Tcl3D: Doing 3D with Tcl

www.tcl3d.org

1 INTRODUCTION....................2
1.1 Architecture overview....................2
1.2 Modules overview....................3
1.3 Supported platforms....................5
1.4 Getting started....................6
2 INSTALLATION....................9
2.1 Installation of a binary distribution....................10
2.2 Installation of a source distribution....................11
2.3 Extending Tcl3D....................16
3 WRAPPING IN DETAIL....................18
3.1 Wrapping description....................18
3.2 Wrapping reference card....................23
4 MODULES IN DETAIL....................24
4.1 tcl3dOgl->Togl: Enhanced Togl widget....................24
4.2 tcl3dOgl->OpenGL: Wrapper for OpenGL functionality....................27
4.3 tcl3dOgl->Util: Tcl3D utility library....................30
4.4 tcl3dCg: Wrapper for NVidia's Cg shading language....................46
4.5 tcl3dSDL: Wrapper for the Simple DirectMedia Library....................46
4.6 tcl3dFTGL: Wrapper for the OpenGL Font Rendering Library....................47
4.7 tcl3dGl2ps: Wrapper for the OpenGL To Postscript Library....................48
4.8 tcl3dOde: Wrapper for the Open Dynamics Engine....................48
4.9 tcl3dGauges: Tcl3D package for displaying gauges....................49
5 MISCELLANEOUS TCL3D INFORMATION....................50
5.1 License information....................50
5.2 Programming hints....................50
5.3 Open issues....................52
5.4 Known bugs....................52
5.5 Starpack internals....................52
6 DEMO APPLICATIONS....................54
7 RELEASE NOTES....................55
7.1 Release history....................55
7.2 Obsolete functions....................58
8 REFERENCES....................60

1 Introduction

Tcl3D enables the 3D functionality of OpenGL and various other portable 3D libraries at the Tcl scripting level.

It's main design requirement is to wrap existing 3D libraries without modification of their header files and with minimal manual code writing. The Tcl API shall be a direct wrapping of the C/C++ based library API's, with a "natural" mapping of C types to according Tcl types.

This is accomplished mostly with the help of ***SWIG*** [22], the Simplified Wrapper and Interface Generator.

Tcl3D is based on ideas of Roger E. Critchlow, who formerly created an OpenGL Tcl binding called ***Frustum*** [28].

1.1 Architecture overview

The ***Tcl3D*** package currently consists of the following building blocks, also called modules throughout the manual:

Tcl3D core module	
tcl3dOgl	**Togl**: Enhanced Togl widget, a Tk widget for displaying OpenGL content.
	OpenGL: Wrapper for core OpenGL functionality (GL Version 3.0, GLU Version 1.2) and OpenGL extensions.
	Util: Tcl3D utility library: Math functions, standard shapes, stop watch, demo support.
Tcl3D optional modules	
tcl3dCg	Wrapper for NVidia's Cg shading language.
tcl3dSDL	Wrapper for the Simple DirectMedia Library.
tcl3dFTGL	Wrapper for the OpenGL Font Rendering library.
tcl3dGl2ps	Wrapper for the OpenGL To Postscript library.
tcl3dOde	Wrapper for the Open Dynamics Engine.
tcl3dGauges	Tcl3D package for displaying gauges.

Table 1.1: Overview of Tcl3D modules

Each module is implemented as a separate Tcl package and can be loaded explicitely with the Tcl package command, ex. `package require tcl3dsdl`. All available Tcl3D modules can be loaded with a single command: `package require tcl3d`.

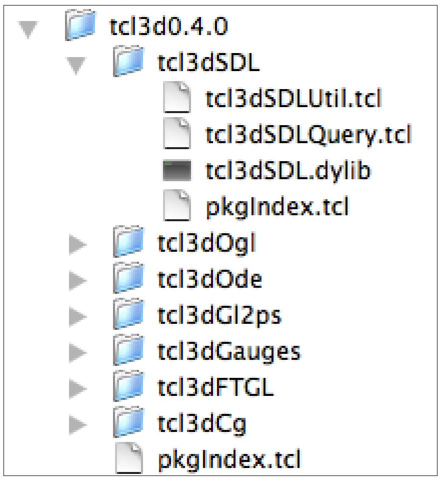


Figure 1.1: Tcl3D package layout

The next figure shows the currently available modules of Tcl3D.

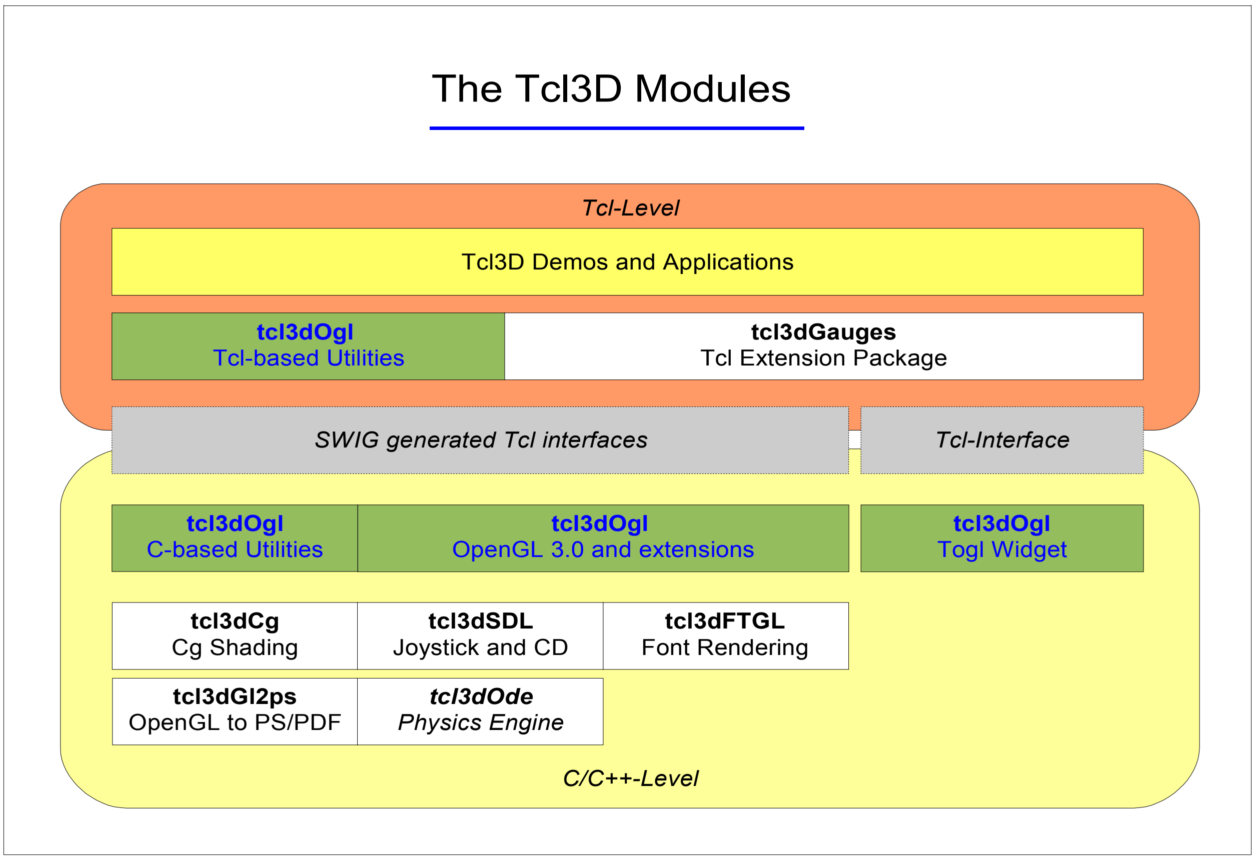

The Tcl3D Modules
Tcl-Level
Tcl3D Demos and Applications
tcl3dOgl Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dOgl C-based Utilities
tcl3dOgl OpenGL 3.0 and extensions
tcl3dOgl Togl Widget
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dGl2ps OpenGL to PS/PDF
tcl3dOde Physics Engine
C/C++-Level

Figure 1.2: Overview of Tcl3D modules

1.2 Modules overview

This chapter gives a short overview of the modules available in Tcl3D.

