever access is the `string` field, which is a pointer to the current value. Tcl doesn't allocate `Tcl_DString` structures; it's up to you to allocate the structure (e.g. as a local variable) and pass its address to the dynamic string library procedures.

After checking its argument count, extracting all of the elements from the initial list, and initializing its dynamic strings, `MapCmd` enters a loop to process the elements of the list. For each element it first creates the command to execute for that element. It does this by calling `Tcl_DStringAppend` to append the part of the command provided in `argv[2]`, then it calls `Tcl_DStringAppendElement` to append the list element as an additional argument. These procedures are similar in that both add new information to the dynamic string. However, `Tcl_DStringAppend` adds the information as raw text whereas `Tcl_DStringAppendElement` converts its string argument to a proper list element and adds that list element to the dynamic string (with a separator space, if needed). It's important to use `Tcl_DStringAppendElement` for the list element so that it becomes a single word of the Tcl command being formed. If `Tcl_DStringAppend` were used instead and the element were "`a b c`" as in the example on page 310, then the command passed to `Tcl_Eval` would be "`addz a b c`" , which would result in an error (too many arguments to the `addz` procedure). When `Tcl_DStringAppendElement` is used the command is "`addz {a b c}`", which parses correctly.

Once `MapCmd` has created the command to execute for an element, it invokes `Tcl_Eval` to evaluate the command. The `Tcl_DStringFree` call frees up any memory that was allocated for the command string and resets the dynamic string to an empty value for use in the next command. If the command returned an error then `MapCmd` returns that same error; otherwise it uses `Tcl_DStringAppendElement` to add the result of the command to the result list as a new list element.

`MapCmd` calls `Tcl_DStringResult` after all of the list elements have been processed. This transfers the value of the string to the interpreter's result in an efficient way (e.g. if the dynamic string uses dynamically allocated memory then `Tcl_DStringResult` just copies a pointer to the result to `interp->result` rather than allocating new memory and copying the string).

Before returning, `MapCmd` must be sure to free up any memory allocated for the dynamic strings. It turns out that this has already been done by `Tcl_DStringFree` for `command` and by `Tcl_DStringResult` for `newList`.

34.2 Command completeness

When an application is reading commands typed interactively, it's important to wait until a complete command has been entered before evaluating it. For example, suppose an application is reading commands from standard input and the user types the following three lines:

```
foreach i {1 2 3 4 5} {
    puts "$i*$i is [expr $i*$i]"
}
```

If the application reads each line separately and passes it to `Tcl_Eval`, a "`missing close-brace`" error will be generated by the first line. Instead, the application should collect input until all the commands read are complete (e.g. there are no unmatched braces or quotes) then execute all of the input as a single script. The procedure `Tcl_CommandComplete` makes this possible. It takes a string as argument and returns 1 if the string contains syntactically complete commands, 0 if the last command isn't yet complete.

The C procedure below uses dynamic strings and `Tcl_CommandComplete` to read and evaluate a command typed on standard input. It collects input until all the commands read are complete, then it evaluates the command(s) and returns the completion code from the evaluation. It uses `Tcl_RecordAndEval` to evaluate the command so that the command is recorded on the history list.

```
int DoOneCmd(Tcl_Interp *interp) {
    char line[200];
    Tcl_DString cmd;
    int result;
    Tcl_DStringInit(&cmd);
    while (1) {
        if (fgets(line, 200, stdin) == NULL) {
            break;
        }
        Tcl_DStringAppend(&cmd, line, -1);
        if (Tcl_CommandComplete(cmd.string)) {
            break;
        }
    }
    result = Tcl_RecordAndEval(interp, cmd.string, 0);
    Tcl_DStringFree(&cmd);
    return result;
}
```

In the example of the previous page `DoOneCmd` will collect all three lines before evaluating them. If an end-of-file occurs `fgets` will return `NULL` and `DoOneCmd` will evaluate the command even if it isn't complete yet.

34.3 String matching

The procedure `Tcl_StringMatch` provides the same functionality as the "`string match`" Tcl command. Given a string and a pattern, it returns `1` if the string matches the pattern using glob-style matching and `0` otherwise. For example, here is a command procedure that uses `Tcl_StringMatch` to implement `lsearch`. It returns the index of the first element in a list that matches a pattern, or `-1` if no element matches:

```
int LsearchCmd(ClientData clientData,
        Tcl_Interp *interp, int argc, char *argv[]) {
    int listArgc, i, result;
    char **listArgv;
    if (argc != 3) {
        interp->result = "wrong # args";
        return TCL_ERROR;
    }
    if (Tcl_SplitList(interp, argv[1], &listArgc,
            &listArgv) != TCL_OK) {
        return TCL_ERROR;
    }
    result = -1;
    for (i = 0; i < listArgc; i++) {
        if (Tcl_StringMatch(listArgv[i], argv[2])) {
            result = i;
            break;
        }
    }
    sprintf(interp->result, "%d", result);
    free((char *) listArgv);
    return TCL_OK;
}
```

Chapter 35
POSIX Utilities

This chapter describes several utilities that you may find useful if you use POSIX system calls in your C code. The procedures can be used to expand "~" notation in file names, to generate messages for POSIX errors and signals, and to manage sub-processes. See Table 35.1 for a summary of the procedure.

35.1 Tilde expansion

Tcl and Tk allow you to use ~ notation when specifying file names, and if you write new commands that manipulate files then you should support tildes also. For example, the command

```
open ~ouster/.login
```

opens the file named `.login` in the home directory of user `ouster`, and

```
open ~/.login
```

opens a file named `.login` in the home directory of the current user (as given by the `HOME` environment variable). Unfortunately, tildes are not supported by the POSIX system calls that actually open files. For example, in the first `open` command above the name actually presented to the `open` system call must be something like

```
/users/ouster/.login
```

where `~ouster` has been replaced by the home directory for `ouster`. `Tcl_TildeSubst` is the procedure that carries out this substitution. It is used internally by Tcl and Tk

```
char *Tcl_TildeSubst(Tcl_Interp *interp, char *name,
    Tcl_DString *resultPtr)
```
If `name` starts with `~`, returns a new name with the `~` and following characters replaced with the corresponding home directory name. If `name` doesn't start with `~`, returns `name`. Uses `*resultPtr` if needed to hold new name (caller need not initialize `*resultPtr`, but must free it by calling `Tcl_DStringFree`). If an error occurs, returns `NULL` and leaves an error message in `interp->result`.

```
char *Tcl_PosixError(Tcl_Interp *interp)
```
Sets the `errorCode` variable in `interp` based on the current value of `errno`, and returns a string identifying the error.

```
char *Tcl_ErrnoId(void)
```
Returns a symbolic name corresponding to the current value of `errno`, such as `ENOENT`.

```
char *Tcl_SignalId(int sig)
```
Returns the symbolic name for `sig`, such as `SIGINT`.

```
char *Tcl_SignalMsg(int sig)
```
Returns a human-readable message describing signal `sig`.

```
int Tcl_CreatePipeline(Tcl_Interp *interp, int argc, char
            *argv[],
    int **pidPtr, int *inPipePtr, int *outPipePtr, int *errFi-
            lePtr)
```
Creates a process pipeline, returns a count of the number of processes created, and stores at `*pidPtr` the address of a `malloc`-ed array of process identifiers. If an error occurs, returns `-1` and leaves an error message in `interp->result`. `InPipePtr`, `outPipePtr`, and `errFilePtr` are used to control default I/O redirection (see text for details).

```
Tcl_DetachPids(int numPids, int *pidPtr)
```
Passes responsibility for `numPids` at `*pidPtr` to Tcl: Tcl will allow them to run in backround and reap them in some future call to `Tcl_ReapDetachedProcs`.

```
Tcl_ReapDetachedProcs(void)
```
Checks to see if any detached processes have exited; if so, cleans up their state.

to process file names before using them in system calls, and you may find it useful if you write C code that deals with POSIX files.

For example, the implementation of the `open` command contains code something like the following:

```
int fd;
Tcl_DString buffer;
char *fullName;
...
```

```
fullName = Tcl_TildeSubst(interp, argv[1], &buffer);
if (fullName == NULL) {
    return TCL_ERROR;
}
fd = open(fullName, ...);
Tcl_DStringFree(fullName);
...
```

Tcl_TildeSubst takes as arguments an interpreter, a file name that may start with a tilde, and a dynamic string. It returns a new file name, which is either the original name (if it didn’t start with ~), a new tilde-expanded name, or NULL if an error occurred; in the last case an error message is left in the interpreter’s result.

If Tcl_TildeSubst has to generate a new name, it uses the dynamic string given by its final argument to store the name. When Tcl_TildeSubst is called the dynamic string should either be uninitialized or empty. Tcl_TildeSubst initializes it and then uses it for the new name if needed. Once the caller has finished using the new file name it must invoke Tcl_DStringFree to release any memory that was allocated for the dynamic string.

35.2 Generating messages

When an error or signal occurs in the C code of a Tcl application, the application should report the error or signal back to the Tcl script that triggered it, usually as a Tcl error. To do this, information about the error or signal must be converted from the binary form used in C to a string form for use in Tcl scripts. Tcl provides four procedures to do this: Tcl_PosixError, Tcl_ErronId, Tcl_SignalId, and Tcl_SignalMsg.

Tcl_PosixError provides a simple “all in one” mechanism for reporting errors in system calls. Tcl_PosixError examines the C variable errno to determine what kind of error occurred, then it calls Tcl_SetErrorCode to set the errorCode variable appropriately and it returns a human-readable string suitable for use in an error message. For example, consider the following fragment of code, which might be part of a command procedure:

```
FILE *f;
...
f = fopen("prolog.ps", "r");
if (f == NULL) {
    char *msg = Tcl_PosixError(interp);
    Tcl_AppendResult(interp,
            "couldn’t open prolog.ps: ", msg,
            (char *) NULL);
    return TCL_ERROR;
}
```

If the file doesn't exist or isn't readable then an error will occur when `fopen` invokes a system call to open the file. An integer code will be stored in the `errno` variable to identify the error and `fopen` will return a null pointer. The above code detects such errors and invokes `Tcl_PosixError`. If the file didn't exist then `Tcl_PosixError` will set `errorCode` to

```
POSIX ENOENT {no such file or directory}
```

and return the string "`no such file or directory`". The code above incorporates `Tcl_PosixError`'s return value into its own error message, which it stores in `interp->result`. In the case of an non-existent file, the code above will return "`couldn't open prolog.ps: no such file or directory`" as its error message.

`Tcl_ErrnoId` takes no arguments and returns the official POSIX name for the error indicated by `errno`. The names are the symbolic ones defined in the header file `errno.h`. For example, if `errno`'s value is `ENOENT` then `Tcl_ErrnoId` will return the string "`ENOENT`". The return value from `Tcl_ErrnoId` is the same as the value that `Tcl_PosixError` will store in the second element of `errorCode`.

`Tcl_SignalId` and `Tcl_SignalMsg` each take a POSIX signal number as argument, and each returns a string describing the signal. `Tcl_SignalId` returns the official POSIX name for the signal as defined in `signal.h`, and `Tcl_SignalMsg` returns a human-readable message describing the signal. For example,

```
Tcl_SignalId(SIGILL)
```

returns the string "`SIGILL`", and

```
Tcl_SignalMsg(SIGILL)
```

returns "`illegal instruction`".

35.3 Creating subprocesses

`Tcl_CreatePipeline` is the procedure that does most of the work of creating subprocesses for `exec` and `open`. It creates one or more subprocesses in a pipeline configuration. It has the following arguments and result:

```
int Tcl_CreatePipeline(Tcl_Interp *interp, int argc,
        char *argv[], int **pidPtr, int *inPipePtr,
        int *outPipePtr, int *errFilePtr)
```

The `argc` and `argv` arguments describe the commands for the subprocesses in the same form they would be specified to `exec`. Each string in `argv` becomes one word of one command, except for special strings like "`>`" and "`|`" that are used for I/O redirection and separators between commands. `Tcl_CreatePipeline` normally returns a count of the number of subprocesses created, and it stores at `*pidPtr` a pointer to an array containing the process identifiers for the new processes. The array is dynamically allocated and must be freed by the caller by passing it to `free`. If an error occurred while spawning the subprocesses (e.g. `argc` and `argv` specified that output should be redirected to a file but the file couldn't be opened) then `Tcl_CreatePipeline` returns `-1` and leaves an error message in `interp->result`.

The last three arguments to `Tcl_CreatePipeline` are used to control I/O to and from the pipeline if `argv` and `argc` don't specify I/O redirection. If these arguments are `NULL` then the first process in the pipeline will takes its standard input from the standard input of the parent, the last process will write its standard output to the standard output of the parent, and all of the processes will use the parent's standard error channel for their error message. If `inPipePtr` is not `NULL` then it points to an integer; `Tcl_CreatePipeline` will create a pipe, connect its output to the standard input of the first subprocess, and store a writable file descriptor for its input at `*inPipePtr`. If `outPipePtr` is not `NULL` then standard output goes to a pipe and a read descriptor for the pipe is stored at `*outPipePtr`. If `errFilePtr` is not `NULL` then `Tcl_CreatePipeline` creates a temporary file and connects the standard error files for all of the subprocesses to that file; a readable descriptor for the file will be stored at `*errFilePtr`. `Tcl_CreatePipeline` removes the file before it returns, so the file will only exist as long as it is open.

If `argv` specifies input or output redirection then this overrides the requests made in the arguments to `Tcl_CreatePipeline`. For example, if `argv` redirects standard input then no pipe is created for standard input; if `inPipePtr` is not `NULL` then `-1` is stored at `*inPipePtr` to indicate that standard input was redirected. If `argv` redirects standard output then no pipe is created for it; if `outPipePtr` is not `NULL` then `-1` is stored at `*outPipePtr`. If `argv` redirects some or all of the standard error output and `errFilePtr` is not `NULL`, the file will still be created and a descriptor will be returned, even though it's possible that no messages will actually appear in the file.

35.4 Background processes

`Tcl_DetachPids` and `Tcl_ReapDetachedProcs` are used to keep track of processes executing in the background. If an application creates a subprocess and abandons it (i.e. the parent never invokes a system call to wait for the child to exit), then the child executes in background and when it exits it becomes a "zombie". It remains a zombie until its parent officially waits for it or until the parent exits. Zombie processes occupy space in the system's process table, so if you create enough of them you will overflow the process table and make it impossible for anyone to create more processes. To keep this from happening, you must invoke a system call such as `waitpid`, which will return the exit status of the zombie process. Once the status has been returned the zombie relinquishes its slot in the process table.

In order to prevent zombies from overflowing the process table you should pass the process identifiers for background processes to `Tcl_DetachPids`:

```
    Tcl_DetachPids(int numPids, int *pidPtr)
```

The `pidPtr` argument points to an array of process identifiers and `numPids` gives the size of the array. Each of these processes now becomes the property of Tcl and the caller should not refer to them again. Tcl will assume responsibility for waiting for the processes after they exit.

In order for Tcl to clean up background processes you may need to call `Tcl_ReapDetachedProcs` from time to time. `Tcl_ReapDetachedProcs` invokes the `waitpid` kernel call on each detached process so that its state can be cleaned up if it has exited. If some of the detached processes are still executing then `Tcl_ReapDetachedProcs` doesn't actually wait for them to exit; it only cleans up the processes that have already exited. Tcl automatically invokes `Tcl_ReapDetachedProcs` each time `Tcl_CreatePipeline` is invoked, so under normal circumstances you won't ever need to invoke it. However, if you create processes without calling `Tcl_CreatePipeline` (e.g. by invoking the `fork` system call) and subsequently pass the processes to `Tcl_DetachPids`, then you should also invoke `Tcl_ReapDetachedProcs` from time to time. For example, a good place to call `Tcl_ReapDetachedProcs` is in the code that creates new subprocesses.

Part IV:

Tk’s C Interfaces

Chapter 36
Introduction

Like Tcl, Tk is a C library package that is linked with applications, and it provides a collection of library procedures that you can invoke from C code in the enclosing application. Although you can do many interesting things with Tk without writing any C code, just by writing Tcl scripts for `wish`, you'll probably find that most large GUI applications require some C code too. The most common reason for using Tk's C interfaces is to build new kinds of widgets. For example, if you write a Tk-based spreadsheet you'll probably need to implement a new widget to display the contents of the spreadsheet; if you write a charting package you'll probably build one or two new widgets to display charts and graphs in various forms; and so on. Some of these widgets could probably be implemented with existing Tk widgets such as canvases or texts, but for big jobs a new widget tailored to the needs of your application can probably do the job more simply and efficiently than any of Tk's general-purpose widgets. Typically you'll build one or two new widget classes to display your application's new objects, then combine your custom widgets with Tk's built-in widgets to create the full user interface of the application.

The main focus of this part of the book is on building new widgets. Most of Tk's library procedures exist for this purpose, and most of the text in this part of the book is oriented towards widget builders. However, you can also use Tk's library procedures to build new geometry managers; this is described in Chapter 43. Or, you may simply need to provide access to some window system feature that isn't supported by the existing Tcl commands, such as the ability to set the border width of a top-level window. In any event, the new features you implement should appear as Tcl commands so that you can use them in scripts. Both the philosophical issues and the library procedures discussed in Part III apply to this part of the book also.

36.1 What’s in a widget?

All widget classes have the same basic structure, consisting of a widget record and six C procedures that implement the widget’s look and feel. More complex widgets may have additional data structures and procedures besides theses, but all widgets have at least these basic components.

A *widget record* is the C data structure that represents the state of a widget. It includes all of the widget’s configuration options plus anything else the widget needs for its own internal use. For example, the widget record for a label widget contains the label’s text or bitmap, its background and foreground colors, its relief, and so on. Each instance of a widget has its own widget record, but all widgets of the same class have widget records with the same structure. One of the first things you will do when designing a new widget class is to design the widget record for that class.

Of the widget’s six core procedures, two are Tcl command procedures. The first of these is called the *create procedure*; it implements the Tcl command that creates widgets of this class. The command’s name is the same as the class name, and the command should have the standard syntax described in Section XXX for creating widgets. The command procedure initializes a new widget record, creates the window for the widget, and creates the widget command for the widget. It is described in more detail in Chapters 37 and 38.