1.2.1 Tcl3D core module

The Tcl3D core module ***tcl3dOgl*** consists of the following 3 sub-modules:

- Togl
- OpenGL

- Util

Togl: Enhanced Togl widget
This module is an enhanced version of the ***Togl*** [6] widget, a Tk widget for displaying OpenGL graphics.

The following enhancements are currently implemented:
- Callback functions in Tcl.
- Better bitmap font support.
- Multisampling support.
- Swap Interval support.

A detailed description of this sub-module can be found in chapter 4.1.

OpenGL: Wrapper for OpenGL functionality
This module wraps OpenGL functionality up to OpenGL Version 3.0, the GLU library functions based on Version 1.2 and most of the available OpenGL extensions.
It is implemented with the help of the ***GLEW*** [13] library.
Standard shapes (box, sphere, cylinder, teapot, …) with a GLUT compatible syntax are supplied here, too.

A detailed description of this sub-module can be found in chapter 4.2.

Util: Tcl3D utility library
This module implements C/C++ and Tcl utilities offering basic functionality needed for 3D programs. It currently contains the following sub-modules:
- 3D vector and transformation matrix module
- Information module
- File utility module
- Color names module
- Large data module (tcl3dVector)
- Image utility module
- Screen capture module
- Timing module
- Random number module
- 3D-model and shapes module
- Virtual track- and arcball module
- C/C++ based utility functions for some of the demo applications.

A detailed description of this sub-module can be found in chapter 4.3.

1.2.2 Tcl3D optional modules

The following Tcl3D optional modules are currently available:
- tcl3dCg
- tcl3dSDL
- tcl3dFTGL
- tcl3dGl2ps
- tcl3dOde
- tcl3dGauges

tcl3dCg: Wrapper for NVidia’s Cg shading language
This module wraps NVidia’s Cg [7] shader library based on version 1.5.0015 and adds some Cg related utility procedures.

A detailed description of this module can be found in chapter 4.4.

tcl3dSDL: Wrapper for the Simple DirectMedia Library
This module wraps the SDL [8] library based on version 1.2.9 and adds some SDL related utility procedures.
Currently only the functions related to joystick and CD-ROM handling have been wrapped and tested.

A detailed description of this module can be found in chapter 4.5.

tcl3dFTGL: Wrapper for the OpenGL Font Rendering Library
This module wraps the FTGL [9] library based on version 2.1.2 and adds some FTGL related utility procedures.

The following font types are available:
- Bitmap font (2D)
- Pixmap font (2D)
- Outline font
- Polygon font
- Texture font
- Extruded font

A detailed description of this module can be found in chapter 4.6.

tcl3dGl2ps: Wrapper for the OpenGL To Postscript Library
This module wraps the GL2PS [11] library based on version 1.3.2 and adds some GL2PS related utility procedures.

GL2PS is a C library providing high quality vector output (PostScript, PDF, SVG) for an OpenGL application.

A detailed description of this module can be found in chapter 4.7.

tcl3dOde: Wrapper for the Open Dynamics Engine
This module wraps the OpenSource physics engine ODE [12] based on version 0.7 and adds some ODE related utility procedures.

Note
- This module is still work in progress. It’s interface may change in the future.

A detailed description of this module can be found in chapter 4.8.

tcl3dGauges: Tcl3D package for displaying gauges
This package implements the following gauges as a pure Tcl package: airspeed, altimeter, compass, tilt-meter.

A detailed description of this module can be found in chapter 4.9.

1.3 Supported platforms

The following table gives an overview on the availability of the different Tcl3D modules on the supported operating systems. It also tries to give an indication on the quality of the module.

	Windows 32-bit		Linux 32-bit		Linux 64-bit		Mac OS X 32-bit (Intel)		IRIX 6.5 n32	
Module	**Wrap**	**Test**	**Wrap**	**Test**	**Wrap**	**Test**	**Wrap**	**Test**	**Wrap**	**Test**
`tcl3dOgl`	++	++	++	++	++	++	++	+	++	+
`tcl3dCg`	++	++	++	++	++	++	++	+	–	–
`tcl3dSDL`	+	++	+	++	+	++	+	0	+	+
`tcl3dFTGL`	++	+	++	+	++	+	++	0	++	+
`tcl3dGl2ps`	++	+	++	+	++	+	++	+	++	+
`tcl3dOde`	+	0	+	0	+	0	+	0	+	0
`tcl3dGauges`	++	+	++	+	++	+	++	+	++	+

Table 1.2: Availability of Tcl3D modules

Legend for Table 1.2:

Column Wrap	**Column Test**
++ Interface of module fully wrapped.	++ Module extensively tested. No errors known.
+ Interface of module partially wrapped.	+ Module tested. Minor errors known.
0 Module not yet wrapped.	0 Module in work.
- Module not available for the platform.	- Module not available for the platform.

Short summary:
The Windows and Linux ports are supported best and are regularly tested on different graphics card and OpenGL driver combinations.
On IRIX every module (except Cg, which is not available for SGI) has been wrapped and seems to be running fine, but no extensive tests have been done.
The OS X port is tested on a MacBook with limited graphics capabilities.

1.4 Getting started

The easiest way to get started, is using a Tcl3D starpack. Starpacks for Windows, Linux, IRIX and Mac OS X (Intel based) can be downloaded from http://www.tcl3d.org/. See chapter 2 for a detailed information about all available Tcl3D packages.

The only prerequisite needed for using the Tcl3D starpack distribution is an installed OpenGL driver. Everything else - even the Tcl interpreter - is contained in the starpack.

The starpacks are distributed as a ZIP-compressed file. Unzipping this file creates a directory containing the starpack `tcl3dsh-OS-VERSION`. Distributions for Unix systems contain an additional shell script `tcl3dsh-OS-VERSION.sh`, which should be used for starting the Tcl3D starpack.
After starting the starpack, a toplevel Tk window labeled `Tcl3D` as well as a console window labeled `Tcl3D Console` should appear, similar to starting a wish shell.
The console window should contain the following two message lines as well as a tcl3d prompt:

```
Type "pres" to start Tcl3D presentation.
Type "inst" to write the Tcl3D installation packages to disk.
tcl3d>
```

Typing `pres` in the console window, starts the Tcl3D presentation showing an introductionary animation as shown in the screenshot below. The available key and mouse bindings are shown in the console window.