The second command procedure is the *widget command procedure*; it implements the widget commands for all widgets of this class. When the widget command is invoked its `clientData` argument points to the widget record for a particular widget; this allows the same C procedure to implement the widget commands for many different widgets (the counter objects described in Section XXX used a similar approach).

The third core procedure for a widget class is its *configure procedure*. Given one or more options in string form, such as “`-background red`”, it parses the options and fills in the widget record with corresponding internal representations such as an `XColor` structure. The configure procedure is invoked by the create procedure and the widget command procedure to handle configuration options specified on their command lines. Chapter 38 describes the facilities provided by Tk to make configure procedures easy to write.

The fourth core procedure is the *event procedure*. It is invoked by Tk’s event dispatcher and typically handles exposures (part of the window needs to be redrawn), window size changes, focus changes, and the destruction of the window. The event procedure does not normally deal with user interactions such as mouse motions and key presses; these are usually handled with class bindings created with the `bind` command as described in Chapter XXX. Chapter 39 describes the Tk event dispatcher, including its facilities for managing X events plus additional features for timers, event-driven file I/O, and idle callbacks

The fifth core procedure is the *display procedure*. It is invoked to redraw part or all of the widget on the screen. Redisplays can be triggered by many things, including window exposures, changes in configuration options, and changes in the input focus. Chapter 40

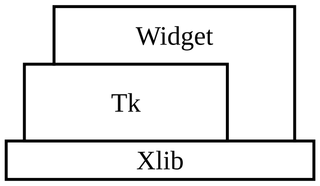


Figure 36.1. Tk hides many of the Xlib interfaces from widgets, but widgets still invoke Xlib directly for a few purposes such as drawing on the screen.

discusses several issues related to redisplay, such as deferred redisplay, double-buffering with pixmaps, and Tk's support for drawing 3-D effects.

The last of a widget's core procedures is its *destroy procedure*. This procedure is called when the widget is destroyed and is responsible for freeing up all of the resources allocated for the widget such as the memory for the widget record and X resources such as colors and pixmaps. Widget destruction is tricky because the widget could be in use at the time it is destroyed; Chapter 41 describes how deferred destruction is used to avoid potential problems.

36.2 Widgets are event-driven

Part II described how the Tcl scripts for Tk applications are event-driven, in that they consist mostly of short responses to user interactions and other events. The C code that implements widgets is also event-driven. Each of the core procedures described in the previous section responds to events of some sort. The create, widget command, and configure procedures all respond to Tcl commands. The event procedure responds to X events, and the display and destroy procedures respond to things that occur either in X or in Tcl scripts.

36.3 Tk vs. Xlib

Xlib is the C library package that provides the lowest level of access to the X Window System. Tk is implemented using Xlib but it hides most of the Xlib procedures from the C code in widgets, as shown in Figure 36.1. For example, Xlib provides a procedure `XCreateWindow` to create a new windows, but you should not use it; instead, call `Tk_CreateWindowFromPath` or one of the other procedures provided by Tk for this purpose. Tk's procedures call the Xlib procedures but also do additional things such as associating a textual name with the window. Similarly, you shouldn't normally call Xlib procedures like `XAllocColor` to allocate colors and other resources; call the corresponding Tk procedures like `Tk_GetColor` instead. In the case of colors, Tk calls Xlib to allocate the color, but it also remembers the colors that are allocated; if you use the same color in many different places, Tk will only communicate with the X server once.

However, Tk does not totally hide Xlib from you. When widgets redisplay themselves they make direct calls to Xlib procedures such as `XDrawLine` and `XDrawString`. Furthermore, many of the structures manipulated by Tk are the same as the structures provided by Xlib, such as graphics contexts and window attributes. Thus you'll need to know quite a bit about Xlib in order to write new widgets with Tk. This book assumes that you are familiar with the following concepts from Xlib:

- Window attributes such as `background_pixel`, which are stored in `XSetWindowAttributes` structures.
- Resources related to graphics, such as pixmaps, colors, graphics contexts, and fonts.
- Procedures for redisplaying, such as `XDrawLine` and `XDrawString`.
- Event types and the `XEvent` structure.

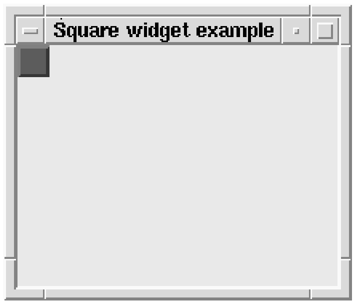
You'll probably find it useful to keep a book on Xlib nearby when reading this book and to refer to the Xlib documentation for specifics about the Xlib structures and procedures. If you haven't used Xlib before I'd suggest waiting to read about Xlib until you need the information. That way you can focus on just the information you need and avoid learning about the parts of Xlib that are hidden by Tk.

Besides Xlib, you shouldn't need to know anything about any other X toolkit or library. For example, Tk is completely independent from the Xt toolkit so you don't need to know anything about Xt. For that matter, if you're using Tk you *can't* use Xt: their widgets are incompatible and can't be mixed together.

36.4 Square: an example widget

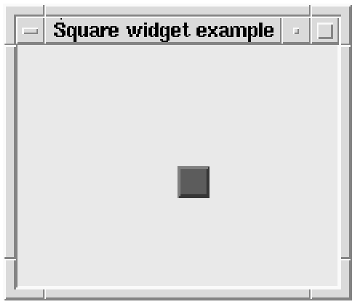
I'll use a simple widget called "square" for examples throughout Part IV. The square widget displays a colored square on a background as shown in Figure 36.2. The widget supports several configuration options, such as colors for the background and for the square, a relief for the widget, and a border width used for both the widget and the square. It also provides three widget commands: `configure`, which is used in the standard way to query and change options; `position`, which sets the position of the square's upper-left corner relative to the upper-left corner of the window, and `size`, which sets the square's size. Figure 36.2 illustrates the `position` and `size` commands.

Given these simple commands many other features can be written as Tcl scripts. For example, the following script arranges for the square to center itself over the mouse cursor on Button-1 presses and to track the mouse as long as Button-1 is held down. It assumes that the square widget is named "`.s`".



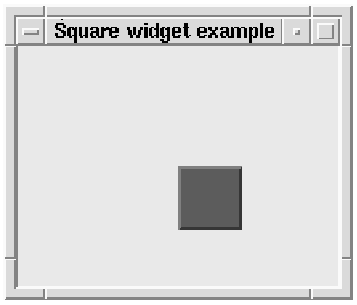
```
square .s
pack .s
wm title .s "Square widget example"
```

(a)



```
.s position 100 75
```

(b)



```
.s size 40
```

(c)

Figure 36.2. A sequence of scripts and the displays that they produce. Figure (a) creates a square widget, Figure (b) invokes the `position` widget command to move the square within its widget, and Figure (c) changes the size of the square.

```
proc center {x y} {
    set a [.s size]
    .s position [expr $x-($a/2)] [expr $y-($a/2)]
}
bind .s <1> {center %x %y}
bind .s <B1-Motion> {center %x %y}
```

Note: *For this particular widget it would probably make more sense to use configuration options instead of the* `position` *and* `size` *commands; I made them widget commands just to illustrate how to write widget commands.*

The implementation of the square widget requires about 320 lines of C code excluding comments, or about 750 lines in a copiously-commented version. The square widget doesn't use all of the features of Tk but it illustrates the basic things you must do to create a new widget. For examples of more complex widgets you can look at the source code for some of Tk's widgets; they have the same basic structure as the square widget and they use the same library procedures that you'll read about in the chapters that follow.

36.5 Design for re-usability

When building a new widget, try to make it as flexible and general-purpose as possible. If you do this then it may be possible for you or someone else to use your widget in new ways that you didn't foresee when you created it. Here are a few specific things to think about:

1. Store all the information about the widget in its widget record. If you use static or global variables to hold widget state then it may not be possible to have more than one instance of the widget in any given application. Even if you don't envision using more than one instance per application, don't do anything to rule this out.
2. Make sure that all of the primitive operations on your widget are available through its widget command. Don't hard-wire the widget's behavior in C. Instead, define the behavior as a set of class bindings using the `bind` command. This will make it easy to change the widget's behavior.
3. Provide escapes to Tcl. Think about interesting ways that you can embed Tcl commands in your widget and invoke them in response to various events. For example, the actions for button widgets and menu items are stored as a Tcl commands that are evaluated when the widgets are invoked, and canvases and texts allow you to associate Tcl commands with their internal objects in order to give them behaviors.
4. Organize the code for your widget in one or a few files that can easily be linked into other applications besides the one you're writing.

Chapter 37
Creating Windows

This chapter presents Tk's basic library procedures for creating windows. It describes the `Tk_Window` type, which is used as a token for windows, then introduces the Tk procedures for creating and deleting windows. Tk provides several macros for retrieving information about windows, which are introduced next. Then the chapter discusses what should be in the create procedure for a widget, using the square widget as an example. The chapter closes with a discussion of delayed window creation. See Table 37.1 for a summary of the procedures discussed in the chapter.

37.1 Tk_Window structures

Tk uses a token of type `Tk_Window` to represent each window. When you create a new window Tk returns a `Tk_Window` token, and you must pass this token back to Tk when invoking procedures to manipulate the window. A `Tk_Window` is actually a pointer to a record containing information about the window, such as its name and current size, but Tk hides the contents of this structure and you may not read or write its fields directly. The only way you can manipulate a `Tk_Window` is to invoke procedures and macros provided by Tk.

37.2 Creating Tk_Windows

Tk applications typically use two procedures for creating windows: `Tk_CreateMainWindow` and `Tk_CreateWindowFromPath`. `Tk_CreateMainWindow` creates a

`Tk_Window Tk_CreateMainWindow(Tcl_Interp *interp, char *screenName, char *appName)`	Creates a new application and returns a token for the application’s main window. `ScreenName` gives the screen on which to create the main window (if `NULL` then Tk picks default), and `appName` gives a base name for the application. If an error occurs, returns `NULL` and stores an error message in `interp->result`.
`Tk_Window Tk_CreateWindowFromPath(Tcl_Interp *interp, Tk_Window tkwin, char *pathName, char *screenName)`	Creates a new window in `tkwin`’s application whose path name is `pathName`. If `screenName` is `NULL` the new window will be an internal window; otherwise it will be a top-level window on `screenName`. Returns a token for the new window. If an error occurs, returns `NULL` and stores an error message in `interp->result`.
`Tk_SetClass(Tk_Window tkwin, char *class)`	Sets `tkwin`’s class to `class`.
`Tk_DestroyWindow(TkWindow tkwin)`	Destroy `tkwin` and all of its descendants in the window hierarchy.
`Tk_Window Tk_NameToWindow(Tcl_Interp *interp, char *pathName, Tk_Window tkwin)`	Returns the token for the window whose path name is `pathName` in the same application as `tkwin`. If no such name exists then returns `NULL` and stores an error message in `interp->result`.
`Tk_MakeWindowExist(TkWindow tkwin)`	Force the creation of the X window for `tkwin`, if it didn’t already exist.

Table 37.1. A summary of basic procedures for window creation and deletion.

new application; it’s usually invoked in the main program of an application. Before invoking `Tk_CreateMainWindow` you should create a Tcl interpreter to use for the application. `Tk_CreateMainWindow` takes three arguments, consisting of the interpreter plus two strings:

```
Tk_Window Tk_CreateMainWindow(Tcl_Interp *interp,
    char *screenName, char *appName)
```

The `screenName` argument gives the name of the screen on which to create the main window. It can have any form acceptable to your X server. For example, on most UNIX-like systems “`unix:0`” selects the default screen of display 0 on the local machine, or “`ginger.cs.berkeley.edu:0.0`” selects screen 0 of display 0 on the machine whose network address is “`ginger.cs.berkeley.edu`”. `ScreenName` may be specified as `NULL`, in which case Tk picks a default server. On UNIX-like systems the default server is normally determined by the `DISPLAY` environment variable.

The last argument to Tk_CreateMainWindow is a name to use for the application, such as "clock" for a clock program or "mx foo.c" for an editor named mx editing a file named foo.c. This is the name that other applications will use to send commands to the new application. Each application must have a unique name; if appName is already in use by some other application then Tk adds a suffix like " #2" to make the name unique. Thus the actual name of the application may be something like "clock #3" or "mx foo.c #4". You can find out the actual name for the application using the Tk_Name macro or by invoking the Tcl command "winfo name .".

Tk_CreateMainWindow creates the application's main window, registers its name so that other applications can send commands to it, and adds all of Tk's commands to the interpreter. It returns the Tk_Window token for the main window. If an error occurs (e.g. screenName doesn't exist or the X server refused to accept a connection) then Tk_CreateMainWindow returns NULL and leaves an error message in interp->result.

Tk_CreateWindowFromPath adds a new window to an existing application. It's the procedure that's usually called when creating new widgets and it has the following prototype:

```
Tk_Window Tk_CreateWindowFromPath(Tcl_Interp *interp,
        Tk_Window tkwin, char *pathName, char *screenName);
```

The tkwin argument is a token for an existing window; its only purpose is to identify the application in which to create the new window. PathName gives the full name for the new window, such as ".a.b.c". There must not already exist a window by this name, but its parent (for example, ".a.b") must exist. If screenName is NULL then the new window is an internal window; otherwise the new window will be a top-level window on the indicated screen. Tk_CreateWindowFromPath returns a token for the new window unless an error occurs, in which case it returns NULL and leaves an error message in interp->result.

Tk also provides a third window-creation procedure called Tk_CreateWindow. This procedure is similar to Tk_CreateWindowFromPath except that the new window's name is specified a bit differently. See the reference documentation for details.

37.3 Setting a window's class

The procedure Tk_SetClass assigns a particular class name to a window. For example,

```
Tk_SetClass(tkwin, "Foo");
```

sets the class of window tkwin to "Foo". Class names are used by Tk for several purposes such as finding options in the option database and event bindings. You can use any string whatsoever as a class name when you invoke Tk_SetClass, but you should make sure the first letter is capitalized: Tk assumes in several places that uncapitalized names are window names and capitalized names are classes.

37.4 Deleting windows

The procedure `Tk_DestroyWindow` takes a `Tk_Window` as argument and deletes the window. It also deletes all of the window's children recursively. Deleting the main window of an application will delete all of the windows in the application and usually causes the application to exit.

37.5 Basic operations on Tk_Windows

Given a textual path name for a window, `Tk_NameToWindow` may be used to find the `Tk_Window` token for the window:

```
Tk_Window Tk_NameToWindow(Tcl_Interp *interp, char *pathName,
        Tk_Window tkwin);
```

`PathName` is the name of the desired window, such as "`.a.b.c`", and `tkwin` is a token for any window in the application of interest (it isn't used except to select a specific application). Normally `Tk_NameToWindow` returns a token for the given window, but if no such window exists it returns `NULL` and leaves an error message in `interp->result`.

Tk maintains several pieces of information about each `Tk_Window` and it provides a set of macros that you can use to access the information. See Table 37.2 for a summary of all the macros. Each macro takes a `Tk_Window` as an argument and returns the corresponding piece of information for the window. For example if `tkwin` is a `Tk_Window` then

```
Tk_Width(tkwin)
```

returns an integer value giving the current width of `tkwin` in pixels. Here are a few of the more commonly used macros:

- `Tk_Width` and `Tk_Height` return the window's dimensions; this information is used during redisplay for purposes such as centering text.
- `Tk_WindowId` returns the X identifier for the window; it is needed when invoking Xlib procedures during redisplay.
- `Tk_Display` returns a pointer to Xlib's `Display` structure corresponding to the window; it is also needed when invoking Xlib procedures.

Some of the macros, like `Tk_InternalBorderWidth` and `Tk_ReqWidth`, are only used by geometry managers (see Chapter 43) and others such as `Tk_Visual` are rarely used by anyone.

Macro Name	Result Type	Meaning
`Tk_Attributes`	`XSetWindowAttributes *`	Window attributes such as border pixel and cursor.
`Tk_Changes`	`XWindowChanges *`	Window position, size, stacking order.
`Tk_Class`	`Tk_Uid`	Name of window's class.
`Tk_Colormap`	`Colormap`	Colormap for window.
`Tk_Depth`	`int`	Bits per pixel.
`Tk_Display`	`Display`	X display for window.
`Tk_Height`	`int`	Current height of window in pixels.
`Tk_InternalBorderWidth`	`int`	Width of internal border in pixels.
`Tk_IsMapped`	`int`	1 if window mapped, 0 otherwise.
`Tk_IsTopLevel`	`int`	1 if top-level, 0 if internal.
`Tk_Name`	`Tk_Uid`	Name within parent. For main window, returns application name.
`Tk_Parent`	`Tk_Window`	Parent, or `NULL` for main window.
`Tk_PathName`	`char *`	Full path name of window.
`Tk_ReqWidth`	`int`	Requested width in pixels.
`Tk_ReqHeight`	`int`	Requested height in pixels.
`Tk_Screen`	`Screen *`	X Screen for window.
`Tk_ScreenNumber`	`int`	Index of window's screen.
`Tk_Visual`	`Visual *`	Information about window's visual characteristics.
`Tk_Width`	`int`	Current width of window in pixels.
`Tk_WindowId`	`Window`	X identifier for window.
`Tk_X`	`int`	X-coordinate within parent window.
`Tk_Y`	`int`	Y-coordinate within parent window.

Table 37.2. Macros defined by Tk for retrieving window state. Each macro takes a `Tk_Window` as argument and returns a result whose type is given in the second column. All of these macros are fast (they simply return fields from Tk's internal structures and don't require any interactions with the X server).

37.6 Create procedures

The create procedure for a widget must do five things: create a new `Tk_Window`; create and initialize a widget record; set up event handlers; create a widget command for the widget; and process configuration options for the widget. The create procedure should be the command procedure for a Tcl command named after the widget's class, and its `client-`

`Data` argument should be the `Tk_Window` token for the main window of the application (this is needed in order to create a new `Tk_Window` in the application).

Figure 37.1 shows the code for `SquareCmd`, which is the create procedure for square widgets. After checking its argument count, `SquareCmd` creates a new window for the widget and invokes `Tk_SetClass` to assign it a class of “`Square`”. The middle part of `SquareCmd` allocates a widget record for the new widget and initializes it. The widget record for squares has the following definition:

```
typedef struct {
    Tk_Window tkwin;
    Display *display;
    Tcl_Interp *interp;
    int x, y;
    int size;
    int borderWidth;
    Tk_3DBorder bgBorder;
    Tk_3DBorder fgBorder;
    int relief;
    GC gc;
    int updatePending;
} Square;
```

The first field of the record is the `Tk_Window` for the widget. The next field, `display`, identifies the X display for the widget (it’s needed during cleanup after the widget is deleted). `Interp` holds a pointer to the interpreter for the application. The `x` and `y` fields give the position of the upper-left corner of the square relative to the upper-left corner of the window, and the `size` field specifies the square’s size in pixels. The last six fields are used for displaying the widget; they’ll be discussed in Chapters 38 and 40.

After initializing the new widget record `SquareCmd` calls `Tk_CreateEventHandler`; this arranges for `SquareEventProc` to be called whenever the widget needs to be redrawn or when various other events occur, such as deleting its window or changing its size; events will be discussed in more detail in Chapter 39. Next `SquareCmd` calls `Tcl_CreateCommand` to create the widget command for the widget. The widget’s name is the name of the command, `SquareWidgetCmd` is the command procedure, and a pointer to the widget record is the `clientData` for the command (using a pointer to the widget record as `clientData` allows a single C procedure to implement the widget commands for all square widgets; `SquareWidgetCommand` will receive a different `clientData` argument depending on which widget command was invoked). Then `SquareCmd` calls `ConfigureSquare` to process any configuration options specified as arguments to the command; Chapter 38 describes how the configuration options are handled. If an error occurs in processing the configuration options then `SquareCmd` destroys the window and returns an error. Otherwise it returns success with the widget’s path name as result.

```
int SquareCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    Tk_Window main = (Tk_Window) clientData;
    Square *squarePtr;
    Tk_Window tkwin;

    if (argc < 2) {
        Tcl_AppendResult(interp, "wrong # args: should be \"",
                argv[0], " pathName ?options?\"", (char *) NULL);
        return TCL_ERROR;
    }

    tkwin = Tk_CreateWindowFromPath(interp, main, argv[1],
            (char *) NULL);
    if (tkwin == NULL) {
        return TCL_ERROR;
    }
    Tk_SetClass(tkwin, "Square");

    squarePtr = (Square *) malloc(sizeof(Square));
    squarePtr->tkwin = tkwin;
    squarePtr->display = Tk_Display(tkwin);
    squarePtr->interp = interp;
    squarePtr->x = 0;
    squarePtr->y = 0;
    squarePtr->size = 20;
    squarePtr->bgBorder = NULL;
    squarePtr->fgBorder = NULL;
    squarePtr->gc = None;
    squarePtr->updatePending = 0;

    Tk_CreateEventHandler(tkwin,
            ExposureMask|StructureNotifyMask, SquareEventProc,
            (ClientData) squarePtr);
    Tcl_CreateCommand(interp, Tk_PathName(tkwin),
        SquareWidgetCmd, (ClientData squarePtr),
        (Tcl_CmdDeleteProc *) NULL);
    if (ConfigureSquare(interp, squarePtr, argc-2, argv+2, 0)
            != TCL_OK) {
        Tk_DestroyWindow(squarePtr->tkwin);
        return TCL_ERROR;
    }
    interp->result = Tk_PathName(tkwin);
    return TCL_OK;
}
```

Figure 37.1. The create procedure for square widgets. This procedure is the command procedure for the `square` command.

37.7 Delayed window creation

`Tk_CreateMainWindow` and `Tk_CreateWindowFromPath` create the Tk data structures for a window, but they do not communicate with the X server to create an actual X window. If you create a `Tk_Window` and immediately fetch its X window identifier using `Tk_WindowId`, the result will be `None`. Tk doesn't normally create the X window for a `Tk_Window` until the window is mapped, which is normally done by a geometry manager (see Chapter 43). The reason for delaying window creation is performance. When a `Tk_Window` is initially created, all of its attributes are set to default values. Many of these attributes will be modified almost immediately when the widget configures itself. It's more efficient to delay the window's creation until all of its attributes have been set, rather than first creating the window and then asking the X server to modify the attributes later.

Delayed window creation is normally invisible to widgets, since the only time a widget needs to know the X identifier for a window is when it invokes Xlib procedures to display it. This doesn't happen until after the window has been mapped, so the X window will have been created by then. If for some reason you should need the X window identifier before a `Tk_Window` has been mapped, you can invoke `Tk_MakeWindowExist`:

```
void Tk_MakeWindowExist(tkwin);
```

This forces the X window for `tkwin` to be created immediately if it hasn't been created yet. Once `Tk_MakeWindowExist` returns, `Tk_WindowId` can be used to retrieve the `Window` token for it.

Chapter 38
Configuring Widgets

The phrase "configuring a widget" refers to all of the setup that must be done prior to actually drawing the widget's contents on the screen. A widget is configured initially as part of creating it, and it may be reconfigured by invoking its widget command. One of the largest components of configuring a widget is processing configuration options such as "`-borderwidth 1m`". For each option the textual value must be translated to an internal form suitable for use in the widget. For example, distances specified in floating-point millimeters must be translated to integer pixel values and font names must be mapped to corresponding `XFontStruct` structures. Configuring a widget also includes other tasks such as preparing X graphics contexts to use when drawing the widget and setting attributes of the widget's window, such as its background color.

This chapter describes the Tk library procedures for configuring widgets, and it presents the square widget's configure procedure and widget command procedure. Chapter 40 will show how to draw a widget once configuration is complete.

38.1 Tk_ConfigureWidget

Tk provides three library procedures, `Tk_ConfigureWidget`, `Tk_ConfigureInfo`, and `Tk_FreeOptions`, that do most of the work of processing configuration options (see Table 38.1). To use these procedures you first create a *configuration table* that describes all of the configuration options supported by your new widget class. When creating a new widget, you pass this table to `Tk_ConfigureWidget` along with `argc`/`argv` information describing the configuration options (i.e. all the arguments in the creation command after the widget name). You also pass in a pointer to the widget record for

`int Tk_ConfigureWidget(Tcl_Interp *interp, Tk_Window tkwin, Tk_ConfigSpec *specs, int argc, char *argv[], char *widgRec, int flags)`	Processes a set of arguments from a Tcl command (`argc` and `argv`) using a table of allowable configuration options (`specs`) and sets the appropriate fiels of a widget record (`widgRec`). `Tkwin` is the widget's window. Normally returns `TCL_OK`; if an error occurs, returns `TCL_ERROR` and leaves an error message in `interp->result`. Flags is normally 0 or `TK_CONFIG_ARGV_ONLY` (see reference documentation for other possibilities).
`int Tk_ConfigureInfo(Tcl_Interp *interp, Tk_Window tkwin, Tk_ConfigSpec *specs, char *widgRec, char * argvName, flags)`	Finds the configuration option in `specs` whose command-line name is `argvName`, locates the value of that option in `widgRec`, and generates in `interp->result` a list describing that configuration option. If `argvName` is `NULL`, generates a list of lists describing all of the options in `specs`. Normally returns `TCL_OK`; if an error occurs, returns `TCL_ERROR` and leaves an error message in `interp->result`. `Flags` is normally 0 (see the reference documentation for other possibilities).
`Tk_FreeOptions(Tk_ConfigSpec *specs, char *widgRec, Display *display, int flags)`	Frees up any resources in `widgRec` that are used by `specs`. `Display` must be the widget's display. `Flags` is normally 0 but can be used to select particular entries in `specs` (see reference documentation for details).
`int Tk_Offset(type, field)`	This is a macro that returns the offset of a field named `field` within a structure whose type is `type`. Used when creating configuration tables.

Table 38.1. A summary of `Tk_ConfigureWidget` and related procedures and macros.

the widget. `Tk_ConfigureWidget` processes each option specified in `argv` according to the information in the configuration table, converting string values to appropriate internal forms, allocating resources such as fonts and colors if necessary, and storing the results into the widget record. For options that aren't explicitly specified in `argv`, `Tk_ConfigureWidget` checks the option database to see if a value is specified there. For options that still haven't been set, `Tk_ConfigureWidget` uses default values specified in the table.

When the `configure` widget command is invoked to change options, you call `Tk_ConfigureWidget` again with the `argc`/`argv` information describing the new option values. `Tk_ConfigureWidget` will process the arguments according to the table and modify the information in the widget record accordingly. When the `configure` widget command is invoked to read out the current settings of options, you call `Tk_ConfigureInfo`. It generates a Tcl result describing one or all of the widget's options in exactly the right form, so all you have to do is return this result from the widget command procedure.

Finally, when a widget is deleted you invoke `Tcl_FreeOptions`. `Tcl_FreeOptions` scans through the table to find options for which resources have been allocated, such as fonts and colors. For each such option it uses the information in the widget record to free up the resource.

38.1.1 Tk_ConfigSpec tables

Most of the work in processing options is in creating the configuration table. The table is an array of records, each with the following structure:

```
typedef struct {
    int type;
    char *argvName;
    char *dbName;
    char *dbClass;
    char *defValue;
    int offset;
    int specFlags;
    Tk_CustomOption *customPtr;
} Tk_ConfigSpec;
```

The `type` field specifies the internal form into which the option's string value should be converted. For example, `TK_CONFIG_INT` means the option's value should be converted to an integer and `TK_CONFIG_COLOR` means that the option's value should be converted to a pointer to an `XColor` structure. For `TK_CONFIG_INT` the option's value must have the syntax of a decimal, hexadecimal, or octal integer and for `TK_CONFIG_COLOR` the option's value must have one of the forms for colors described in Section XXX. For `TK_CONFIG_COLOR` Tk will allocate an `XColor` structure, which must later be freed (e.g. by calling `Tk_FreeOptions`). More than 20 different option types are defined by Tk; see the reference documentation for details on each of the supported types.

`ArgvName` is the option's name as specified on command lines, e.g. "`-background`" or "`-font`". The `dbName` and `dbClass` fields give the option's name and class in the option database. The `defValue` field gives a default value to use for the option if it isn't specified on the command line and there isn't a value for it in the option database; `NULL` means there is no default for the option.

The `offset` field tells where in the widget record to store the converted value of the option. It is specified as a byte displacement from the beginning of the record. You should use the `Tk_Offset` macro to generate values for this field. For example,

```
Tk_Offset(Square, relief)
```

produces an appropriate offset for the `relief` field of a record whose type is `Square`.

The `specFlags` field contains an OR-ed combination of flag bits that provide additional control over the handling of the option. A few of the flags will be discussed below; see the reference documentation for a complete listing. Finally, the `customPtr` field provides additional information for application-defined options. It’s only used when the type is `TK_CONFIG_CUSTOM` and should be `NULL` in other cases. See the reference documentation for details on defining custom option types.

Here is the option table for square widgets:

```
Tk_ConfigSpec configSpecs[] = {
    {TK_CONFIG_BORDER, "-background", "background",
"Background",
        "#cdb79e", Tk_Offset(Square, bgBorder),
        TK_CONFIG_COLOR_ONLY, (Tk_CustomOption *) NULL},
    {TK_CONFIG_BORDER, "-background", "background",
        "Background", "white", Tk_Offset(Square, bgBorder),
        TK_CONFIG_MONO_ONLY, (Tk_CustomOption *) NULL},
    {TK_CONFIG_SYNONYM, "-bd", "borderWidth", (char *) NULL,
        (char *) NULL, 0, 0, (Tk_CustomOption *) NULL},
    {TK_CONFIG_SYNONYM, "-bg", "background", (char *) NULL,
        (char *) NULL, 0, 0, (Tk_CustomOption *) NULL},
    {TK_CONFIG_PIXELS, "-borderwidth", "borderWidth",
        "BorderWidth", "1m", Tk_Offset(Square, borderWidth),
        0, (Tk_CustomOption *) NULL},
    TK_CONFIG_SYNONYM, "-fg", "foreground", (char *) NULL,
        (char *) NULL, 0, 0, (Tk_CustomOption *) NULL},
    {TK_CONFIG_BORDER, "-foreground", "foreground",
        "Foreground", "#b03060", Tk_Offset(Square, fgBorder),
        TK_CONFIG_COLOR_ONLY, (Tk_CustomOption *) NULL},
    {TK_CONFIG_BORDER, "-foreground", "foreground",
        "Foreground", "black", Tk_Offset(Square, fgBorder),
        TK_CONFIG_MONO_ONLY, (Tk_CustomOption *) NULL},
    {TK_CONFIG_RELIEF, "-relief", "relief", "Relief",
        "raised", Tk_Offset(Square, relief), 0,
        (Tk_CustomOption *) NULL},
    {TK_CONFIG_END, (char *) NULL, (char *) NULL, ,
        (char *) NULL, (char *) NULL, 0, 0,
        (Tk_CustomOption *) NULL}
};
```

This table illustrates three additional features of `Tk_ConfigSpecs` structures. First, there are two entries each for the `-background` and `-foreground` options. The first entry for each option has the `TK_CONFIG_COLOR_ONLY` flag set, which causes Tk to use that option if the display is a color display and to ignore it if the display is monochrome. The second entry specifies the `TK_CONFIG_MONO_ONLY` flag so it is only used for monochrome displays. This feature allows different default values to be specified for color and mono displays (the current color model for the window determines whether the it considered to be color or monochrome; see Section XXX). Second, the options `-bd`, `-bg`, and `-fg` have type `TK_CONFIG_SYNONYM`. This means that each of these options is a synonym for some other option; the `dbName` field identifies the other option and the other fields are ignored. For example, if the `-bd` option is specified with the above table, Tk will actually use the table entry for the `-borderwidth` option. Third, the last entry in the table must have type `TK_CONFIG_END`; Tk depends on this to locate the end of the table.

38.1.2 Invoking Tk_ConfigureWidget

Suppose that `Tk_ConfigureWidget` is invoked as follows:

```
Tcl_Interp *interp;
Tk_Window tkwin;
char *argv[] = {"-relief", "sunken", "-bg", "blue"};
Square *squarePtr;
int code;
...
code = Tk_ConfigureWidget(interp, tkwin, configSpecs,
        4, argv, (char *) squarePtr, 0);
```

A call much like this will occur if a square widget is created with the Tcl command

```
square .s -relief sunken -bg blue
```

The `-relief` option will be processed according to type `TK_CONFIG_RELIEF`, which dictates that the option's value must be a valid relief, such as "`raised`" or "`sunken`". In this case the value specified is `sunken`; `Tk_ConfigureWidget` converts this string value to the integer value `TK_RELIEF_SUNKEN` and stores that value in `squarePtr->relief`. The `-bg` option will be processed according to the `configSpecs` entry for `-background`, which has type `TK_CONFIG_BORDER`. This type requires that the option's value be a valid color name; Tk creates a data structure suitable for drawing graphics in that color in `tkwin`, and it computes additional colors for drawing light and dark shadows to produce 3-dimensional effects. All of this information is stored in the new structure and a token for that structure is stored in the `bgBorder` field of `squarePtr`. In Chapter 40 you'll see how this token is used to draw the widget.

Since the `-borderwidth` and `-foreground` options weren't specified in `argv`, `Tk_ConfigureWidget` looks them up in the option database using the information for those options in `configSpecs`. If it finds values in the option database then it will use them in the same way as if they had been supplied in `argv`.

If an option isn't specified in the option database then `Tk_ConfigureWidget` uses the default value specified in its table entry. For example, for `-borderwidth` it will use the default value "`1m`". Since the option has type `TK_CONFIG_PIXELS`, this string must specify a screen distance in one of the forms described in Section XXX. "`1m`" specifies a distance of one millimeter; Tk converts this to the corresponding number of pixels and stores the result as an integer in `squarePtr->borderWidth`. If the default value for an option is `NULL` then `Tk_ConfigureWidget` does nothing at all if there is no value in either `argv` or the option database; the value in the widget record will retain whatever value it had when `Tk_ConfigureWidget` is invoked.

Note: *If an entry in the configuration table has no default value then you must initialize the corresponding field of the widget record before invoking* `Tk_ConfigureWidget`. *If* *there is a default value then you need not initialize the field in the widget record since* `Tk_ConfigureWidget` *will always store a proper value there.*

38.1.3 Errors

`Tk_ConfigureWidget` normally returns `TCL_OK`. If an error occurs then it returns `TCL_ERROR` and leaves an error message in `interp->result`. The most common form of error is a value that doesn't make sense for the option type, such as "`abc`" for the `-bd` option. `Tk_ConfigureWidget` returns as soon as it encounters an error, which means that some of the fields of the widget record may not have been set yet; these fields will be left in an initialized state (such as `NULL` for pointers, `0` for integers, `None` for X resources, etc.).

38.1.4 Reconfiguring

`Tk_ConfigureWidget` gets invoked not only when a widget is created but also during the `configure` widget command. When reconfiguring you probably won't want to consider the option database or default values. You'll want to process only the options that are specified explicitly in `argv`, leaving all the unspecified options with their previous values. To accomplish this, specify `TK_CONFIG_ARGV_ONLY` as the last argument to `Tk_ConfigureWidget`:

```
code = Tk_ConfigureWidget(interp, tkwin, configSpecs,
        argc, argv, (char *) squarePtr,
        TK_CONFIG_ARGV_ONLY);
```

38.1.5 Tk_ConfigureInfo

If a `configure` widget command is invoked with a single argument, or with no arguments, then it returns configuration information. For example, if `.s` is a square widget then

```
.s configure -background
```

should return a list of information about the `-background` option and

```
.s configure
```

should return a list of lists describing all the options, as described in Section XXX. `Tk_ConfigureInfo` does all the work of generating this information in the proper format. For the square widget it might be invoked as follows:

```
code = Tk_ConfigureInfo(interp, tkwin, configSpecs,
        (char *) squarePtr, argv[2], 0);
```

`Argv[2]` specifies the name of a particular option (e.g. `-background` in the first example above). If information is to be returned about all options, as in the second example above, then `NULL` should be specified as the option name. `Tk_ConfigureInfo` sets `interp->result` to hold the proper value and returns `TCL_OK`. If an error occurs (because a bad option name was specified, for example) then `Tk_ConfigureInfo` stores an error message in `interp->result` and returns `TCL_ERROR`. In either case, the widget command procedure can leave `interp->result` as it is and return `code` as its completion code.