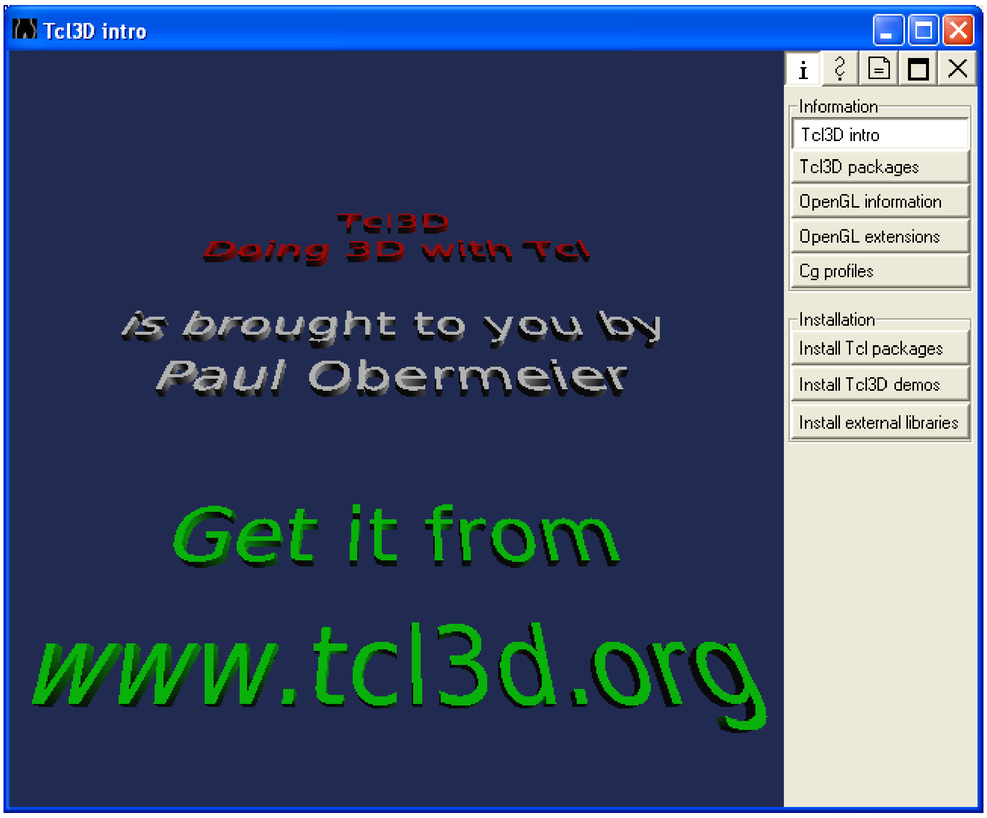


Figure 1.3: Tcl3D presentation intro

Binding	Action
`Key-Escape`	Exit the program
`Key-Left`	Move text to the left
`Key-Right`	Move text to the right
`Key-i`	Increase distance from viewer
`Key-d`	Decrease distance from viewer
`Key-Up`	Increase speed
`Key-Down`	Decrease speed
`Key-plus`	Rotate text
`Key-minus`	Rotate text (other direction)
`Key-space`	Set speed of text to zero
`Key-r`	Reset speed and position of text
`Mouse-1`	Start animation
`Mouse-2`	Stop animation

Table 1.3: Tcl3D presentation shortcuts

The presentation can also be started directly by using `-pres` as a command line parameter to the Tcl3D starpack.

Description of the Tcl3D starpack

The Starpack ***tcl3dsh*** can be used as
- a standalone executable like wish with builtin Tcl3D
- a test and presentation program for Tcl3D
- an installer for the Tcl3D specific libraries, the external libraries and demo programs

The Tcl3D presentation is divided into 3 sections:

- Information and installation
- Help and documentation
- Demos and tutorials

The information menu gives you access to different types of information (OpenGL, Tcl3D, ...), which are shown as animated OpenGL text. More detailed information can be obtained by using the ***tcl3dInfo.tcl*** script located in the demos directory in category Tcl3DSpecific.

The help and documentation menu gives you some online information about how to use the Tcl3D presentation framework.

The demo and tutorials menu has lots of sample programs, divided into 3 categories:

- ***Library specific demos*** contains scripts showing features specific to the wrapped library.
- ***Tutorials and books*** contains scripts, which have been converted from C to Tcl3D, coming from the following sources:
  OpenGL Red Book
  NeHe tutorials
  Kevin Harris CodeSampler web site
  Vahid Kazemi's GameProgrammer page
- ***Tcl3D specific demos*** contains scripts demonstrating and testing Tcl3D specific features.

Some notes about the demos contained in the Starpack:

Depending on your operating system, graphics card and driver, some of the programs may raise an error message or will not work properly.
As the demos contained within the Starpack were written to be standalone programs, no error recovery was implemented. The programs typically just quit. This is, why you may get a confirmation window from time to time, asking you, if you want to quit the presentation.
In most cases, you may proceed with other demos, but be warned, that strange effects may occur.

2 Installation

Precompiled packages for Windows, Linux, IRIX and Intel based Mac OS X, the source code of the Tcl3D package as well as test and demonstration programs can be downloaded from the Tcl3D home page at http://www.tcl3d.org.

Please report problems or errors to info@tcl3d.org.

Use the following script when sending bug reports or questions to supply me with information about your environment.

```
catch { console show }

package require tcl3d
togl .t

# Print information about the OS.
parray tcl_platform

# Print information about the Tcl3D modules.
puts [tcl3dGetPackageInfo]

# Print information about the OpenGL driver.
puts [tcl3dOglGetVersions]

# If it's a problem with an OpenGL extension, you should also
# include the output of the following statement:
# puts [tcl3dOglGetExtensions]
```

The following distribution packages are currently available. Which packages are needed, depends on the proposed usage. See the next chapters for detailed information.

Documents	
`Tcl3D-Manual-VERSION.odt`	Tcl3D user manual (this document). OpenOffice format.
`Tcl3D-Manual-VERSION.pdf`	Tcl3D user manual (this document). PDF format.
`Tcl3D-RefManual-VERSION.pdf`	Tcl3D reference manual.
`Tcl3D-DemoRef-VERSION.pdf`	Tcl3D demo programs reference.
Demos	
`tcl3d-demos-VERSION.zip`	Tcl3D demo sources.
`tcl3d-demoimgs-VERSION.zip`	Screenshots of all Tcl3D demo programs.
Starpacks	
`tcl3dsh-win32-VERSION.zip`	Tcl3D Starpack for Windows.
`tcl3dsh-Linux-VERSION.zip`	Tcl3D Starpack for 32-bit Linux.
`tcl3dsh-Linux64-VERSION.zip`	Tcl3D Starpack for 64-bit Linux.
`tcl3dsh-Darwin-VERSION.zip`	Tcl3D Starpack for Mac OS X.
`tcl3dsh-IRIX64-VERSION.zip`	Tcl3D Starpack for SGI IRIX.
Binary packages	
`tcl3d-win32-VERSION.zip`	External libraries (DLL's) and Tcl3D package for Windows.
`tcl3d-Linux-VERSION.zip`	External libraries (DSO's) and Tcl3D package for 32-bit Linux.
`tcl3d-Linux64-VERSION.zip`	External libraries (DSO's) and Tcl3D package for 64-bit Linux.
`tcl3d-Darwin-VERSION.zip`	External libraries (DSO's) and Tcl3D package for Mac OS X.
`tcl3d-IRIX64-VERSION.zip`	External libraries (DSO's) and Tcl3D package for SGI IRIX.
Sources	
`tcl3d-src-VERSION.zip`	Tcl3D source distribution.
`tcl3d-starpack-VERSION.zip`	Tcl3D sources for creating Starpacks.

Table 2.1: Tcl3D distribution packages

The term VERSION is a template for the Tcl3D version number, i.e. for the currently available version it must be replaced with 0.4.0.

2.1 Installation of a binary distribution

There are two possibilities to install a Tcl3D binary distribution onto your computer.

2.1.1 Installation from a Tcl3D starpack

The following prerequisites are needed when installing from a Tcl3D starpack:

- An ***OpenGL*** driver suitable for your graphics card. It is recommend to download and install an up-to-date OpenGL driver from the manufacturer of your graphics card, especially if intending to write shader programs in GLSL or Cg.

Download, unzip and start a Tcl3D starpack presentation as described in chapter 1.4.

In the right menu pane, you will see 3 buttons in the Installation and Information menu (see Figure 1.3 on page 7).
These allow you to extract the Tcl3D packages (***tcl3d0.4.0***), the external libraries (***extlibs***) and the demo programs (***demos***) onto the file system, so you can use Tcl3D from tclsh or wish.

- The Tcl3D package folder (***tcl3d0.4.0***) should be copied into the library section of your Tcl installation (ex. ***C:\Tcl\lib***). If write access to this Tcl directory is not permitted, you can copy the ***tcl3d0.4.0*** directory somewhere else, eg. ***C:\mytcl3d*** or ***/home/user/mytcl3d***. To have Tcl look for packages in this location, you must set the `TCLLIBPATH` environment variable with the above specified directory name as value. Note, that on Windows the path must be written with slashes (not backslashes): `set TCLLIBPATH = C:/mytcl3d`

- The files contained in the external libraries folder (***extlibs***) should be copied into a directory, which is listed in your PATH environment variable (Windows) or your LD_LIBRARY_PATH environment variable (Unix).
- The demonstration programs folder (***demos***) can be copied to any convenient place of your file system.

Now you are ready for using Tcl3D from a standard Tcl interpreter by starting a `tclsh` or `wish` program and issuing the following command: `package require tcl3d`.

Alternatively you can extract the 3 installation folders with one of the following methods:
- Start the Tcl3D starpack and issue the command `inst` in the console.
- Start the Tcl3D starpack with command line parameter `-inst`.

Both steps will copy the 3 above described package folders into the directory containing the starpack.

2.1.2 Installation from a binary package

The following prerequisites are needed when using a Tcl3D binary package:
- An ***OpenGL*** driver suitable for your graphics card. It is recommend to download and install an up-to-date OpenGL driver from the manufacturer of your graphics card, especially if intending to write shader programs in GLSL or Cg.
- A ***Tcl/Tk*** version greater or equal to 8.4.
- The ***Img*** extension is needed to have access to various image formats, which are used as OpenGL textures.
- For some demos the ***snack*** extension is used.
- To generate screenshots from the Tcl3D presentation, the ***Twapi*** extension is needed on Windows.

It is therefore recommended to use an ActiveTcl distribution [23], which contains all of the above listed Tcl extensions.

Download and unzip the following distribution packages suitable for your operating system:
- `tcl3d-OS-0.4.0.zip`
- `tcl3d-demos-0.4.0.zip`

Then copy the resulting folders into the appropriate directories as described in the previous chapter.

2.2 Installation of a source distribution

This chapter outlines the general process of compiling, customising and installing the Tcl3D package. See the file ***Readme.txt*** in the source code distribution for additional up-to-date information.

2.2.1 Step 1: Prerequisites

The following prerequisites are needed when using a Tcl3D source package:
- An ***OpenGL*** driver suitable for your graphics card. It is recommend to download and install an up-to-date OpenGL driver from the manufacturer of your graphics card, especially if intending to write shader programs in GLSL or Cg.
- A ***Tcl/Tk*** version greater or equal to 8.4.
- The ***Img*** extension is needed to have access to various image formats, which are used as OpenGL textures.
- For some demos the ***snack*** extension is used.

- To generate screenshots from the Tcl3D presentation, the ***Twapi*** extension is needed on Windows.

It is therefore recommended to use an ActiveTcl distribution [23], which contains all of the above listed Tcl extensions.

To build the Tcl3D modules from source, the following additional tools need to be installed and accessable from the command line:

Tool	Version	URL
GNU make	>= 3.79	http://www.gnu.org/
SWIG	>= 1.3.19	http://www.swig.org/

Table 2.2: Tools for building Tcl3D

Note

- A binary version of SWIG version 1.3.24 for IRIX is available from my private home page http://www.posoft.de/.
- Tcl3D has been generated and tested with SWIG versions 1.3.24 and 1.3.29. These versions are recommended.
- See chapter 5.4 for known bugs with other SWIG versions.

Download and unzip the following distribution packages suitable for your operating system:

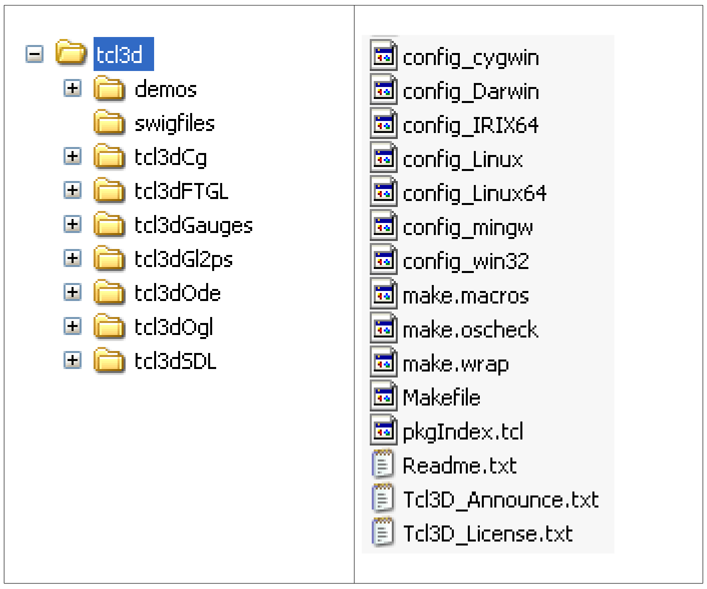
- `tcl3d-src-0.4.0.zip`
- `tcl3d-OS-0.4.0.zip`
- `tcl3d-demos-0.4.0.zip`
- `tcl3d-starpack-0.4.0.zip`

Example installation procedures

Version 1: Tcl3D-Basic: OpenGL support, no external libraries

Needed:	`tcl3d-src-0.4.0.zip`
Recommended:	`tcl3d-demos.0.4.0.zip`

Unzip `tcl3d-src-0.4.0.zip` in a folder of your choice. This creates a new folder ***tcl3d*** containing the sources. Unzip `tcl3d-demos.0.4.0.zip` into the new folder ***tcl3d***.
You should end up with a directory and file structure as shown in the next figure.


tcl3d
demos
swigfiles
tcl3dCg
tcl3dFTGL
tcl3dGauges
tcl3dGl2ps
tcl3dOde
tcl3dOgl
tcl3dSDL

config_cygwin
config_Darwin
config_IRIX64
config_Linux
config_Linux64
config_mingw
config_win32
make.macros
make.oscheck
make.wrap
Makefile
pkgIndex.tcl
Readme.txt
Tcl3D_Announce.txt
Tcl3D_License.txt

Figure 2.1: Tcl3D-Basic directory structure

If only basic OGL support is needed, disable the optional modules by commenting all WRAP_* macro lines in file ***make.wrap***.
The presentation framework ***presentation.tcl*** works, but the texts are displayed as 2D bitmaps only. Most OpenGL only demos should work.