38.1.6 Tk_FreeOptions

The library procedure `Tk_FreeOptions` is usually invoked after a widget is deleted in order to clean up its widget record. For some option types, such as `TK_CONFIG_BORDER`, `Tk_ConfigureWidget` allocates resources which must eventually be freed. `Tk_FreeOptions` takes care of this:

```
void Tk_FreeOptions(Tk_ConfigSpec *specs, char *widgRec,
          Display *display, int flags);
```

`Specs` and `widgRec` should be the same as in calls to Tk_ConfigureWidget. `Display` identifies the X display containing the widget (it's needed for freeing certain options) and `flags` should normally be 0 (see the reference documentation for other possibilities). `Tk_FreeOptions` will scan `specs` looking for entries such as `TK_CONFIG_BORDER` whose resources must be freed. For each such entry it checks the widget record to be sure a resource is actually allocated (for example, if the value of a string resource is `NULL` it means that no memory is allocated). If there is a resource allocated then `Tk_FreeOptions` passes the value from the widget record to an appropriate procedure to free up the resource and resets the value in the widget record to a state such as `NULL` to indicate that it has been freed.

38.1.7 Other uses for configuration tables

Configuration tables can be used for other things besides widgets. They are suitable for any situation where textual information must be converted to an internal form and stored in fields of a structure, particularly if the information is specified in the same form as for widget options, e.g.

```
-background blue -width 1m
```

Tk uses configuration tables internally for configuring menu entries, for configuring canvas items, and for configuring display attributes of tags in text widgets.

38.2 Resource caches

The X window system provides a number of different resources for applications to use. Windows are one example of a resource; other examples are graphics contexts, fonts, pixmaps, colors, and cursors. An application must allocate resources before using them and free them when they're no longer needed. X was designed to make resource allocation and deallocation as cheap as possible, but it is still expensive in many situations because it requires communication with the X server (for example, font allocation requires communication with the server to make sure the font exists). If an application uses the same resource in several different places (e.g. the same font in many different windows) it is wasteful to allocate separate resources for each use: this wastes time communicating with the server and it wastes space in the X server to keep track of the copies of the resource.

Tk provides a collection of *resource caches* in order to reduce the costs of resource management. When your application needs a particular resource you shouldn't call Xlib to allocate it; call the corresponding Tk procedure instead. Tk keeps track of all the resources used by the application and allows them to be shared. If you use the same font in many different widgets, Tk will call X to allocate a font for the first widget, but it will re-use this font for all the other widgets. When the resource is no longer needed anywhere in the application (e.g. all the widgets using the font have been destroyed) then Tk will invoke the Xlib procedure to free up the resource. This approach saves time as well as memory in the X server.

If you allocate a resource through Tk you must treat it as read-only since it may be shared. For example, if you allocate a graphics context with `Tk_GetGC` you must not change the background color of the graphics context, since this would affect the other uses of the graphics context. If you need to modify a resource after creating it then you should not use Tk's resource caches; call Xlib directly to allocate the resource so that you can have a private copy.

Most of the resources for a widget are allocated automatically by `Tk_ConfigureWidget`, and `Tk_ConfigureWidget` uses the Tk resource caches. The following subsections describe how to use the Tk resource caches directly, without going through `Tk_ConfigureWidget`.

38.2.1 Graphics contexts

Graphics contexts are the resource that you are most likely to allocate directly. They are needed whenever you draw information on the screen and `Tk_ConfigureWidget` does not provide facilities for allocating them. Thus most widgets will need to allocate a few graphics contexts in their configure procedures. The procedure `Tk_GetGC` allocates a graphics context and is similar to the Xlib procedure `XCreateGC`:

```
GC Tk_GetGC(Tk_Window tkwin, unsigned long valueMask,
        XGCValues *valuePtr)
```

The `tkwin` argument specifies the window in which the graphics context will be used. `ValueMask` and `ValuePtr` specify the fields of the graphics context. `ValueMask` is an OR-ed combination of bits such as `GCForeground` or `GCFont` that indicate which fields of `valuePtr` are significant. `ValuePtr` specifies values of the selected fields. `Tk_GetGC` returns the X resource identifier for a graphics context that matches `valueMask` and `valuePtr`. The graphics context will have default values for all of the unspecified fields.

When you're finished with a graphics context you must free it by calling `Tk_FreeGC`:

```
Tk_FreeGC(Display *display, GC gc)
```

The `display` argument indicates the display for which the graphics context was allocated and the `gc` argument identifies the graphics context (`gc` must have been the return value from some previous call to `Tk_GetGC`). There must be exactly one call to `Tk_FreeGC` for each call to `Tk_GetGC`.

38.2.2 Other resources

Although resources other than graphics contexts are normally allocated and deallocated automatically by `Tk_ConfigureWidget` and `Tk_FreeOptions`, you can also allocate them explicitly using Tk library procedures. For each resource there are three procedures. The first procedure (such as `Tk_GetColor`) takes a textual description of the resource in the same way it might be specified as a configuration option and returns a suitable resource or an error. The second procedure (such as `Tk_FreeColor`) takes a resource allocated by the first procedure and frees it. The third procedure takes a resource and returns the textual description that was used to allocate it. The following resources are supported in this way:

Bitmaps: the procedures `Tk_GetBitmap`, `Tk_FreeBitmap`, and `Tk_NameOfBitmap` manage `Pixmap` resources with depth one. You can also invoke `Tk_DefineBitmap` to create new internally-defined bitmaps, and `Tk_SizeOfBitmap` returns the dimensions of a bitmap.

Colors : the procedures `Tk_GetColor`, `Tk_FreeColor`, and `Tk_NameOfColor` manage `XColor` structures. You can also invoke `Tk_GetColorByValue` to specify a color with integer intensities rather than a string.

Cursors: the procedures `Tk_GetCursor`, `Tk_FreeCursor`, and `Tk_NameOfCursor` manage `Cursor` resources. You can also invoke `Tk_GetCursorFromData` to define a cursor based on binary data in the application.

Fonts: the procedures `Tk_GetFontStruct`, `Tk_NameOfFontStruct`, and `Tk_FreeFontStruct` manage `XFontStruct` structures.

3-D borders: the procedures `Tk_Get3DBorder`, `Tk_Free3DBorder`, and `Tk_NameOf3DBorder` manage `Tk_3DBorder` resources, which are used to draw objects with beveled edges that produce 3-D effects. Associated with these procedures are other procedures such as `Tk_Draw3DRectangle` that draw objects on the screen (see Section 40.3). In addition you can invoke `Tk_3DBorderColor` to retrieve the `XColor` structure for the border's base color.

38.3 Tk_Uids

When invoking procedures like `Tk_GetColor` you pass in a textual description of the resource to allocate, such as “`red`” for a color. However, this textual description is not a normal C string but rather a *unique identifier*, which is represented with the type `Tk_Uid`:

```
typedef char *Tk_Uid;
```

A `Tk_Uid` is like an atom in Lisp. It is actually a pointer to a character array, just like a normal C string, and a `Tk_Uid` can be used anywhere that a string can be used. However, `Tk_Uid`’s have the property that any two `Tk_Uid`’s with the same string value also have the same pointer value: if `a` and `b` are `Tk_Uid`’s and

```
(strcmp(a,b) == 0)
```

then

```
(a == b)
```

Tk uses `Tk_Uid`’s to specify resources because they permit fast comparisons for equality.

If you use `Tk_ConfigureWidget` to allocate resources then you won’t have to worry about `Tk_Uid`’s (Tk automatically translates strings from the configuration table into `Tk_Uid`’s). But if you call procedures like `Tk_GetColor` directly then you’ll need to use `Tk_GetUid` to turn strings into unique identifiers:

```
Tk_Uid Tk_GetUid(char *string)
```

Given a string argument, `Tk_GetUid` returns the corresponding `Tk_Uid`. It just keeps a hash table of all unique identifiers that have been used so far and returns a pointer to the key stored in the hash table.

Note: If you pass strings directly to procedures like `Tk_GetColor` *without converting them to unique identifiers then you will get unpredictable results. One common symptom is that the application uses the same resource over and over even though you think you’ve specified different values for each use. Typically what happens is that the same string buffer was used to store all of the different values. Tk just compares the string address rather than its contents, so the values appear to Tk to be the same.*

38.4 Other translators

Tk provides several other library procedures that translate from strings in various forms to internal representations. These procedures are similar to the resource managers in Section 38.2 except that the internal forms are not resources that require freeing, so typically there is just a “get” procedure and a “name of” procedure with no “free” procedure. Below is a quick summary of the availabile translators (see the reference documentation for details):

Anchors: `Tk_GetAnchor` and `Tk_NameOfAnchor` translate between strings containing an anchor positions such as “`center`” or “`ne`” and integers with values defined by symbols such as `TK_ANCHOR_CENTER` or `TK_ANCHOR_NE`.

Cap styles: `Tk_GetCapStyle` and `Tk_NameOfCapStyle` translate betwen strings containing X cap styles ("`butt`", "`projecting`", or "`round`") and integers with values defined by the X symbols `CapButt`, `CapProjecting`, and `CapRound`.

Join styles: `Tk_JoinStyle` and `Tk_NameOfJoinStyle` translate between strings containing X join styles ("`bevel`", "`miter`", or "`round`") and integers with values defined by the X symbols `JoinBevel`, `JoinMiter`, and `JoinRound`.

Justify styles: `Tk_GetJustify` and `Tk_NameOfJustify` translate between strings containing styles of justification ("`left`", "`right`", "`center`", or "`fill`") and integers with values defined by the symbols `TK_JUSTIFY_LEFT`, `TK_JUSTI-FY_RIGHT`, `TK_JUSTIFY_CENTER`, and `TK_JUSTIFY_FILL`.

Reliefs: `Tk_GetRelief` and `Tk_NameOfRelief` translate between strings containing relief names ("`raised`", "`sunken`", "`flat`", "`groove`", or "`ridge`") and integers with values defined by the symbols `TK_RELIEF_RAISED`, `TK_RELIEF_-SUNKEN`, etc.

Screen distances: `Tk_GetPixels` and `Tk_GetScreenMM` process strings that contain screen distances in any of the forms described in Section XXX, such as "`1.5m`" or "`2`". `Tk_GetPixels` returns an integer result in pixel units, and `Tk_GetScreenMM` returns a real result whose units are millimeters.

Window names: `Tk_NameToWindow` translates from a string containing a window path name such as "`.dlg.quit`" to the `Tk_Window` token for the corresponding window.

X atoms: `Tk_InternAtom` and `Tk_GetAtomName` translate between strings containing the names of X atoms (e.g. "RESOURCE_MANAGER") and X `Atom` tokens. Tk keeps a cache of atom names to avoid communication with the X server.

38.5 Changing window attributes

Tk provides a collection of procedures for modifying a window's attributes (e.g. background color or cursor) and configuration (e.g. position or size). These procedures are summarized in Table 38.2. The procedures have the same arguments as the Xlib procedures with corresponding names. They perform the same functions as the Xlib procedures except that they also retain a local copy of the new information so that it can be returned by the macros described in Section 37.5. For example, `Tk_ResizeWindow` is similar to the Xlib procedure `XResizeWindow` in that it modifies the dimensions of a window. However, it also remembers the new dimensions so they can be accessed with the `Tk_Width` and `Tk_Height` macros.

Only a few of the procedures in Table 38.2, such as `Tk_SetWindowBackground`, are normally invoked by widgets. Widgets should definitely *not* invoke procedures like

`Tk_ChangeWindowAttributes(Tk_Window tkwin, unsigned int value-Mask, XSetWindowAttributes *attsPtr)`
`Tk_ConfigureWindow(Tk_Window tkwin, unsigned int valueMask, XWindowChanges *valuePtr)`
`Tk_DefineCursor(Tk_Window tkwin, Cursor cursor)`
`Tk_MoveWindow(Tk_Window tkwin, int x, int y)`
`Tk_MoveResizeWindow(Tk_Window tkwin, int x, int y, unsigned int width, unsigned int height)`
`Tk_ResizeWindow(Tk_Window tkwin, unsgined int width, unsigned int height)`
`Tk_SetWindowBackground(Tk_Window tkwin, unsigned long pixel)`
`Tk_SetWindowBackgroundPixmap(Tk_Window tkwin, Pixmap pixmap)`
`Tk_SetWindowBorder(Tk_Window tkwin, unsigned long pixel)`
`Tk_SetWindowBorderPixmap(Tk_Window tkwin, Pixmap pixmap)`
`Tk_SetWindowBorderWidth(Tk_Window tkwin, int width)`
`Tk_SetWindowColormap(Tk_Window tkwin, Colormap colormap)`
`Tk_UndefineCursor(Tk_Window tkwin)`

Table 38.2. Tk procedures for modifying attributes and window configuration information. `Tk_ChangeWindowAttributes` and `Tk_ConfigureWindow` allow any or all of the attributes or configuration to be set at once (`valueMask` selects which values should be set); the other procedures set selected fields individually.

`Tk_MoveWindow` or `Tk_ResizeWindow`: only geometry managers should change the size or location of a window.

38.6 The square configure procedure

Figure 38.1 contains the code for the square widget's configure procedure. Its `argv` argument contains pairs of strings that specify configuration options.Most of the work is done by `Tk_ConfigureWidget`. Once `Tk_ConfigureWidget` returns, `Configur-`

```
int ConfigureSquare(Tcl_Interp *interp, Square *squarePtr,
        int argc, char *argv[], int flags) {
    if (Tk_ConfigureWidget(interp, squarePtr->tkwin, configSpecs,
            argc, argv, (char *) squarePtr, flags) != TCL_OK) {
        return TCL_ERROR;
    }
    Tk_SetWindowBackground(squarePtr->tkwin,
            Tk_3DBorderColor(squarePtr->bgBorder));
    if (squarePtr->gc == None) {
        XGCValues gcValues;
        gcValues.function = GXcopy;
        gcValues.graphics_exposures = False;
        squarePtr->gc = Tk_GetGC(squarePtr->tkwin,
                GCFunction|GCGraphicsExposures, &gcValues);
    }
    Tk_GeometryRequest(squarePtr->tkwin, 200, 150);
    Tk_SetInternalBorder(squarePtr->tkwin,
            squarePtr->borderWidth);
    if (!squarePtr->updatePending) {
        Tk_DoWhenIdle(DisplaySquare, (ClientData) squarePtr);
        squarePtr->updatePending = 1;
    }
    return TCL_OK;
}
```

Figure 38.1. The configure procedure for square widgets. It is invoked by the creation procedure and by the widget command procedure to set and modify configuration options.

`eSquare` extracts the color associated with the `-background` option and calls `Tk_SetWindowBackground` to use it as the background color for the widget's window. Then it allocates a graphics context that will be used during redisplay to copy bits from an off-screen pixmap into the window (unless some previous call to the procedure has already allocated the graphics context). Next `ConfigureSquare` calls `Tk_GeometryRequest` and `Tk_SetInternalBorderWidth` to provide information to its geometry manager (this will be discussed in Chapter 43). Finally, it arranges for the widget to be redisplayed; this will be discussed in Chapter 40.

38.7 The square widget command procedure

Figures 38.2 and 38.3 contain the C code for `SquareWidgetCommand`, which implements widget commands for square widgets. The main portion of the procedure consists of a series of `if` statements that compare `argv[1]` successively to "`configure`", "`position`", and "`size`", which are the three widget commands defined for squares. If

```
int SquareWidgetCmd(ClientData clientData, Tcl_Interp *interp,
        int argc, char *argv[]) {
    Square *squarePtr = (Square *) clientData;
    int result = TCL_OK;

    if (argc < 2) {
        Tcl_AppendResult(interp, "wrong # args: should be \"",
                argv[0], " option ?arg arg ...?\"",
                (char *) NULL);
        return TCL_ERROR;
    }

    Tk_Preserve((ClientData) squarePtr);
    if (strcmp(argv[1], "configure") == 0) {
        if (argc == 2) {
            result = Tk_ConfigureInfo(interp, squarePtr->tkwin,
                    (char *) squarePtr, (char *) NULL, 0);
        } else if (argc == 3) {
            result = Tk_ConfigureInfo(interp, squarePtr->tkwin,
                    (char *) squarePtr, argv[2], 0);
        } else {
            result = ConfigureSquare(interp, squarePtr,
                    argc-2, argv+2, TK_CONFIG_ARGV_ONLY);
        }
    } else if (strcmp(argv[1], "position") == 0) {
        if ((argc != 2) && (argc != 4)) {
            Tcl_AppendResult(interp,"wrong # args: should be \"",
                    argv[0], " position ?x y?\"", (char *) NULL);
            goto error;
        }
        if (argc == 4) {
            if ((Tk_GetPixels(interp, squarePtr->tkwin,
                    argv[2], &squarePtr->x) != TCL_OK) ||
                    (Tk_GetPixels(interp, squarePtr->tkwin,
                    argv[3], &squarePtr->y) != TCL_OK)) {
                goto error;
            }
            KeepInWindow(squarePtr);
        }
        sprintf(interp->result, "%d %d", squarePtr->x,
                squarePtr->y);
    } else if (strcmp(argv[1], "size") == 0) {
```

Figure 38.2. The widget command procedure for square widgets. Continued in Figure 38.3.

```
    if ((argc != 2) && (argc != 3)) {
            Tcl_AppendResult(interp, "wrong # args: should be \"",
                    argv[0], " size ?amount?\"", (char *) NULL);
            goto error;
        }
        if (argc == 3) {
            int i;
            if (Tk_GetPixels(interp, squarePtr->tkwin, argv[2],
                    &i) != TCL_OK) {
                goto error;
            }
            if ((i <= 0) || (i > 100)) {
                Tcl_AppendResult(interp, "bad size \"", argv[2],
                        "\"", (char *) NULL);
                goto error;
            }
            squarePtr->size = i;
            KeepInWindow(squarePtr);
        }
        sprintf(interp->result, "%d", squarePtr->size);
    } else {
        Tcl_AppendResult(interp, "bad option \"", argv[1],
                "\": must be configure, position, or size",
                (char *) NULL);
        goto error;
    }
    if (!squarePtr->updatePending) {
        Tk_DoWhenIdle(DisplaySquare, (ClientData) squarePtr);
        squarePtr->updatePending = 1;
    }
    Tk_Release((ClientData) squarePtr);
    return result;

    error:
    Tk_Release((ClientData) squarePtr);
    return TCL_ERROR;
}
```

Figure 38.3. The widget command procedure for square widgets, continued from Figure 38.2.

`argv[1]` matches one of these strings then the corresponding code is executed; otherwise an error is generated.