Version 2: Tcl3D-Complete: OpenGL support plus optional modules

Needed:	`tcl3d-src-0.4.0.zip`
Needed:	`tcl3d-OS-0.4.0.zip`
Recommended:	`tcl3d-demos.0.4.0.zip`

Unzip `tcl3d-src-0.4.0.zip` in a folder of your choice. This creates a new folder ***tcl3d*** containing the sources. Unzip `tcl3d-demos.0.4.0.zip` into the new folder ***tcl3d***.
Unzip `tcl3d-OS-0.4.0.zip` into a temporary folder. Then copy the dynamic libraries contained in subfolder ***extlibs/OS*** into a directory, which is listed in your PATH environment variable (Windows) or your LD_LIBRARY_PATH environment variable (Unix).

You should end up with a directory and file structure as shown in figure 2.1.

If you want to build the ***tcl3dCg*** module, you have to download and install the Cg toolkit version 1.5.0015 from [7]. After installation, copy all the Cg header files into the ***tcl3dCg/Cg*** directory. These files are not included in the Tcl3D distribution because of license issues. The dynamic libraries of Cg are included in the Tcl3D distribution package `tcl3d-OS-0.4.0.zip`.
If you want to wrap only a sub-set of the supported optional modules, edit the ***make.wrap*** file appropriately. See chapter 2.2.3 Step 3: Customization for details.

Version 3: Tcl3D-Star: Tcl3D-Basic or Tcl3D-Complete with Starpack support

Needed:	`Installation of Version 1 or 2`
Needed:	`tcl3d-starpack-0.4.0.zip`

Perform the steps as described for Version 1 or 2. Additionally copy the folder ***extlibs*** contained in distribution package `tcl3d-OS-0.4.0.zip` into the source code folder ***tcl3d***. Then unzip `tcl3d-starpack-0.4.0.zip` into the source code folder ***tcl3d***.

You should end up with a directory and file structure as shown in the next figure.

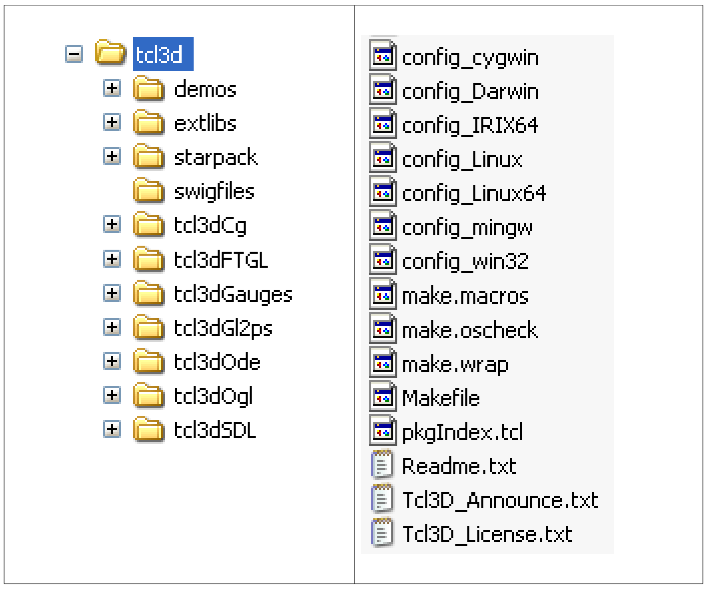


Figure 2.2: Tcl3D-Complete Starpack directory structure

Note

- The starpack distribution package contains Tclkits for all supported operating systems, as well as supporting Tcl packages needed for the Tcl3D demonstration programs.

2.2.2 Step 2: Configuration

Before compiling, edit the appropriate ***config_**** file to fit your platform/compiler combination:

Operating system	Compiler	Configuration file
Windows	Visual C++ 6.0, 7.1, 8.0	***config_win32***
Windows	CygWin (gcc)	***config_cygwin***
Windows	MinGW (gcc)	***config_msys***
Linux (32-bit)	gcc	***config_Linux***
Linux (64-bit)	gcc	***config_Linux64***
Mac OS X	gcc	***config_Darwin***
SGI IRIX 6.5	gcc, MIPS Pro 7.3	***config_IRIX64***

Table 2.3: Tcl3D configuration files

Note

- For Unix systems, the name after the underscore is derived from the Unix commands `uname -s` and `uname -m`. See the file ***make.oscheck*** for details on the mapping of the command output.

The following lines in the ***config_**** files may be edited:

`WITH_DEBUG`	If you don't want debug information, remove ALL characters after the equal sign.
`INSTDIR`	Set to your preferred installation directory.
`TCLDIR`	Set to where your Tcl installation is located on disk.
`TCLMINOR`	Set to your installed Tcl minor version.

Table 2.4: Tcl3D configuration variables

Examples:

Compile with debugging information. The Tcl installation is located in ***/usr/local***. We install the Tcl3D package into the same location as the Tcl distribution. The installed Tcl version is 8.4.

```
WITH_DEBUG = 1
INSTDIR  = /usr/local
TCLDIR   = /usr/local
TCLMINOR = 4
```

Compile without debugging information. The Tcl installation is located in ***C:\Programme\Tcl***. We install the Tcl3D package into a separate directory. The installed Tcl version is 8.4.

```
WITH_DEBUG =
INSTDIR  = C:\Programme\Tcl
TCLDIR   = C:\Programme\poSoft
TCLMINOR = 4
```

Instead of editing the configuration file, you may alternatively create a file called ***make.private*** in the top level directory of Tcl3D and add lines according to your needs.

```
ifeq ($(MACHINE),win32)
INSTDIR = F:\Programme\poSoft
TCLDIR  = F:\Programme\Tcl
endif
ifeq ($(CONFIG),mingw)
INSTDIR = F:/Programme/poSoft
TCLDIR  = F:/Programme/Tcl
endif
```

2.2.3 Step 3: Customization

The optional modules can be included or excluded from the compilation step by setting the following macros in file ***make.wrap*** in the top level directory of the Tcl3D source tree.

Macro name	Description	Additional check file
`WRAP_CG`	Customize support for tcl3dCg	***Cg/cg.h***
`WRAP_SDL`	Customize support for tcl3dSDL	***include/SDL.h***
`WRAP_FTGL`	Customize support for tcl3dFTGL	***include/FTGL.h***
`WRAP_GL2PS`	Customize support for tcl3dGl2ps	***gl2ps.h***
`WRAP_ODE`	Customize support for tcl3dOde	***ode/ode.h***

Table 2.5: Customization settings

Note

- Do not set a macro to 0, but comment the corresponding line (i.e. undefine), as shown in the following example:
  `WRAP_FEATURE = 1` enables the feature
  `# WRAP_FEATURE = 1` disables the feature

Each Makefile of an optional module additionally checks for the existence of an important include file (as listed in column "Additional check file") to enable extension support for Tcl3D.

2.2.4 Step 4: Compilation and installation

The following commands should compile and install the Tcl3D package:

```
> gmake
> gmake install
```

The make process prints out lines about the success of wrapping optional modules:

```
Tcl3D built with Cg support
Tcl3D built without ODE support
...
```

The starpack is not generated by default. If you installed the starpack distribution package, you have to go into the directory ***starpack*** and call `make` there.

Note

- To test the generated starpack, copy it into a temporary directory and start it from there, as the starpack will copy all external libraries into the current directory.

First installation tests

Start a ***tclsh*** or ***wish*** shell and type the following two commands:

```
> package require tcl3d
> togl .t
```
Now use either the command `tcl3dShowPackageInfo` for graphical package information or `tcl3dGetPackageInfo` for textual package information.
If these procedures fails, you may try the low level information supplied in the Tcl array `__tcl3dPkgInfo`:

```
> parray __tcl3dPkgInfo
__tcl3dPkgInfo(tcl3dcg,avail)      = 0
__tcl3dPkgInfo(tcl3dcg,version)    = Cg library not wrapped
__tcl3dPkgInfo(tcl3dftgl,avail)    = 1
__tcl3dPkgInfo(tcl3dftgl,version)  = 0.4.0
```

Version ***Tcl3D-Basic*** should print out information similar to the lines listed below, when calling `tcl3dGetPackageInfo`:

```
{tcl3dcg      0 {Cg library not wrapped} {}}
{tcl3dftgl    0 {FTGL library not wrapped} {}}
{tcl3dgauges  1 0.4.0 {}}
{tcl3dgl2ps   0 {GL2PS library not wrapped} {}}
{tcl3dode     0 {ODE library not wrapped} {}}
{tcl3dogl     1 0.4.0 {1.2 APPLE-1.4.56}}
{tcl3dsdl     0 {SDL library not wrapped} {}}
```

Version ***Tcl3D-Complete*** should print out information similar to the lines listed below, when calling `tcl3dGetPackageInfo`:

```
{tcl3dcg      1 0.4.0 1.5.0015}
{tcl3dftgl    1 0.4.0 2.1.2}
{tcl3dgauges  1 0.4.0 {}}
{tcl3dgl2ps   1 0.4.0 1.3.2}
{tcl3dode     1 0.4.0 0.7.0}
{tcl3dogl     1 0.4.0 {1.2 APPLE-1.4.56}}
{tcl3dsdl     1 0.4.0 1.2.9}
```

2.3 Extending Tcl3D

TODO: This chapter will be filled in a future release.

2.3.1 General information

Each optional module wrapping a library (eg. SDL) has to have at least 2 files in folder ***tclfiles***: ***pkgIndex.tcl*** and ***tcl3dSDLQuery.tcl***.
The latter file contains procedures to query functionality related to the package. All procedures contained in this file must be able to work, even if the corresponding dynamic library does not exist or is just a dummy.
This file must be loaded in ***pkgIndex.tcl*** before the dynamic library. All other package related Tcl files should be loaded after the dynamic library.

2.3.2 Extending with a Tcl utility

2.3.3 Extending with a C/C++ utility

2.3.4 Extending with a newer version of an external library

2.3.5 Extending with a new external library

3 Wrapping in detail

This chapter explains, how parameters and return values of the C and C++-based library functions are mapped to Tcl command parameters and return values. The intention of the wrapping mechanism was to be as close to the C interface and use Tcl standard types wherever possible:

- C functions are mapped to Tcl commands.
- C constants are mapped to Tcl global variables.
- Some C enumerations are mapped to Tcl global variables and are inserted into a Tcl hash table for lookup by name.

The mapping described in this chapter is consistently applied to all libraries wrapped with Tcl3D. It is optimized to work best with the OpenGL interface.

3.1 Wrapping description

Conventions used in this chapter:

- Every type of parameter is explained with a typical example from the OpenGL wrapping.
- The notation TYPE stands for any scalar value (char, int, float, enum etc. as well as inherited scalar types like GLboolean, GLint, GLfloat, etc.). It is **not** used for type void or GLvoid.
- The notation `STRUCT` stands for any C struct.
- The decision how to map C to Tcl types was mainly inspired to fit the needs of the OpenGL library best. The same conventions are used for the optional modules, too.
- Function parameters declared as const pointers are interpreted as input parameters. Parameters declared as pointer are interpreted output parameters.

3.1.1 Scalar input parameters

The mapping of most scalar types is handled by SWIG standard typemaps.

Scalar types as function input parameter must be supplied as numerical value.

Input parameter	**TYPE**
C declaration	`void glTranslatef (`**`GLfloat x, GLfloat y, GLfloat z`**`);`

C example	`glTranslatef (1.0, 2.0, 3.0);`
	`glTranslatef (x, y, z);`

Tcl example	`glTranslatef 1.0 2.0 3.0`
	`glTranslatef $x $y $z`

Table 3.1: Wrapping of a scalar input parameter

The mapping of the following enumerations is handled differently (see file ***tcl3dConstHash.i***). They can be specified either as numerical value like the other scalar types, or additionally as a name identical to the enumeration name.

- `GLboolean`
- `GLenum`
- `GLbitfield`
- `CGenum`
- `CGGLenum`
- `CGprofile`
- `CGtype`

- `CGresource`
- `CGerror`

The mapping is explained using the 3 OpenGL enumeration types. The Cg types are handled accordingly.

`GLenum` as function input parameter can be supplied as numerical value or as name.

Input parameter	GLenum
C declaration	`void glEnable (`**`GLenum cap`**`);`
C example	`glEnable (GL_BLEND);`

Tcl example	`glEnable GL_BLEND`
	`glEnable $::GL_BLEND`

Table 3.2: Wrapping of a GLenum input parameter

`GLbitfield` as function input parameter can be supplied as numerical value or as name.

Note

- A combination of bit masks has to be specified as a numerical value like this:
  `glClear [expr $::GL_COLOR_BUFFER_BIT | $::GL_DEPTH_BUFFER_BIT]`

Input parameter	GLbitfield
C declaration	`void glClear (`**`GLbitfield mask`**`);`
C example	`glClear (GL_COLOR_BUFFER_BIT);`

Tcl example	`glClear GL_COLOR_BUFFER_BIT`
	`glClear $::GL_COLOR_BUFFER_BIT`

Table 3.3: Wrapping of a GLbitfield input parameter

`GLboolean` as function input parameter can be supplied as numerical value or as name.

Input parameter	GLboolean
C declaration	`void glEdgeFlag (`**`GLboolean flag`**`);`
C example	`glEdgeFlag (GL_TRUE);`

Tcl example	`glEdgeFlag GL_TRUE`
	`glEdgeFlag $::GL_TRUE`

Table 3.4: Wrapping of a GLboolean input parameter

3.1.2 Pointer input parameters

The mapping of `const TYPE` pointers is handled in file ***tcl3dPointer.i***.

Constant pointers as function input parameter must be supplied as a Tcl list.