The `configure` widget command is handled in one three ways, depending on how many additional arguments it receives. If at most one additional argument is provided then `SquareWidgetCmd` calls `Tk_ConfigureInfo` to create descriptive information for one or all of the widget's configuration options. If two or more additional arguments are

```
void KeepInWindow(Square *squarePtr) {
    int i, bd;
    bd = 0;
    if (squarePtr->relief != TK_RELIEF_FLAT) {
        bd = squarePtr->borderWidth;
    }
    i = (Tk_Width(squarePtr->tkwin) - bd)
            - (squarePtr->x + squarePtr->size);
    if (i < 0) {
        squarePtr->x += i;
    }
    i = (Tk_Height(squarePtr->tkwin) - bd)
            - (squarePtr->y + squarePtr->size);
    if (i < 0) {
        squarePtr->y += i;
    }
    if (squarePtr->x < bd) {
        squarePtr->x = bd;
    }
    if (squarePtr->y < bd) {
        squarePtr->y = bd;
    }
}
```

Figure 38.4. The `KeepInWindow` procedure adjusts the location of the square to make sure that it is visible in the widget's window.

provided then `SquareWidgetCmd` passes the additional arguments to `ConfigureSquare` for processing; `SquareWidgetCmd` specifies the `TK_CONFIG_ARGV_ONLY` flag, which `ConfigureSquare` passes on to `Tk_ConfigureWidget` so that options not specified explicitly by `argv` are left as-is.

The `position` and `size` widget commands change the geometry of the square displayed in the widget, and they have similar implementations. If new values for the geometry are specified then each command calls `Tk_GetPixels` to convert the argument(s) to pixel distances. The `size` widget command also checks to make sure that the new size is within a particular range of values. Then both commands invoke `KeepInWindow`, which adjusts the position of the square if necessary to ensure that it is fully visible in the widget's window (see Figure 38.4). Finally, the commands print the current values into `interp->result` to return them as result.

`SquareWidgetCmd` invokes the procedures `Tk_Preserve` and `Tk_Release` as a way of preventing the widget record from being destroyed while the widget command is executing. Chapter 41 will discuss these procedures in more detail. The square widget is so simple that the calls aren't actually needed, but virtually all real widgets do need them so I put them in `SquareWidgetCmd` too.

Chapter 39
Events

This chapter describes Tk's library procedures for event handling. The code you'll write for event handling divides into three parts. The first part consists of code that creates event handlers: it informs Tk that certain callback procedures should be invoked when particular events occur. The second part consists of the callbacks themselves. The third part consists of top-level code that invokes the Tk event dispatcher to process events.

Tk supports three kinds of events: X events, file events (e.g. a particular file has just become readable), and timer events. Tk also allows you to create *idle callbacks*, which cause procedures to be invoked when Tk runs out of other things to do; idle callbacks are used to defer redisplays and other computations until all pending events have been processed. Tk's procedures for event handling are summarized in Table 39.1.

If you are not already familiar with X events, I recommend reading about them in your favorite Xlib documentation before reading this chapter.

39.1 X events

The X window server generates a number of different events to report interesting things that occur in the window system, such as mouse presses or changes in a window's size. Chapter XXX showed how you can use Tk's `bind` command to write event handlers as Tcl scripts. This section describes how to write event handlers in C. Typically you'll only use C handlers for four kinds of X events:

`Expose`: these events notify the widget that part or all of its window needs to be redisplayed.

`void Tk_CreateEventHandler(Tk_Window tkwin, unsigned long mask, Tk_EventProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked whenever any of the events selected by `mask` occurs for `tkwin`.
`void Tk_DeleteEventHandler(Tk_Window tkwin, unsigned long mask, Tk_EventProc *proc, ClientData clientData)`	Deletes the event handler that matches `mask`, `proc`, and `clientData`, if such a handler exists.
`void Tk_CreateFileHandler(int fd, int mask, Tk_FileProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked whenver one of the conditions indicated by `mask` occurs for the file whose descriptor number is `fd`.
`void Tk_DeleteFileHandler(int fd)`	Deletes the file handler for `fd`, if one exists.
`Tk_TimerToken Tk_CreateTimerHandler(int milliseconds, Tk_TimerProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked after `milliseconds` have elapsed. Returns a token that can be used to cancel the callback.
`void Tk_DeleteTimerHandler(Tk_TimerToken token)`	Cancels the timer callback indicated by `token`, if it hasn't yet triggered.
`void Tk_DoWhenIdle(Tk_IdleProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked when Tk has nothing else to do.
`void Tk_CancelIdleCall(Tk_IdleProc *proc, ClientData clientData)`	Deletes any existing idle callbacks for `idleProc` and `clientData`.
`void Tk_CreateGenericHandler(Tk_GenericProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked whenever any X event is received by this process.
`void Tk_DeleteGenericHandler(Tk_GenericProc *proc, ClientData clientData)`	Deletes the generic handler given by `proc` and `clientData`, if such a handler exists.
`void Tk_MainLoop(void)`	Processes events until there are no more windows left in this process.
`int Tk_DoOneEvent(int flags)`	Processes a single event of any sort and then returns. `Flags` is normally 0 but may be used to restrict the events that will be processed or to return immediately if there are no pending events.

Table 39.1. A summary of the Tk library procedures for event handling.

ConfigureNotify: these events occur when the window's size or position changes so that it can adjust its layout accordingly (e.g. centered text may have to be repositioned).

FocusIn and FocusOut: these events notify the widget that it has gotten or lost the input focus, so it can turn on or off its insertion cursor.

DestroyNotify: these events notify the widget that its window has been destroyed, so it should free up the widget record and any associated resources.

The responses to these events are all relatively obvious and it is unlikely that a user or application developer would want to deal with the events so it makes sense to hard-code the responses in C. For most other events, such as key presses and mouse actions, it's better to define the handlers in Tcl with the bind command. As a widget writer you can create class bindings to give the widget its default behavior, then users can modify the class bindings or augment them with additional widget-specific bindings. By using Tcl as much as possible you'll make your widgets more flexible.

The procedure Tk_CreateEventHandler is used by widgets to register interest in X events:

```
void Tk_CreateEventHandler(Tk_Window tkwin, unsigned long
mask,
        Tk_EventProc *proc, ClientData clientData);
```

The tkwin argument identifies a particular window and mask is an OR'ed combination of bits like KeyPressMask and StructureNotifyMask that select the events of interest (refer to Xlib documentation for details on the mask values that are available). When one of the requested events occurs for tkwin Tk will invoke proc to handle the event. Proc must match the following prototype:

```
typedef void Tk_EventProc(ClientData clientData, XEvent
*eventPtr);
```

Its first argument will be the same as the clientData value that was passed to Tk_CreateEventHandler and the second argument will be a pointer to a structure containing information about the event (see your Xlib documentation for details on the contents of an XEvent structure). There can exist any number of event handlers for a given window and mask but there can be only one event handler with a particular tkwin, mask, proc, and clientData. If a particular event matches the tkwin and mask for more than one handler then all of the matching handlers are invoked, in the order in which they were created.

For example, the C code for the square widget deals with Expose, ConfigureNotify, and DestroyNotify events. To process these events, the following code is present in the create procedure for squares (see Figure 37.1 on page 335):

```
Tk_CreateEventHandler(squarePtr->tkwin,
        ExposureMask|StructureNotifyMask,
        SquareEventProc, (ClientData) squarePtr);
```

```
void SquareEventProc(ClientData clientData, XEvent *eventPtr) {
    Square *squarePtr = (Square *) clientData;
    if (eventPtr->type == Expose) {
        if ((eventPtr->xexpose.count == 0)
                && !squarePtr->updatePending) {
            Tk_DoWhenIdle(DisplaySquare, (ClientData) squarePtr);
            squarePtr->updatePending = 1;
        }
    } else if (eventPtr->type == ConfigureNotify) {
        KeepInWindow(squarePtr);
        if (!squarePtr->updatePending) {
            Tk_DoWhenIdle(DisplaySquare, (ClientData) squarePtr);
            squarePtr->updatePending = 1;
        }
    } else if (eventPtr->type == DestroyNotify) {
        Tcl_DeleteCommand(squarePtr->interp,
                Tk_PathName(squarePtr->tkwin));
        squarePtr->tkwin = NULL;
        if (squarePtr->flags & REDRAW_PENDING) {
            Tk_CancelIdleCall(DisplaySquare,
                    (ClientData) squarePtr);
        }
        Tk_EventuallyFree((ClientData) squarePtr, DestroySquare);
    }
}
```

Figure 39.1. The event procedure for square widgets.

The `ExposureMask` bit selects `Expose` events and `StructureNotifyMask` selects both `ConfigureNotify` and `DestroyNotify` events, plus several other types of events. The address of the widget's record is used as the `ClientData` for the callback, so it will be passed to `SquareEventProc` as its first argument.

Figure 39.1 contains the code for `SquareEventProc`, the event procedure for square widgets. Whenever an event occurs that matches `ExposureMask` or `StructureNotifyMask` Tk will invoke `SquareEventProc`. `SquareEventProc` casts its `clientData` argument back into a `Square *` pointer, then checks to see what kind of event occurred. For `Expose` events `SquareEventProc` arranges for the widget to be redisplayed. For `ConfigureNotify` events, `SquareEventProc` calls `KeepInWindow` to make sure that the square is still visible in the window (see Figure 38.4 on page 352), then `SquareEventProc` arranges for the widget to be redrawn. For `DestroyNotify` events `SquareEventProc` starts the process of destroying the widget and freeing its widget record; this process will be discussed in more detail in Chapter 41.

If you should need to cancel an existing X event handler you can invoke `Tk_DeleteEventHandler` with the same arguments that you passed to `Tk_CreateEventHandler` when you created the handler:

```
void Tk_DeleteEventHandler(Tk_Window tkwin, unsigned long
mask,
        Tk_EventProc *proc, ClientData clientData);
```

This deletes the handler corresponding to `tkwin`, `mask`, `proc`, and `clientData` so that its callback will not be invoked anymore. If no such handler exists then the procedure does nothing. Tk automatically deletes all of the event handlers for a window when the window is destroyed, so most widgets never need to call `Tk_DeleteEventHandler`.

39.2 File events

Event-driven programs like Tk applications should not block for long periods of time while executing any one operation, since this prevents other events from being serviced. For example, suppose that a Tk application attempts to read from its standard input at a time when no input is available. The application will block until input appears. During this time the process will be suspended by the operating system so it cannot service X events. This means, for example, that the application will not be able to respond to mouse actions nor will it be able to redraw itself. Such behavior is likely to be annoying to the user, since he or she expects to be able to interact with the application at any time.

File handlers provide an event-driven mechanism for reading and writing files that may have long I/O delays. The procedure `Tk_CreateFileHandler` creates a new file handler:

```
void Tk_CreateFileHandler(int fd, int mask, Tk_FileProc *proc,
        ClientData clientData);
```

The `fd` argument gives the number of a POSIX file descriptor (e.g. 0 for standard input, 1 for standard output, and so on). `Mask` indicates when `proc` should be invoked. It is an OR'ed combination of the following bits:

`TK_READABLE` means that Tk should invoke `proc` whenever there is data waiting to be read on `fd`;

`TK_WRITABLE` means that Tk should invoke `proc` whenever `fd` is capable of accepting more output data;

`TK_EXCEPTION` means that Tk should invoke `proc` whenever an exceptional condition is present for `fd`.

The callback procedure for file handlers must match the following prototype:

```
typedef void Tk_FileProc(ClientData clientData,
        int mask);
```

The clientData argument will be the same as the clientData argument to Tk_CreateFileHandler and mask will contain a combination of the bits TK_READABLE, TK_WRITABLE, and TK_EXCEPTION to indicate the state of the file at the time of the callback. There can exist only one file handler for a given file at a time; if you call Tk_CreateFileHandler at a time when there exists a handler for fd then the new handler replaces the old one.

Note: You can temporarily disable a file handler by setting its mask to 0. You can reset the mask later when you want to re-enable the handler.

To delete a file handler, call Tk_DeleteFileHandler with the same fd argument that was used to create the handler:

```
void Tk_DeleteFileHandler(int fd);
```

This removes the handler for fd so that its callback will not be invoked again.

With file handlers you can do event-driven file I/O. Rather than opening a file, reading it from start to finish, and then closing the file, you open the file, create a file handler for it, and then return. When the file is readable the callback will be invoked. It issues exactly one read request for the file, processes the data returned by the read, and then returns. When the file becomes readable again (perhaps immediately) then the callback will be invoked again. Eventually, when the entire file has been read, the file will become readable and the read call will return an end-of-file condition. At this point the file can be closed and the file handler deleted. With this approach, your application will still be able to respond to X events even if there are long delays in reading the file.

For example, wish uses a file handler to read commands from its standard input. The main program for wish creates a file handler for standard input (file descriptor 0) with the following statement:

```
...
Tk_CreateFileHandler(0, TK_READABLE, StdinProc, (ClientData)
NULL);
Tcl_DStringInit(&command);
...
```

In addition to creating the callback, this code initializes a dynamic string that will be used to buffer lines of input until a complete Tcl command is ready for evaluation. Then the main program enters the event loop as will be described in Section 39.6. When data becomes available on standard input StdinProc will be invoked. Its code is as follows:

```
void StdinProc(ClientData clientData, int mask) {
    int count, code;
    char input[1000];
    count = read(0, input, 1000);
    if (count <= 0) {
        ... handle errors and end of file ...
    }
    Tcl_DStringAppend(&command, input, count);
    if (Tcl_CmdComplete(Tcl_DStringValue(&command)) {
        code = Tcl_Eval(interp,
                Tcl_DStringValue(&command));
        Tcl_DStringFree(&command);
        ...
    }
    ...
}
```

After reading from standard input and checking for errors and end-of file, `StdinProc` adds the new data to the dynamic string's current contents. Then it checks to see if the dynamic string contains a complete Tcl command (it won't, for example, if a line such as "`foreach i $x {`" has been entered but the body of the `foreach` loop hasn't yet been typed). If the command is complete then `StdinProc` evaluates the command and clears the dynamic string for the next command.

Note: It is usually best to use non-blocking I/O with file handlers, just to be absolutely sure that I/O operations don't block. To request non-blocking I/O, specify the flag `O_NONBLOCK` *to the* `fcntl` *POSIX system call. If you use file handlers for writing to files with long output delays, such as pipes and network sockets, it's essential that you use use non-blocking I/O; otherwise if you supply too much data in a* `write` *system call the output buffers will fill and the process will be put to sleep.*

Note: For ordinary disk files it isn't necessary to use the event-driven approach described in this section, since reading and writing these files rarely incurs noticeable delays. File handlers are useful primarily for files like terminals, pipes, and network connections, which can block for indefinite periods of time.

39.3 Timer events

Timer events trigger callbacks after particular time intervals. For example, widgets use timer events to display blinking insertion cursors. When the cursor is first displayed in a widget (e.g. because it just got the input focus) the widget creates a timer callback that will trigger in a few tenths of a second. When the timer callback is invoked it turns the cursor off if it was on, or on if it was off, and then reschedules itself by creating a new timer callback that will trigger after a few tenths of a second more. This process repeats indefinitely so that the cursor blinks on and off. When the widget wishes to stop displaying the cursor altogether (e.g. because it has lost the input focus) it cancels the callback and turns the cursor off.

The procedure `Tk_CreateTimerHandler` creates a timer callback:

```
Tk_TimerToken Tk_CreateTimerHandler(int milliseconds,
        Tk_TimerProc *proc, ClientData clientData);
```

The `milliseconds` argument specifies how many milliseconds should elapse before the callback is invoked. `Tk_CreateTimerHandler` returns immediately, and its return value is a token that can be used to cancel the callback. After the given interval has elapsed Tk will invoke `proc`. `Proc` must match the following prototype:

```
void Tk_TimerProc(ClientData clientData);
```

Its argument will be the same as the `clientData` argument passed to `Tk_CreateTimerHandler`. `Proc` is only called once, then Tk deletes the callback automatically. If you want `proc` to be called over and over at regular intervals then `proc` should reschedule itself by calling `Tk_CreateTimerHandler` each time it is invoked.

Note: There is no guarantee that `proc` *will be invoked at exactly the specified time. If the application is busy processing other events when the specified time occurs then* `proc` *won't be invoked until the next time the application invokes the event dispatcher, as described in Section 39.6.*

`Tk_DeleteTimerHandler` cancels a timer callback:

```
void Tk_DeleteTimerHandler(Tk_TimerToken token);
```

It takes a single argument, which is a token returned by a previous call to `Tk_CreateTimerHandler`, and deletes the callback so that it will never be invoked. It is safe to invoke `Tk_DeleteTimerHandler` even if the callback has already been invoked; in this case the procedure has no effect.

39.4 Idle callbacks

The procedure `Tk_DoWhenIdle` creates an *idle callback*:

```
void Tk_DoWhenIdle(Tk_IdleProc *proc, ClientData clientData);
```

This arranges for `proc` to be invoked the next time the application becomes idle. The application is idle when Tk's main event-processing procedure, `Tk_DoOneEvent`, is called and no X events, file events, or timer events are ready. Normally when this occurs `Tk_DoOneEvent` will suspend the process until an event occurs. However, if there exist idle callbacks then all of them are invoked. Idle callbacks are also invoked when the `update` Tcl command is invoked. The `proc` for an idle callback must match the following prototype:

```
typedef void Tk_IdleProc(ClientData clientData);
```

It returns no result and takes a single argument, which will be the same as the `clientData` argument passed to `Tk_DoWhenIdle`.

`Tk_CancelIdleCall` deletes an idle callback so that it won't be invoked after all:

```
void Tk_CancelIdleCall(Tk_IdleProc *proc, ClientData
clientData);
```

`Tk_CancelIdleCall` deletes all of the idle callbacks that match `idleProc` and `clientData` (there can be more than one). If there are no matching idle callbacks then the procedure has no effect.