Input parameter	const TYPE[SIZE], const TYPE *

C declaration	`void glMaterialfv (GLenum face, GLenum pname,`
	`const GLfloat *params``);`

C example	`GLfloat mat_diffuse = { 0.7, 0.7, 0.7, 1.0 };`
	`glMaterialfv (GL_FRONT, GL_DIFFUSE, mat_diffuse);`

Tcl example	`set mat_diffuse { 0.7 0.7 0.7 1.0 }`
	`glMaterialfv GL_FRONT GL_DIFFUSE $mat_diffuse`

Table 3.5: Wrapping of a pointer input parameter

Note

- This type of parameter is typically used to specify small vectors (2D, 3D and 4D) as well as control points for NURBS.
- Unlike in the C version, specifying data with the scalar version of a function (ex. `glVertex3f`) is faster than the vector version (ex. `glVertex3fv`) in Tcl.
- Tcl lists given as parameters to a Tcl3D function have to be flat, i.e. they are not allowed to contain sublists. When working with lists of lists, you have to flatten the list, before supplying it as an input parameter to a Tcl3D function. One way to do this is shown in the example below.

```
set ctrlpoints {
      {-4.0 -4.0 0.0} {-2.0 4.0 0.0}
      { 2.0 -4.0 0.0} { 4.0 4.0 0.0}
}
glMap1f GL_MAP1_VERTEX_3 0.0 1.0 3 4 [join $ctrlpoints]
```

The mapping of `const void` pointers is handled by SWIG standard typemaps.

Constant void pointers as function input parameter must be given as a pointer to a contiguous piece of memory of appropriate size.

Input parameter	**const void[SIZE], const void ***
C declaration	`void glVertexPointer (GLint size, GLenum type, GLsizei stride, const GLvoid *ptr);`
C example	`static GLint vertices[] = { 25, 25, 100, 325, 175, 25, 175, 325, 250, 25, 325, 325}; glVertexPointer (2, GL_INT, 0, vertices);`
Tcl example	`set vertices [tcl3dVectorFromArgs GLint \ 25 25 100 325 175 25 \ 175 325 250 25 325 325] glVertexPointer 2 GL_INT 0 $::vertices`

Table 3.6: Wrapping of a void pointer input parameter

Note

- The allocation of usable memory can be accomplished with the use of the `tcl3dVector` commands, which are described in chapter 4.3.5.
- This type of parameter is typically used to supply image data or vertex arrays. See also the description of the image utility module in chapter 4.3.6.

3.1.3 Output parameters

The mapping of non-constant pointers is handled by the SWIG standard typemaps.

Non-constant pointers as function output parameter must be given as a pointer to a contiguous piece of memory of appropriate size (`tcl3dVector`). See note above.

Output parameter	TYPE[SIZE], void[SIZE], TYPE *, void *

C declaration	`void glGetFloatv (GLenum pname, GLfloat *params);`
	
	`void glReadPixels (GLint x, GLint y, GLsizei width, GLsizei height, GLenum format, GLenum type, GLvoid *pixels);`

C example	`GLfloat values[2];`
	`glGetFloatv (GL_LINE_WIDTH_GRANULARITY, values);`
	
	`GLubyte *vec = malloc (w * h * 3);`
	`glReadPixels (0, 0, w, h, GL_RGB, GL_UNSIGNED_BYTE, vec);`

Tcl example	`set values [tcl3dVector GLfloat 2]`
	`glGetFloatv GL_LINE_WIDTH_GRANULARITY $values`
	
	`set vec [tcl3dVector GLubyte [expr $w * $h * 3]]`
	`glReadPixels 0 0 $w $h GL_RGB GL_UNSIGNED_BYTE $vec`

Table 3.7: Wrapping of a pointer output parameter

3.1.4 Function return values

The mapping of return values is handled by the SWIG standard typemaps.

Scalar return values are returned as the numerical value.
Pointer to structs are returned with the standard SWIG mechanism of encoding the pointer in an ASCII string.

Function return	TYPE, STRUCT *

C declaration	`GLuint glGenLists (GLsizei range);`
	
	`GLUnurbs* gluNewNurbsRenderer (void);`

C example	`GLuint sphereList = glGenLists(1);`
	
	`GLUnurbsObj *theNurb = gluNewNurbsRenderer();`
	`gluNurbsProperty (theNurb, GLU_SAMPLING_TOLERANCE, 25.0);`

Tcl example	`set sphereList [glGenLists 1]`
	
	`set theNurb [gluNewNurbsRenderer]`
	`gluNurbsProperty $theNurb GLU_SAMPLING_TOLERANCE 25.0`

Table 3.8: Wrapping of a function return value

The next lines show an example of SWIG's pointer encoding:

```
% set theNurb [gluNewNurbsRenderer]
% puts $theNurb
_10fa1500_p_GLUnurbs
```

The returned name can only be used in functions expecting a pointer to the appropriate struct.

3.1.5 Exceptions from the standard rules

The GLU library as specified in header file ***glu.h*** does not provide an API, that is using the `const` specifier as consistent as the GL core library. So one class of function parameters (`TYPE*`) is handled differently with GLU functions. Arguments of type `TYPE*` are used both as input and output parameters in the C version. In GLU 1.2 most functions use this type as input parameter. Only two functions use this type as an output parameter.

So for GLU functions there is the exception, that `TYPE*` is considered an input parameter and therefore is wrapped as a Tcl list.

Input parameter	TYPE * (GLU only)

C declaration	`void gluNurbsCurve (GLUnurbs *nobj, GLint nknots,`
	`GLfloat *knot, GLint stride,`
	`GLfloat *ctlarray, GLint order,`
	`GLenum type);`

C example	`GLfloat curvePt[4][2] = {{0.25, 0.5}, {0.25, 0.75},`
	`{0.75, 0.75}, {0.75, 0.5}};`
	`GLfloat curveKnots[8] = {0.0, 0.0, 0.0, 0.0,`
	`1.0, 1.0, 1.0, 1.0};`
	`gluNurbsCurve (theNurb, 8, curveKnots, 2,`
	`&curvePt[0][0], 4, GLU_MAP1_TRIM_2);`

Tcl example	`set curvePt {0.25 0.5  0.25 0.75  0.75 0.75  0.75 0.5}`
	`set curveKnots {0.0 0.0 0.0 0.0 1.0 1.0 1.0 1.0}`
	`gluNurbsCurve $theNurb 8 $curveKnots 2 $curvePt 4`
	`GLU_MAP1_TRIM_2`

Table 3.9: Wrapping of GLU functions

The two aforementioned functions, which provide output parameters with `TYPE*` are `gluProject` and `gluUnProject`. These are handled as a special case in the SWIG interface file ***glu.i***. The 3 output parameters are given the keyword OUTPUT, so SWIG handles them in a special way: SWIG builds a list consisting of the normal function return value, and all parameters marked with that keyword. This list will be the return value of the corresponding Tcl command.