Idle callbacks are used to implement the delayed operations described in Section XXX. The most common use of idle callbacks in widgets is for redisplay. It is generally a bad idea to redisplay a widget immediately when its state is modified, since this can result in multiple redisplays. For example, suppose the following set of Tcl commands is invoked to change the color, size, and location of a square widget `.s`:

```
.s configure -foreground purple
.s size 2c
.s position 1.2c 3.1c
```

Each of these commands modifies the widget in a way that requires it to be redisplayed, but it would be a bad idea for each command to redraw the widget. This would result in three redisplays, which are unnecessary and can cause the widget to flash as it steps through a series of changes. It is much better to wait until all of the commands have been executed and then redisplay the widget once. Idle callbacks provide a way of knowing when all of the changes have been made: they won't be invoked until all available events have been fully processed.

For example, the square widget uses idle callbacks for redisplaying itself. Whenever it notices that it needs to be redrawn it invokes the following code:

```
if (!squarePtr->updatePending) {
    Tk_DoWhenIdle(DisplaySquare, (ClientData) squarePtr);
    squarePtr->updatePending = 1;
}
```

This arranges for `DisplaySquare` to be invoked as an idle handler to redraw the widget. The `updatePending` field of the widget record keeps track of whether `DisplaySquare` has already been scheduled, so that it will only be scheduled once. When `DisplaySquare` is finally invoked it resets `updatePending` to zero.

39.5 Generic event handlers

The X event handlers described in Section 39.1 only trigger when particular events occur for a particular window managed by Tk. Generic event handlers provide access to events that aren't associated with a particular window, such as `MappingNotify` events, and to events for windows not managed by Tk (such as those in other applications). Generic event handlers are rarely needed and should be used sparingly.

To create a generic event handler, call `Tk_CreateGenericHandler`:

```
void Tk_CreateGenericHandler(Tk_GenericProc *proc,
        ClientData clientData);
```

This will arrange for `proc` to be invoked whenever any X event is received by the application. `Proc` must match the following prototype:

```
typedef int Tk_GenericProc(ClientData clientData,
        XEvent *eventPtr);
```

Its `clientData` argument will be the same as the `clientData` passed to `Tk_CreateGenericHandler` and `eventPtr` will be a pointer to the X event. Generic handlers are invoked before normal event handlers, and if there are multiple generic handlers then they are called in the order in which they were created. Each generic handler returns an integer result. If the result is non-zero it indicates that the handler has completely processed the event and no further handlers, either generic or normal, should be invoked for the event.

The procedure `Tk_DeleteGenericHandler` deletes generic handlers:

```
Tk_DeleteGenericHandler(Tk_GenericProc *proc,
        ClientData clientData);
```

Any generic handlers that match `proc` and `clientData` are removed, so that `proc` will not be invoked anymore.

Note: `Tk_CreateGenericHandler` *does nothing to ensure that the desired events are actually sent to the application. For example, if an application wishes to respond to events for a window in some other application then it must invoke* `XSelectInput` *to notify the X server that it wants to receive the events. Once the events arrive, Tk will dispatch them to the generic handler. However, an application should never invoke* `XSelectInput` *for a window managed by Tk, since this will interfere with Tk's event management.*

39.6 Invoking the event dispatcher

The preceding sections described the first two parts of event management: creating event handlers and writing callback procedures. The final part of event management is to invoke the Tk event dispatcher, which waits for events to occur and invokes the appropriate callbacks. If you don't invoke the dispatcher then no events will be processed and no callbacks will be invoked.

Tk provides two procedures for event dispatching: `Tk_MainLoop` and `Tk_DoOneEvent`. Most applications only use `Tk_MainLoop`. It takes no arguments and returns no result and it is typically invoked once, in the main program after initialization. `Tk_MainLoop` calls the Tk event dispatcher repeatedly to process events. When all available events have been processed it suspends the process until more events occur, and it repeats this over and over. It returns only when every `Tk_Window` created by the process has been deleted (e.g. after the "`destroy .`" command has been executed). A typical main program for a Tk application will create a Tcl interpreter, call `Tk_CreateMainWindow` to create a Tk application plus its main window, perform other application-specific initialization (such as evaluating a Tcl script to create the application's interface), and then call `Tk_MainLoop`. When `Tk_MainLoop` returns the main program exits. Thus Tk provides top-level control over the application's execution and all of the application's useful work is carried out by event handlers invoked via `Tk_MainLoop`.

The second procedure for event dispatching is `Tk_DoOneEvent`, which provides a lower level interface to the event dispatcher:

```
int Tk_DoOneEvent(int flags)
```

The `flags` argument is normally 0 (or, equivalently, `TK_ALL_EVENTS`). In this case `Tk_DoOneEvent` processes a single event and then returns 1. If no events are pending then `Tk_DoOneEvent` suspends the process until an event arrives, processes that event, and then returns 1.

For example, `Tk_MainLoop` is implemented using `Tk_DoOneEvent`:

```
void Tk_MainLoop(void) {
    while (tk_NumMainWindows > 0) {
        Tk_DoOneEvent(0);
    }
}
```

The variable `tk_NumMainWindows` is maintained by Tk to count the total number of main windows (i.e. applications) managed by this process. `Tk_MainLoop` just calls `Tk_DoOneEvent` over and over until all the main windows have been deleted.

`Tk_DoOneEvent` is also used by commands such as `tkwait` that want to process events while waiting for something to happen. For example, the "`tkwait window`" command processes events until a given window has been deleted, then it returns. Here is the C code that implements this command:

```
int done;
...
Tk_CreateEventHandler(tkwin, StructureNotifyMask,
WaitWindowProc,
        (ClientData) &done);
done = 0;
while (!done) {
    Tk_DoOneEvent(0);
}
...
```

The variable `tkwin` identifies the window whose deletion is awaited. The code creates an event handler that will be invoked when the window is deleted, then invokes `Tk_DoOneEvent` over and over until the `done` flag is set to indicate that `tkwin` has been deleted. The callback for the event handler is as follows:

```
void WaitWindowProc(ClientData clientData, XEvent *eventPtr) {
    int *donePtr = (int *) clientData;
    if (eventPtr->type == DestroyNotify) {
        *donePtr = 1;
    }
}
```

The `clientData` argument is a pointer to the flag variable. `WaitWindowProc` checks to make sure the event is a `DestroyNotify` event (`StructureNotifyMask` also selects several other kinds of events, such as `ConfigureNotify`) and if so it sets the flag variable to one.

The `flags` argument to `Tk_DoOneEvent` can be used to restrict the kinds of events it will consider. If it contains any of the bits `TK_X_EVENTS`, `TK_FILE_EVENTS`, `TK_TIMER_EVENTS`, or `TK_IDLE_EVENTS`, then only the events indicated by the specified bits will be considered. Furthermore, if `flags` includes the bit `TK_DONT_-WAIT`, or if no X, file, or timer events are requested, then `Tk_DoOneEvent` won't suspend the process; if no event is ready to be processed then it will return immediately with a 0 result to indicate that it had nothing to do. For example, the "`update idletasks`" command is implemented with the following code, which uses the `TK_IDLE_EVENTS` flag:

```
while (Tk_DoOneEvent(TK_IDLE_EVENTS) != 0) {
    /* empty loop body */
}
```

Chapter 40
Displaying Widgets

Tk provides relatively little support for actually drawing things on the screen. For the most part you just use Xlib functions like `XDrawLine` and `XDrawString`. The only procedures provided by Tk are those summarized in Table 40.1, which create three-dimensional effects by drawing light and dark shadows around objects (they will be discussed more in Section 40.3). This chapter consists mostly of a discussion of techniques for delaying redisplays and for using pixmaps to double-buffer redisplays. These techniques reduce redisplay overheads and help produce smooth visual effects with mimimum flashing.

40.1 Delayed redisplay

The idea of delayed redisplay was already introduced in Section 39.4. Rather than redrawing the widget every time its state is modified, you should use `Tk_DoWhenIdle` to schedule the widget's display procedure for execution later, when the application has finished processing all available events. This allows any other pending changes to the widget to be completed before it's redrawn.

Delayed redisplay requires you to keep track of what to redraw. For simple widgets such as the square widget or buttons or labels or entries, I recommend the simple approach of redrawing the entire widget whenever you redraw any part of it. This eliminates the need to remember which parts to redraw and it will have fine performance for widgets like the ones mentioned above.

For larger and more complex widgets like texts or canvases it isn't practical to redraw the whole widget after each change. This can take a substantial amount of time and cause annoying delays, particularly for operations like dragging where redisplays happen many

```
void Tk_Fill3DRectangle(Display *display, Drawable drawable,
    Tk_3DBorder border, int x, int y, int width, int height,
    int borderWidth, int relief)
```

Fills the area of `drawable` given by `x`, `y`, `width`, and `height` with the background color from `border`, then draws a 3-D border `borderWidth` pixels wide around (but just inside) the rectangle. `Relief` specifies the 3-D appearance of the border.

```
void Tk_Draw3DRectangle(Display *display, Drawable drawable,
    Tk_3DBorder border, int x, int y, int width, int height,
    int borderWidth, int relief)
```

Same as `Tk_Fill3DRectangle` except only draws the border.

```
void Tk_Fill3DPolygon(Display *display, Drawable drawable,
    Tk_3DBorder border, XPoint *pointPtr, int numPoints,
    int borderWidth, int leftRelief)
```

Fills the area of a polygon in `drawable` with the background color from `border`. The polygon is specified by `pointPtr` and `numPoints` and need not be closed. Also draws a 3-D border around the polygon. `Border-Width` specifies the width of the border, measured in pixels to the left of the polygon's trajectory (if negative then the border is drawn on the right). `LeftRelief` specifies the 3-D appearance of the border (e.g. `TK_RELIE-F_RAISED` means the left side of the trajectory appears higher than the right).

```
void Tk_Fill3DPolygon(Display *display, Drawable drawable,
    Tk_3DBorder border, XPoint *pointPtr, int numPoints,
    int borderWidth, int leftRelief)
```

Same as `Tk_Fill3DPolygon`, except only draws the border without filling the interior of the polygon.

Table 40.1. A summary of Tk's procedures for drawing 3-D effects.

times per second. For these widgets you should keep information in the widget record about which parts of the widget need to be redrawn. The display procedure can then use this information to redraw only the affected parts.

I recommend recording what to redraw in the simplest (coarsest) way that gives adequate performance. Keeping redisplay information on a very fine grain is likely to add complexity to your widgets and probably won't improve performance noticeably over a coarser mechanism. For example, the Tk text widget does not record what to redraw on a character-by-character basis; instead, it keeps track of which lines on the screen need to be redrawn. The minimum amount that is ever redrawn is one whole line. Most redisplays only involve one or two lines, and today's workstations are fast enough to redraw hundreds of lines per second, so the widget can keep up with the user even if redraws are occurring dozens of times a second (such as when the user is dragging one end of the selection). Tk's canvases optimize redisplay by keeping a rectangular bounding box that includes all of the modified objects. If two small objects at opposite corners of the window are modified simultaneously then the redisplay area will include the entire window, but this doesn't happen very often. In more common cases, such as dragging a single small object, the bounding box approach requires only a small fraction of the window's area to be redrawn.

40.2 Double-buffering with pixmaps

If you want to achieve smooth dragging and other visual effects then you should not draw graphics directly onto the screen, because this tends to cause annoying flashes. The reason for the flashes is that widgets usually redisplay themselves by first clearing an area to its background color and then drawing the foreground objects. While you're redrawing the widget the monitor is continuously refreshing itself from display memory. Sometimes the widget will be refreshed on the screen after it has been cleared but before the objects have been redrawn. For this one screen refresh the widget will appear to be empty; by the time of the next refresh you'll have redrawn all the objects so they'll appear again. The result is that the objects in the widget will appear to flash off, then on. This flashing is particularly noticeable during dynamic actions such as dragging or animation where redisplays happen frequently.

To avoid flashing it's best to use a technique called *double-buffering*, where you redisplay in two phases using an off-screen pixmap. The display procedure for the square widget, shown in Figure 40.1, uses this approach. It calls `XCreatePixmap` to allocate a pixmap the size of the window, then it calls `Tk_Fill3DRectangle` twice to redraw the widget in the pixmap. Once the widget has been drawn in the pixmap, the contents are copied to the screen by calling `XCopyArea`. With this approach the screen makes a smooth transition from the widget's previous state to its new state. It's still possible for the screen to refresh itself during the copy from pixmap to screen but each pixel will be drawn in either its correct old value or its correct new value.

Note: *If you compile the square widget into* `wish` *you can use the dragging script from Section 36.4 to compare double-buffering with drawing directly on the screen. To make a version of the square widget that draws directly on the screen, just delete the calls to* `XCreatePixmap`, `XCopyArea`, *and* `XFreePixmap` *in* `DisplaySquare` *and replace the* `pm` *arguments to* `Tk_Fill3DRectangle` *with* `TkWindowId(tkwin)`. *Or, you can use the version of the square widget that comes with the Tk distribution; it has a* `-dbl` *option that you can use to turn double-buffering on and off dynamically.*

40.3 Drawing procedures

Tk provides only four procedures for actually drawing graphics on the screen, which are summarized in Table 40.1. These procedures make it easy to produce the three-dimensional effects required for Motif widgets, where light and dark shadows are drawn around objects to make them look raised or sunken.

```
void DisplaySquare(ClientData clientData) {
    Square *squarePtr = (Square *) clientData;
    Tk_Window tkwin = squarePtr->tkwin;
    Pixmap pm;
    squarePtr->updatePending = 0;
    if (!Tk_IsMapped(tkwin)) {
        return;
    }
    pm = XCreatePixmap(Tk_Display(tkwin), Tk_WindowId(tkwin),
            Tk_Width(tkwin), Tk_Height(tkwin), Tk_Depth(tkwin));
    Tk_Fill3DRectangle(Tk_Display(tkwin), pm, squarePtr->bgBorder
         0, 0, Tk_Width(tkwin), Tk_Height(tkwin),
        squarePtr->borderWidth, squarePtr->relief);
    Tk_Fill3DRectangle(Tk_Display(tkwin), pm, squarePtr->fgBorder,
        squarePtr->x, squarePtr->y, squarePtr->size, squarePtr-
>size,
        squarePtr->borderWidth, squarePtr->relief);
    XCopyArea(Tk_Display(tkwin), pm, Tk_WindowId(tkwin),
        squarePtr->copyGC, 0, 0, Tk_Width(tkwin), Tk_Height(tkwin),
        0, 0);
    XFreePixmap(Tk_Display(tkwin), pm);
}
```

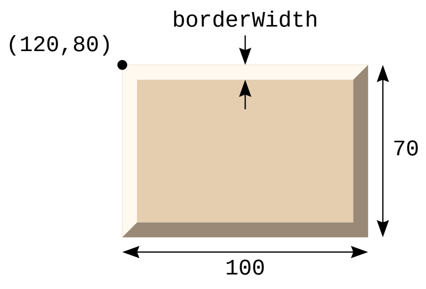
Figure 40.1. The display procedure for square widgets. It first clears `squarePtr->updatePending` to indicate that there is no longer an idle callback for `DisplaySquare` scheduled, then it makes sure that the window is mapped (if not then there's no need to redisplay). It then redraws the widget in an off-screen pixmap and copies the pixmap onto the screen when done.

Before using any of the procedures in Table 40.1 you must allocate a `Tk_3DBorder` object. A `Tk_3DBorder` records three colors (a base color for "flat" background surfaces and lighter and darker colors for shadows) plus X graphics contexts for displaying objects using those colors. Chapter 38 described how to allocate `Tk_3DBorders`, for example by using a configuration table entry of type `TK_CONFIG_BORDER` or by calling `Tk_Get3DBorder`.

Once you've created a `Tk_3DBorder` you can call `Tk_Fill3DRectangle` to draw rectangular shapes with any of the standard reliefs:

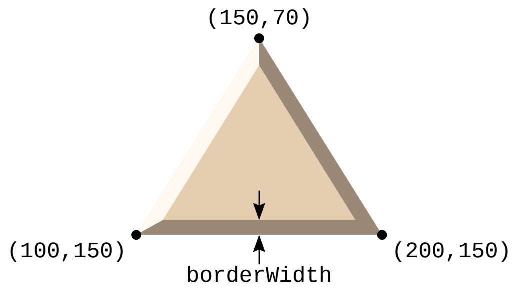
```
void Tk_Fill3DRectangle(Display *display, Drawable drawable,
        Tk_3DBorder border, int x, int y,int width, int
height,
        int borderWidth, int relief);
```

The `display` and `drawable` arguments specify the pixmap or window where the rectangle will be drawn. `Display` is usually specified as `Tk_Display(tkwin)` where `tkwin` is the window being redrawn. `Drawable` is usually the off-screen pixmap being used for display, but it can also be `Tk_WindowId(tkwin)`. `Border` specifies the col-



```
Tk_Fill3DRectangle(display,
drawable,
    border, 120, 80, 100, 70,
    borderWidth,
TK_RELIEF_RAISED);
```

(a)



```
static XPoint points[] =
{{200,150},
    {150,70}, {100,150}};
Tk_Fill3DPolygon(display,
drawable,
```

(b)

Figure 40.2. Figure (a) shows a call to `Tk_Fill3DRectangle` and the graphic that is produced; the border is drawn entirely inside the rectangular area. Figure (b) shows a call to `Tk_Fill3DPolygon` and the resulting graphic. The relief `TK_RELIEF_RAISED` specifies that the left side of the path should appear higher than the right, and that the border should be drawn entirely on the left side of the path if `borderWidth` is positive.

ors to be used for drawing the rectangle. `X`, `y`, `width`, `height`, and `borderWidth` specify the geometry of the rectangle and its border, all in pixel units (see Figure 40.2). Lastly, `relief` specifies the desired 3D effect, such as `TK_RELIEF_RAISED` or `TK_RELIEF_RIDGE`. `Tk_Fill3DRectangle` first fills the entire area of the rectangle with the “flat” color from `border` then it draws light and dark shadows `borderWidth` pixels wide around the edge of the rectangle to produce the effect specified by `relief`.

`Tk_Fill3DPolygon` is similar to `Tk_Fill3DRectangle` except that it draws a polygon instead of a rectangle:

```
void Tk_Fill3DPolygon(Display *display, Drawable drawable,
        Tk_3DBorder border, XPoint *pointPtr, int numPoints,
        int borderWidth, int leftRelief);
```

`Display`, `drawable`, and `border` all have the same meaning as for `Tk_Fill3-DRectangle`. `PointPtr` and `numPoints` define the polygon’s shape (see your Xlib documentation for information about `XPoint` structures) and `borderWidth` gives the width of the border, all in pixel units. `LeftRelief` defines the relief of the left side of the polygon’s trajectory relative to its right side. For example, if `leftRelief` is specified as `TK_RELIEF_RAISED` then the left side of the trajectory will appear higher than the right side. If `leftRelief` is `TK_RELIEF_RIDGE` or `TK_RELIEF_GROOVE` then the border will be centered on the polygon's trajectory; otherwise it will be drawn on the left side of the polygon's trajectory if `borderWidth` is positive and on the right side if `borderWidth` is negative. See Figure 40.2 for an example.

The procedures `Tk_Draw3DRectangle` and `Tk_Draw3DPolygon` are similar to `Tk_Fill3DRectangle` and `Tk_Fill3DPolygon` except that they only draw the border without filling the interior of the rectangle or polygon.

Chapter 41
Destroying Widgets

This chapter describes how widgets should clean themselves up when they are destroyed. For the most part widget destruction is fairly straightforward: it's just a matter of freeing all of the resources associated with the widget. However, there is one complicating factor, which is that a widget might be in use at the time it is destroyed. This leads to a two-phase approach to destruction where some of the cleanup may have to be delayed until the widget is no longer in use. Tk's procedures for window destruction, most of which have to do with delayed cleanup, are summarized in Table 41.1.

41.1 Basics

Widgets can be destroyed in three different ways. First, the `destroy` Tcl command can be invoked; it destroys one or more widgets and all of their descendants in the window hierarchy. Second, C code in the application can invoke `Tk_DestroyWindow`, which has the same effect as the `destroy` command:

```
void Tk_DestroyWindow(Tk_Window tkwin);
```

`Tk_DestroyWindow` is not invoked very often but it is used, for example, to destroy a new widget immediately if an error is encountered while configuring it (see Figure 37.1 on page 373). The last way for a widget to be destroyed is for someone to delete its X window directly. This does not occur very often, and is not generally a good idea, but in some cases it may make sense for a top-level window to be deleted externally (by the window manager, for example).

`void Tk_DestroyWindow(Tk_Window tkwin)`	Destroys `tkwin` and all of its descendants in the widget hierarchy.
`void Tk_Preserve(ClientData clientData)`	Makes sure that `clientData` will not be freed until a matching call to `Tk_Release` has been made.
`void Tk_Release(ClientData clientData)`	Cancels a previous `Tk_Preserve` call for `clientData`. May cause `clientData` to be freed.
`void Tk_EventuallyFree(ClientData clientData Tk_FreeProc *freeProc)`	Invokes `freeProc` to free up `clientData` unless `Tk_Preserve` has been called for it; in this case `freeProc` won't be invoked until each `Tk_Preserve` call has been cancelled with a call to `Tk_Release`.

Table 41.1. A summary of the Tk library procedures for destroying widgets and delaying object cleanup.

A widget should handle all of these forms of window destruction in the same way using a handler for `DestroyNotify` events. Tk makes sure that a `DestroyNotify` event is generated for each window that is destroyed and doesn't free up its `Tk_Window` structure until after the handlers for the event have been invoked. When a widget receives a `DestroyNotify` event it typically does four things to clean itself up:

1. It deletes the widget command for the widget by calling `Tcl_DeleteCommand`.
2. It cancels any idle callbacks and timer handlers for the widget, such as the idle callback to redisplay the widget.
3. It frees any resources allocated for the widget. Most of this can be done by calling `Tk_FreeOptions`, but widgets usually have a few resources such as graphics contexts that are not directly associated with configuration options.
4. It frees the widget record.

For square widgets the first two of these actions are carried out in the event procedure, and the third and fourth actions are carried out in a separate procedure called `DestroySquare`. `DestroySquare` is the *destroy procedure* for square widgets; it is invoked indirectly from the event procedure using the mechanism discussed in Section 41.2 below. Its code is shown in Figure 41.1.

41.2 Delayed cleanup

The most delicate aspect of widget destruction is that the widget could be in use at the time it is destroyed; special precautions must be taken to delay most of the widget cleanup

```
void DestroySquare(ClientData clientData) {
    Square *squarePtr = (Square *) clientData;
    Tk_FreeOptions(configSpecs, (char *) squarePtr,
            squarePtr->display, 0);
    if (squarePtr->gc != None) {
        Tk_FreeGC(squarePtr->display, squarePtr->gc);
    }
    free((char *) squarePtr);
}
```

Figure 41.1. The destroy procedure for square widgets.

until the widget is no longer in use. For example, suppose that a dialog box `.dlg` contains a button that is created with the following command:

```
button .dlg.quit -text Quit -command "destroy .dlg"
```

The purpose of this button is to destroy the dialog box. Now suppose that the user clicks on the button with the mouse. The binding for `<ButtonRelease-1>` invokes the button's `invoke` widget command:

```
.dlg.quit invoke
```

The `invoke` widget command evaluates the button's `-command` option as a Tcl script, which destroys the dialog and all its descendants, including the button itself. When the button is destroyed a `DestroyNotify` event is generated, which causes the button's event procedure to be invoked to clean up the destroyed widget. Unfortunately it is not safe for the event procedure to free the button's widget record because the `invoke` widget command is still pending on the call stack: when the event procedure returns, control will eventually return back to the widget command procedure, which may need to reference the widget record. If the event procedure frees the widget record then the widget command procedure will make wild references into memory. Thus in this situation it is important to wait until the widget command procedure completes before freeing the widget record.

However, a button widget might also be deleted at a time when there is no `invoke` widget command pending (e.g. the user might click on some other button, which destroys the entire application). In this case the cleanup must be done by the event procedure since there won't be any other opportunity for the widget to clean itself up. In other cases there could be several nested procedures each of which is using the widget record, so it won't be safe to clean up the widget record until the last of these procedures finishes.

In order to handle all of these cases cleanly Tk provides a mechanism for keeping track of whether an object is in use and delaying its cleanup until it is no longer being used. `Tk_Preserve` is invoked to indicate that an object is in use and should not be freed:

```
void Tk_Preserve(ClientData clientData);
```

The clientData argument is a token for an object that might potentially be freed; typically it is the address of a widget record. For each call to Tk_Preserve there must eventually be a call to Tk_Release:

```
void Tk_Release(ClientData clientData);
```

The clientData argument should be the same as the corresponding argument to Tk_Preserve. Each call to Tk_Release cancels a call to Tk_Preserve for the object; once all calls to Tk_Preserve have been cancelled it is safe to free the object.

When Tk_Preserve and Tk_Release are being used to manage an object you should call Tk_EventuallyFree to free the object:

```
void Tk_EventuallyFree(ClientData clientData,
        Tk_FreeProc *freeProc);
```

ClientData must be the same as the clientData argument used in calls to Tk_Preserve and Tk_Release, and freeProc is a procedure that actually frees the object. FreeProc must match the following prototype:

```
typedef void Tk_FreeProc(ClientData clientData);
```

Its clientData argument will be the same as the clientData argument to Tk_EventuallyFree. If the object hasn't been protected with calls to Tk_Preserve then Tk_EventuallyFree will invoke freeProc immediately. If Tk_Preserve has been called for the object then freeProc won't be invoked immediately; instead it will be invoked later when Tk_Release is called. If Tk_Preserve has been called multiple times then freeProc won't be invoked until each of the calls to Tk_Preserve has been cancelled by a separate call to Tk_Release.

I recommend that you use these procedures in the same way as in the square widget. Place a call to Tk_Preserve at the beginning of the widget command procedure and a call to Tk_Release at the end of the widget command procedure, and be sure that you don't accidentally return from the widget command procedure without calling Tk_Release, since this would prevent the widget from ever being freed. Then divide the widget cleanup code into two parts. Put the code to delete the widget command, idle callbacks, and timer handlers directly into the event procedure; this code can be executed immediately without danger, and it prevents any new invocations of widget code. Put all the code to cleanup the widget record into a separate delete procedure like DestroySquare, and call Tk_EventuallyFree from the event procedure with the delete procedure as its freeProc argument.

This approach is a bit conservative but it's simple and safe. For example, most widgets have only one or two widget commands that could cause the widget to be destroyed, such as the invoke widget command for buttons. You could move the calls to Tk_Preserve and Tk_Release so that they only occur around code that might destroy the widget, such as a Tcl_GlobalEval call. This will save a bit of overhead by eliminating calls to Tk_Preserve and Tk_Release where they're not needed. However, Tk_Preserve and Tk_Release are fast enough that this optimization won't save much time and it means you'll constantly have to be on the lookout to add more calls to

`Tk_Preserve` and `Tk_Release` if you modify the widget command procedure. If you place the calls the beginning and end of the procedure you can make any modifications you wish to the procedure without having to worry about issues of widget cleanup. In fact, the square widget doesn't need calls to `Tk_Preserve` and `Tk_Release` at all, but I put them in anyway so that I won't have to remember to add them later if I modify the widget command procedure.

For most widgets the only place you'll need calls to `Tk_Preserve` and `Tk_Release` is in the widget command procedure. However, if you invoke procedures like `Tcl_Eval` anywhere else in the widget's code then you'll need additional `Tk_Preserve` and `Tk_Release` calls there too. For example, widgets like canvases and texts implement their own event binding mechanisms in C code; these widgets must invoke `Tk_Preserve` and `Tk_Release` around the calls to event handlers.

The problem of freeing objects while they're in use occurs in many contexts in Tk applications. For example, it's possible for the `-command` option for a button to change the button's `-command` option. This could cause the memory for the old value of the option to be freed while it's still being evaluated by the Tcl interpreter. To eliminate this problem the button widget evaluates a copy of the script rather than the original. In general whenever you make a call whose behavior isn't completely predictable, such as a call to `Tcl_Eval` and its cousins, you should think about all the objects that are in use at the time of the call and take steps to protect them. In some simple cases making local copies may be the simplest solution, as with the `-command` option; in more complex cases I'd suggest using `Tk_Preserve` and `Tk_Release`; they can be used for objects of any sort, not just widget records.

Note: `Tk_Preserve` *and* `Tk_Release` *implement a form of short-term reference counts. They are implemented under the assumption that objects are only in use for short periods of time such as the duration of a particular procedure call, so that there are only a few protected objects at any given time. You should not use them for long-term reference counts where there might be hundreds or thousands of objects that are protected at a given time, since they will be very slow in these cases.*

Chapter 42
Managing the Selection

This chapter describes how to manipulate the X selection from C code. The low-level protocols for claiming the selection and transmitting it between applications are defined by X's Inter-Client Communications Convention Manual (ICCCM) and are very complicated. Fortunately Tk takes care of all the low-level details for you and provides three simpler operations that you can perform on the selection:

- Create a *selection handler*, which is a callback procedure that can supply the selection when it is owned in a particular window and retrieved with a particular target.
- Claim ownership of the selection for a particular window.
- Retrieve the selection from its current owner in a particular target form.

Each of these three operations can be performed either using Tcl scripts or by writing C code. Chapter XXX described how to manipulate the selection with Tcl scripts and much of that information applies here as well, such as the use of targets to specify different ways to retrieve the selection. Tcl scripts usually just retrieve the selection; claiming ownership and supplying the selection are rarely done from Tcl. In contrast, it's common to create selection handlers and claim ownership of the selection from C code but rare to retrieve the selection. See Table 42.1 for a summary of the Tk library procedures related to the selection.

42.1 Selection handlers

Each widget that supports the selection, such as an entry or text, must provide one or more *selection handlers* to supply the selection on demand when the widget owns it. Each han-

`Tk_CreateSelHandler(Tk_Window tkwin, Atom target, Tk_SelectionProc *proc, ClientData clientData, Atom format)`	Arranges for `proc` to be invoked whenever the selection is owned by `tkwin` and is retrieved in the form given by `target`. `Format` specifies the form in which Tk should transmit the selection to the requestor, and is usually `XA_STRING`.
`Tk_DeleteSelHandler(Tk_Window tkwin, Atom target)`	Removes the handler for `tkwin` and `target`, if one exists.
`Tk_OwnSelection(Tk_Window tkwin, Tk_LostSelProc *proc, ClientData clientData)`	Claims ownership of the selection for `tkwin` and notifies the previous owner, if any, that it has lost the selection. `Proc` will be invoked later when `tkwin` loses the selection.
`Tk_ClearSelection(Tk_Window tkwin)`	Cancels any existing selection for the display containing `tkwin`.
`int Tk_GetSelection(Tcl_Interp *interp, Tk_Window tkwin, Atom target, Tk_GetSelProc *proc, ClientData clientData)`	Retrieves the selection for `tkwin`'s display in the format specified by `target` and passes it to `proc` in one or more pieces. Returns `TCL_OK` or `TCL_ERROR` and leaves an error message in `interp->result` if an error occurs.

Table 42.1. A summary of Tk's procedures for managing the selection.

dler returns the selection in a particular target form. The procedure `Tk_CreateSelHandler` creates a new selection handler:

```
void Tk_CreateSelHandler(Tk_Window tkwin, Atom target,
        Tk_SelectionProc *proc, ClientData clientData,
        Atom format);
```

`Tkwin` is the window from which the selection will be provided; the handler will only be asked to supply the selection when the selection is owned by `tkwin`. `Target` specifies the target form in which the handler can supply the selection; the handler will only be invoked when the selection is retrieved with that target. `Proc` is the address of the handler callback, and `clientData` is a one-word value to pass to `proc`. `Format` tells Tk how to transmit the selection to the requestor and is usually `XA_STRING` (see the reference documentation for other possibilities).

The callback procedure for a selection handler must match the following prototype:

```
typedef int Tk_SelectionProc(ClientData clientData,
        int offset, char *buffer, int maxBytes);
```

The `clientData` argument will be the same as the `clientData` argument passed to `Tk_CreateSelHandler`; it is usually the address of a widget record. `Proc` should place a null-terminated string at `buffer` containing up to `maxBytes` of the selection starting at byte offset within the selection. The procedure should return a count of the number of non-null bytes copied, which must be maxBytes unless there are fewer than maxBytes left in the selection. If the widget no longer has a selection (because, for example, the user deleted the selected range of characters) the selection handler should return -1.

Usually the entire selection will be retrieved in a single request: offset will be 0 and maxBytes will be large enough to accommodate the entire selection. However, very large selections will be retrieved in transfers of a few thousand bytes each. Tk will invoke the callback several times using successively higher values of offset to retrieve successive portions of the selection. If the callback returns a value less than maxBytes it means that the entire remainder of the selection has been returned. If its return value is maxBytes it means that there may be additional information in the selection so Tk will call it again to retrieve the next portion. You can assume that maxBytes will always be at least a few thousand.

For example, Tk's entry widgets have a widget record of type Entry with three fields that are used to manage the selection:

string points to a null-terminated string containing the text in the entry;

selectFirst is the index in string of the first selected byte (or -1 if nothing is selected);

selectLast is the index of the last selected byte.

An entry will supply the selection in only one target form (STRING) so it only has a single selection handler. The create procedure for entries contains a statement like the following to create the selection handler, where entryPtr is a pointer to the widget record for the new widget:

```
Tk_CreateSelHandler(entryPtr->tkwin, XA_STRING,
        EntryFetchSelection, (ClientData) entryPtr,
        XA_STRING);
```

The callback for the selection handler is defined as follows:

```
int EntryFetchSelection(ClientData clientData, int offset,
        char *buffer, int maxBytes) {
    Entry *entryPtr = (Entry *) clientData;
    int count;
    if (entryPtr->selectFirst < 0) {
        return -1;
    }
    count = entryPtr->selectLast + 1 - entryPtr->selectFirst
        - offset;
    if (count > maxBytes) {
        count = maxBytes;
    }
    if (count <= 0) {
        count = 0;
    } else {
        strncpy(buffer, entryPtr->string
        + entryPtr->selectFirst + offset, count);
    }
    buffer[count] = 0;
    return count;
}
```

If a widget wishes to supply the selection in several different target forms it should create a selection handler for each target. When the selection is retrieved, Tk will invoke the handler for the target specified by the retriever.

Tk automatically provides handlers for the following targets:

`APPLICATION`: returns the name of the application, which can be used to `send` commands to the application containing the selection.

`MULTIPLE`: used to retrieve the selection in multiple target forms simultaneously. Refer to ICCCM documenation for details.

`TARGETS`: returns a list of all the targets supported by the current selection owner (including all the targets supported by Tk).

`TIMESTAMP`: returns the time at which the selection was claimed by its current owner.

`WINDOW_NAME`: returns the path name of the window that owns the selection.

A widget can override any of these default handlers by creating a handler of its own.

42.2 Claiming the selection

The previous section showed how a widget can supply the selection to a retriever. However, before a widget will be asked to supply the selection it must first claim ownership of the selection. This usually happens during widget commands that select something in the widget, such as the `select` widget command for entries and listboxes. To claim ownership of the selection a widget should call `Tk_OwnSelection`:

```
void Tk_OwnSelection(Tk_Window tkwin, Tk_LostSelProc *proc,
        (ClientData) clientData);
```

`Tk_OwnSelection` will communicate with the X server to claim the selection for `tkwin`; as part of this process the previous owner of the selection will be notified so that it can deselect itself. `Tkwin` will remain the selection owner until either some other window claims ownership, `tkwin` is destroyed, or `Tk_ClearSelection` is called. When `tkwin` loses the selection Tk will invoke `proc` so that the widget can deselect itself and display itself accordingly. `Proc` must match the following prototype:

```
typedef void Tk_LostSelProc(ClientData clientData);
```

The `clientData` argument will be the same as the `clientData` argument to `Tk_OwnSelection`; it is usually a pointer to the widget's record.

Note: `Proc` *will only be called if some other window claims the selection or if* `Tk_ClearSelection` *is invoked. It will not be called if the owning widget is destroyed.*

If a widget claims the selection and then eliminates its selection (for example, the selected text is deleted) the widget has three options. First, it can continue to service the selection and return 0 from its selection handlers; anyone who retrieves the selection will receive an empty string. Second, the widget can continue to service the selection and return -1 from its selection handlers; this will return an error (“no selection”) to anyone who attempts to retrieve it. Third, the widget can call `Tk_ClearSelection`:

```
void Tk_ClearSelection(Tk_Window tkwin);
```

The `tkwin` argument identifies a display. Tk will claim the selection away from whatever window owned it (either in this application or any other application on `tkwin`’s display) and leave the selection unclaimed, so that all attempts to retrieve it will result in errors. This approach will have the same effect returning -1 from the selection handlers except that the selection handlers will never be invoked at all.

42.3 Retrieving the selection

If an application wishes to retrieve the selection, for example to insert the selected text into an entry, it usually does so with the “`selection get`” Tcl command. This section describes how to retrieve the selection at C level, but this facility is rarely needed. The only situation where I recommend writing C code to retrieve the selection is in cases where the selection may be very large and a Tcl script may be noticeably slow. This might occur in a text widget, for example, where a user might select a whole file in one window and then copy it into another window. If the selection has hundreds of thousands of bytes then a C implementation of the retrieval will be noticeably faster than a Tcl implementation.

To retrieve the selection from C code, invoke the procedure `Tk_GetSelection`:

```
typedef int Tk_GetSelection(Tcl_Interp *interp,
        Tk_Window tkwin, Atom target, Tk_GetSelProc *proc,
        ClientData clientData);
```

The `interp` argument is used for error reporting. `Tkwin` specifies the window on whose behalf the selection is being retrieved (it selects a display to use for retrieval), and `target` specifies the target form for the retrieval. `Tk_GetSelection` doesn’t return the selection directly to its caller. Instead, it invokes `proc` and passes it the selection. This makes retrieval a bit more complicated but it allows Tk to buffer data more efficiently. Large selections will be retrieved in several pieces, with one call to `proc` for each piece. `Tk_GetSelection` normally returns `TCL_OK` to indicate that the selection was successfully retrieved. If an error occurs then it returns `TCL_ERROR` and leaves an error message in `interp->result`.

`Proc` must match the following prototype:

```
typedef int Tk_GetSelProc(ClientData clientData,
        Tcl_Interp *interp, char *portion);
```

The `clientData` and `interp` arguments will be the same as the corresponding arguments to `Tk_GetSelection`. `Portion` points to a null-terminated ASCII string containing part or all of the selection. For small selections a single call will be made to `proc` with the entire contents of the selection. For large selections two or more calls will be made with successive portions of the selection. `Proc` should return `TCL_OK` if it successfully processes the current portion of the selection. If it encounters an error then it should return `TCL_ERROR` and leave an error message in `interp->result`; the selection retrieval will be aborted and this same error will be returned to `Tk_GetSelection`'s caller.

For example, here is code that retrieves the selection in target form `STRING` and prints it on standard output:

```
    ...
    if (Tk_GetSelection(interp, tkwin,
            Tk_InternAtom(tkwin, "STRING"), PrintSel,
            (ClientData) stdout) != TCL_OK) {
        ...
    }
    ...
int PrintSel(ClientData clientData, Tcl_Interp *interp,
        char *portion) {
    FILE *f = (FILE *) clientData;
    fputs(portion, f);
    return TCL_OK;
}
```

The call to `Tk_GetSelection` could be made, for example, in the widget command procedure for a widget, where `tkwin` is the `Tk_Window` for the widget and `interp` is the interpreter in which the widget command is being processed. The `clientData` argument is used to pass a `FILE` pointer to `PrintSel`. The output could be written to a different file by specifying a different `clientData` value.

Chapter 43
Geometry Management

Tk provides two groups of library procedures for geometry management. The first group of procedures implements a communication protocol between slave windows and their geometry managers. Each widget calls Tk to provide geometry information such as the widget's preferred size and whether or not it has an internal grid. Tk then notifies the relevant geometry manager, so that the widget does not have to know which geometry manager is responsible for it. Each geometry manager calls Tk to identify the slave windows it will manage, so that Tk will know who to notify when geometry information changes for the slaves. The second group of procedures is used by geometry managers to place slave windows. It includes facilities for mapping and unmapping windows and for setting their sizes and locations. All of these procedures are summarized in Table 43.1.

43.1 Requesting a size for a widget

Each widget is responsible for informing Tk of its geometry needs; Tk will make sure that this information is forwarded to any relevant geometry managers. There are three pieces of information that the slave can provide: requested size, internal border, and grid. The first piece of information is provided by calling `Tk_GeometryRequest`:

```
void Tk_GeometryRequest(Tk_Window tkwin, int width, height);
```

This indicates that the ideal dimensions for `tkwin` are `width` and `height`, both specified in pixels. Each widget should call `Tk_GeometryRequest` once when it is created and again whenever its preferred size changes (such as when its font changes); normally the calls to `Tk_GeometryRequest` are made by the widget's configure procedure. In

`Tk_GeometryRequest(Tk_Window tkwin, int width, int height)`	Informs the geometry manager for tkwin that the preferred dimensions for `tkwin` are `width` and `height`.
`Tk_SetInternalBorder(Tk_Window tkwin, int width)`	Informs any relevant geometry managers that `tkwin` has an internal border `width` pixels wide and that slave windows should not be placed in this border region.
`Tk_SetGrid(Tk_Window tkwin, int reqWidth, int reqHeight, int widthInc, int heightInc)`	Turns on gridded geometry management for `tkwin`'s top-level window and specifies the grid geometry. The dimensions requested by `Tk_GeometryRequest` correspond to grid dimensions of `reqWidth` and `reqHeight`, and `widthInc` and `heightInc` specify the dimensions of a single grid cell.
`Tk_ManageGeometry(Tk_Window tkwin, Tk_GeometryProc *proc, ClientData clientData)`	Arranges for `proc` to be invoked whenever `Tk_GeometryRequest` is invoked for `tkwin`. Used by geometry managers to claim ownership of a slave window.
`int Tk_ReqHeight(Tk_Window tkwin)`	Returns the height specified in the most recent call to `Tk_GeometryRequest` for `tkwin` (this is a macro, not a procedure).
`int Tk_ReqWidth(Tk_Window tkwin)`	Returns the width specified in the most recent call to `Tk_GeometryRequest` for `tkwin` (this is a macro, not a procedure).
`int Tk_InternalBorderWidth(Tk_Window tkwin)`	Returns the border width specified in the most recent call to `Tk_InternalBorderWidth` for `tkwin` (this is a macro, not a procedure).
`Tk_MapWindow(Tk_Window tkwin)`	Arranges for `tkwin` to be displayed on the screen whenever its ancestors are mapped.
`Tk_UnmapWindow(Tk_Window tkwin)`	Prevents `tkwin` and its descendants from appearing on the screen.
`Tk_MoveWindow(Tk_Window tkwin, int x, int y)`	Positions `tkwin` so that its upper-left pixel (including any borders) appears at coordinates `x` and `y` in its parent.
`Tk_MoveResizeWindow(Tk_Window tkwin, int x, int y, unsigned int width, unsigned int height)`	Changes `tkwin`'s position within its parent and also its size.
`Tk_ResizeWindow(Tk_Window tkwin, unsigned int width, unsigned int height)`	Sets the inside dimensions of `tkwin` (not including its external border, if any) to `width` and `height`.

Table 43.1. A summary of Tk's procedures for geometry management.

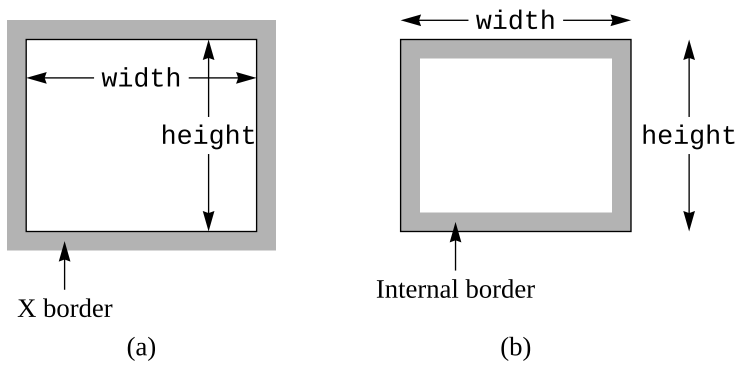


Figure 43.1. X borders and internal borders. (a) shows an official X border, which is drawn by X outside the area of the window. (b) shows an internal border drawn by a widget, where the area occupied by the border is part of the window's official area. In both figures `width` and `height` are the official X dimensions of the window.

addition, geometry managers will sometimes call `Tk_GeometryRequest` on a window's behalf. For example, the packer resets the requested size for each master window that it manages to match the needs of all of its slaves. This overrides the requested size set by the widget and results in the shrink-wrap effects shown in Chapter XXX.

43.2 Internal borders

The X window system allows each window to have a border that appears just outside the window. The official height and width of a window are the inside dimensions, which describe the usable area of the window and don't include the border. Unfortunately, though, X requires the entire border of a window to be drawn with a single solid color or stipple. To achieve the Motif three-dimensional effects, the upper and left parts of the border have to be drawn differently than the lower and right parts. This means that X borders can't be used for Motif widgets. Instead, Motif widgets draw their own borders, typically using Tk procedures such as `Tk_Draw3DRectangle`. The border for a Motif widget is drawn around the perimeter of the widget but inside the official X area of the widget. This kind of border is called an *internal border.* Figure 43.1 shows the difference between external and internal borders.

If a widget has an internal border then its usable area (the part that's inside the border) is smaller than its official X area. This complicates geometry management in two ways. First, each widget has to include the border width (actually, twice the border width) in the width and height that it requests via `Tk_GeometryRequest`. Second, if a master window has an internal border then geometry managers should not place slave windows on top of the border; the usable area for arranging slaves should be the area inside the border. In order for this to happen the geometry managers must know about the presence of the internal border. The procedure `Tk_SetInternalBorder` is provided for this purpose:

```
void Tk_SetInternalBorder(Tk_Window tkwin, int width);
```

This tells geometry managers that `tkwin` has an internal border that is `width` pixels wide and that slave widgets should not overlap the internal border. Widgets with internal borders normally call `Tk_SetInternalBorder` in their configure procedures at the same time that they call `Tk_GeometryRequest`. If a widget uses a normal X border, or if it has an internal border but doesn't mind slaves being placed on top of the border, then it need not call `Tk_SetInternalBorder`, or it can call it with a `width` of 0.

43.3 Grids

Gridded geometry management was introduced in Section XXX. The goal is to allow the user to resize a top-level window interactively, but to constrain the resizing so that the window's dimensions always lie on a grid. Typically this means that a particular subwindow displaying fixed-width text always has a width and height that are an integral number of characters. The window manager implements constrained resizes, but the application must supply it with the geometry of the grid. In order for this to happen, the widget that determines the grid geometry must call `Tk_SetGrid`:

```
void Tk_SetGrid(Tk_Window tkwin, int gridWidth, int
gridHeight,
          int widthInc, int heightInc);
```

The `gridWidth` and `gridHeight` arguments specify the number of grid units corresponding to the pixel dimensions requested in the most recent call to `Tk_GeometryRequest`. They allow the window manager to display the window's current size in grid units rather than pixels. The `widthInc` and `heightInc` arguments specify the number of pixels in a grid unit. Tk passes all of this information on to the window manager, and it will then constrain interactive resizes so that `tkwin`'s top-level window always has dimensions that lie on a grid defined by its requested geometry, `gridWidth`, and `gridHeight`.

Widgets that support gridding, such as texts, normally have a `-setgrid` option . If `-setgrid` is 0 then the widget doesn't call `Tk_SetGrid`; this is done if gridded resizing isn't wanted (e.g. the widget uses a variable-width font) or if some other widget in the top-level window is to be the one that determines the grid. If `-setgrid` is 1 then the widget calls `Tk_SetGrid`; typically this happens in the configure procedure at the same time that other geometry-related calls are made. If the widget's grid geometry changes (for example, its font might change) then the widget calls `Tk_SetGrid` again.

43.4 Geometry managers

The remainder of this chapter describes the Tk library procedures that are used by geometry managers. It is intended to provide the basic information that you need to write a new geometry manager. This section provides an overview of the structure of a geometry manager and the following sections describe the Tk library procedures.

A typical geometry manager contains four main procedures. The first procedure is a command procedure that implements the geometry manager's Tcl command. Typically each geometry manager provides a single command that is used by the application designer to provide information to the geometry manager: `pack` for the packer, `place` for the placer, and so on. The command procedure collects information about each slave and master window managed by the geometry manager and allocates a C structure for each window to hold the information. For example, the packer uses a structure with two parts. The first part is used if the window is a master; it includes information such as a list of slaves for that master. The second part is used if the window is a slave; it includes information such as the side against which the slave is to be packed and padding and filling information. If a window is both a master and a slave then both parts are used. Each geometry manager maintains a hash table (using Tcl's hash table facilities) that maps from widget names to the C structure for geometry management.

The second procedure for a geometry manager is its *layout procedure*. This procedure contains all of the actual geometry calculations. It uses the information in the structures created by the command procedure, plus geometry information provided by all of the slaves, plus information about the current dimensions of the master. The layout procedure typically has two phases. In the first phase it scans all of the slaves for a master, computes the ideal size for the master based on the needs of its slaves, and calls `Tk_GeometryRequest` to set the requested size of the master to the ideal size. This phase only exists for geometry managers like the packer that reflect geometry information upwards through the widget hierarchy. For geometry managers like the placer, the first phase is skipped. In the second phase the layout procedure recomputes the geometries for all of the slaves of the master.

The third procedure is a *request callback* that Tk invokes whenever a slave managed by the geometry manager calls `Tk_GeometryRequest`. The callback arranges for the layout procedure to be executed, as will be described below.

The final procedure is an event procedure that is invoked when a master window is resized or when a master or slave window is destroyed. If a master window is resized then the event procedure arranges for the layout procedure to be executed to recompute the geometries of all of its slaves. If a master or slave window is destroyed then the event procedure deletes all the information maintained by the geometry manager for that window. The command procedure creates event handlers that cause the event procedure to be invoked.

The layout procedure must be invoked after each call to the command procedure, the request callback, or the event procedure. Usually this is done with an idle callback, so that the layout procedure doesn't actually execute until all pending work is completed. Using an idle callback can save a lot of time in situations such as the initial creation of a complex panel. In this case the command procedure will be invoked once for each of many slave windows, but there won't be enough information to compute the final layout until all of the invocations have been made for all of the slaves. If the layout procedure were invoked immediately it would just waste time computing layouts that will be discarded almost immediately. With the idle callback, layout is deferred until complete information is available for all of the slaves.

43.5 Claiming ownership

A geometry manager uses the procedure `Tk_ManageGeometry` to indicate that it wishes to manage the geometry for a given slave window:

```
void Tk_ManageGeometry(Tk_Window tkwin, Tk_GeometryProc *proc,
        ClientData clientData);
```

From this point on, whenever `Tk_GeometryRequest` is invoked for `tkwin`, Tk will invoke `proc`. There can be only one geometry manager for a slave at a given time, so any previous geometry manager is cancelled. A geometry manager can also disown a slave by calling `Tk_ManageGeometry` with a null value for `proc`. `Proc` must match the following prototype:

```
typedef void Tk_GeometryProc(ClientData clientData,
        Tk_Window tkwin);
```

The `clientData` and `tkwin` arguments will be the same as those passed to `Tk_ManageGeometry`. Usually `Tk_ManageGeometry` is invoked by the command procedure for a geometry manager, and usually `clientData` is a pointer to the structure holding the geometry manager's information about `tkwin`.

43.6 Retrieving geometry information

When a widget calls `Tk_GeometryRequest` or `Tk_SetInternalBorder` Tk saves the geometry information in its data structure for the widget. The geometry manager's layout procedure can retrieve the requested dimensions of a slave with the macros `Tk_ReqWidth` and `Tk_ReqHeight`, and it can retrieve the width of a master's internal border with the macro `Tk_InternalBorderWidth`. It can also retrieve the master's actual dimensions with the `Tk_Width` and `Tk_Height` macros, which were originally described in Section 37.5.

Note: *Geometry managers need not worry about the gridding information provided with the* `Tk_SetGrid` *procedure. This information doesn't affect geometry managers at all. It is simply passed on to the window manager for use in controlling interactive resizes.*

43.7 Mapping and setting geometry

A geometry manager does two things to control the placement of a slave window. First, it determines whether the slave window is mapped or unmapped, and second, it sets the size and location of the window.

X allows a window to exist without appearing on the screen. Such a window is called *unmapped*: neither it nor any of its descendants will appear on the screen. In order for a window to appear, it and all of its ancestors (up through the nearest top-level window) must be *mapped*. All windows are initially unmapped. When a geometry manager takes responsibility for a window it must map it by calling `Tk_MapWindow`:

```
void Tk_MapWindow(Tk_Window tkwin);
```

Usually the geometry manager will call `Tk_MapWindow` in its layout procedure once it has decided where the window will appear. If a geometry manager decides not to manage a window anymore (e.g. in the "`pack forget`" command) then it must unmap the window to remove it from the screen:

```
void Tk_UnmapWindow(Tk_Window tkwin);
```

Some geometry managers may temporarily unmap windows during normal operation. For example, the packer unmaps a slave if there isn't enough space in its master to display it; if the master is enlarged later then the slave will be mapped again.

Tk provides three procedures that a geometry manager's layout procedure can use to position slave windows:

```
void Tk_MoveWindow(Tk_Window tkwin, int x, int y);
void Tk_ResizeWindow(Tk_Window tkwin, unsigned int width,
        unsigned int height);
void Tk_MoveResizeWindow(Tk_Window tkwin, int x, int y,
        unsigned int width, unsigned int height);
```

`Tk_MoveWindow` moves a window so that its upper left corner appears at the given location in its parent; `Tk_ResizeWindow` sets the dimensions of a window without moving it; and `Tk_MoveResize` both moves a window and changes its dimensions.

The position specified to `Tk_MoveWindow` or `Tk_MoveResizeWindow` is a position in the slave's parent. However, most geometry managers allow the master for a slave to be not only its parent but any descendant of the parent. Typically the layout procedure will compute the slave's location relative to its master; before calling `Tk_MoveWindow` or `Tk_MoveResizeWindow` it must translate these coordinates to the coordinate system of the slave's parent. The following code shows how to transform coordinates `x` and `y` from the master to the parent, assuming that `slave` is the slave window and `master` is its master:

```
int x, y;
Tk_Window slave, master, parent, ancestor;
...
for (ancestor = master; ancestor != Tk_Parent(slave);
        ancestor = Tk_Parent(ancestor)) {
```

```
        x += Tk_X(ancestor) + Tk_Changes(ancestor)->border_width;
        y += Tk_Y(ancestor) + Tk_Changes(ancestor)->border_width;
    }
```