Definition in glu.h	Redefinition in SWIG interface file glu.i

`extern GLint gluUnProject (`
`GLdouble winX, GLdouble winY,`
`GLdouble winZ,`
`const GLdouble *model,`
`const GLdouble *proj,`
`const GLint *view,`
`GLdouble* objX,`
`GLdouble* objY,`
`GLdouble* objZ);`
	`GLint gluUnProject (`
	`GLdouble winX, GLdouble winY,`
	`GLdouble winZ,`
	`const GLdouble *model,`
	`const GLdouble *proj,`
	`const GLint *view,`
	`GLdouble* OUTPUT,`
	`GLdouble* OUTPUT,`
	`GLdouble* OUTPUT);`

Table 3.10: Wrapping exceptions for GLU

Example usage (see Redbook example ***unproject.tcl*** for complete code):

```
glGetIntegerv GL_VIEWPORT $viewport
glGetDoublev  GL_MODELVIEW_MATRIX  $mvmatrix
glGetDoublev  GL_PROJECTION_MATRIX $projmatrix
set viewList [tcl3dVectorToList $viewport 4]
set mvList   [tcl3dVectorToList $mvmatrix 16]
set projList [tcl3dVectorToList $projmatrix 16]

set realy [expr [$viewport get 3] - $y - 1]
set winList [gluUnProject $x $realy 0.0 $mvList $projList $viewList]
puts "gluUnProject return value: [lindex $winList 0]"
puts [format "World coords at z=0.0 are (%f, %f, %f)" \
     [lindex $winList 1] [lindex $winList 2] [lindex $winList 3]]
```

Note

- The above listed exceptions are only valid for the GLU library. The optional modules have not been analysed in-depth regarding the constness of parameters.

3.2 Wrapping reference card

- The notation `TYPE` stands for any scalar value (`char`, `int`, `float`, etc. as well as inherited scalar types like `GLboolean`, `GLint`, `GLfloat`, etc.). It is not used for type `void` or `GLvoid`.
- The notation `STRUCT` stands for any C struct.

C parameter type	Tcl parameter type
Input parameter	
`TYPE`	Numerical value.
`GLboolean`	Numerical value or name of constant.
`GLenum`	Numerical value or name of constant.
`GLbitfield`	Numerical value or name of constant.
`CGenum`	Numerical value or name of constant.
`CGGLenum`	Numerical value or name of constant.
`CGprofile`	Numerical value or name of constant.
`CGtype`	Numerical value or name of constant.
`CGresource`	Numerical value or name of constant.
`CGerror`	Numerical value or name of constant.
`const TYPE[SIZE]`	Tcl list.
`const TYPE *`	Tcl list.
`const void *`	tcl3dVector
Output parameter	
`TYPE *`	tcl3dVector
`void *`	tcl3dVector
Return value	
`TYPE`	Numerical value.
`STRUCT *`	SWIG encoded pointer to struct.

Table 3.11: Tcl3D wrapping reference

4 Modules in detail

This chapter explains in detail the different modules, Tcl3D is currently built upon.

Tcl3D core module:

• Togl	Enhanced Togl widget
• OpenGL	Wrapper for OpenGL functionality
• Util	Tcl3D utility library

Tcl3D optional modules:

• tcl3dCg	Wrapper for NVidia's Cg shading language
• tcl3dSDL	Wrapper for the Simple DirectMedia Library
• tcl3dFTGL	Wrapper for the OpenGL Font Rendering Library
• tcl3dGl2ps	Wrapper for the OpenGL To Postscript Library
• tcl3dOde	Wrapper for the Open Dynamics Engine
• tcl3dGauges	Tcl3D package for displaying gauges

4.1 tcl3dOgl->Togl: Enhanced Togl widget

Togl [6] is a Tk widget with support to display graphics in an OpenGL context. The original version only supported issuing drawing commands in C. To be usable from the Tcl level, it has been extended with configuration options for specifying Tcl callback commands.

Requirements for this module: None, all files are contained in the Tcl3D distribution.

4.1.1 Togl commands

The following is a list of currently available Togl commands. The commands changed or new in Tcl3D are marked bold and explained in detail below. For a description of the other commands see the original Togl documentation.

`configure`
`render`
`swapbuffers`
`makecurrent`
`postredisplay`
`loadbitmapfont`
`unloadbitmapfont`

Bitmap fonts

Specifying bitmap fonts can be accomplished with the `loadbitmapfont` command.
The font can either be specified in XLFD format or Tk-like with the following options:

-family	courier|times|...
-weight	medium|bold
-slant	regular|italic
-size	PixelSize

Examples:

```
$toglwin loadbitmapfont -*-courier-bold-r-*-*-10-*-*-*-*-*-*-*
$toglwin loadbitmapfont -family fixed -size 12 -weight medium -slant regular
```

See the ***tcl3dToglFonts.tcl*** and ***tcl3dFont.tcl*** demos for more examples, on how to use fonts with Togl.

4.1.2 Togl options

The following is a list of currently available Togl options. The options changed or new in Tcl3D are marked bold and explained in detail below. For a description of the other options see the original Togl documentation.

-height	-width	-setgrid	
-rgba	-redsize	-greensize	-bluesize
-double	-depth	-depthsize	-accum
-accumredsize	-accumgreensize	-accumbluesize	-accumalphasize
-alpha	-alphasize	-stencil	-stencilsize
-auxbuffers	-privatecmap	-overlay	-stereo
-cursor	-time	-sharelist	-sharecontext
-ident	-indirect	-pixelformat	
-swapinterval	**-multisamplebuffers**	**-multisamplesamples**	
-createproc	**-displayproc**	**-reshapeproc**	

These configuration options behave like standard Tcl options and can be queried as such:

```
% package require tcl3d ; # or just package require tcl3dogl
0.4.0
% togl .t
% .t configure
{-height height Height 400 400} …
{-displayproc displayproc Displayproc {} {}} …
% .t configure -displayproc tclDisplayFunc
% .t configure -displayproc
-displayproc displayproc Displayproc {} tclDisplayFunc
```

Callback procedures

To be usable from the Tcl level, the Togl widget has been extended to support 3 new configuration options for specifying Tcl callback procedures:

-createproc	ProcName	Procedure is called when a new widget is created.
-reshapeproc	ProcName	Procedure is called when the widget's size is changed.
-displayproc	ProcName	Procedure is called when the widget's content needs to be redrawn.

Default settings are:

```
{-createproc  createproc  Createproc  {} {}}
{-displayproc displayproc Displayproc {} {}}
{-reshapeproc reshapeproc Reshapeproc {} {}}
```

The callback procedures must have the following signatures:

```
proc CreateProc  { toglwin } { ... }
proc ReshapeProc { toglwin width height } { ... }
proc DisplayProc { toglwin } { ... }
```

Display options

-swapinterval	Enable/disable synchronisation to vertical blank signal

`-multisamplebuffers`	Enable/disable the multisample buffer
`-multisamplesamples`	Set the number of multisamples

Default settings are:

```
{-swapinterval swapInterval SwapInterval 0 0}
{-multisamplebuffers multisampleBuffers MultisampleBuffers 0 0}
{-multisamplesamples multisampleSamples MultisampleSamples 2 2}
```

Note

- Multisampling was implemented for the Togl widget in Tcl3D version 0.3.2. If working with older version of Tcl3D, you may enable multisampling outside of Tcl3D as follows:
  With NVidia cards, you can enable multisampling under Windows via the NVidia driver GUI. Under Linux you can set the environment variable `__GL_FSAA_MODE` to 1.
- The default value for `-swapinterval` has been changed in version 0.4.0 from 1 to 0, i.e. if this option is not specified, a Tcl3D program does not wait for the vertical blank signal, but runs at maximum speed.

4.1.3 A simple Tcl3D template

A template for a Tcl3D application looks like follows:

```
package require tcl3d

proc tclCreateFunc { toglwin } {
    glShadeModel GL_SMOOTH          ; # Enable smooth shading
    glClearColor 0.0 0.0 0.0 0.5    ; # Black background
    glClearDepth 1.0                ; # Depth buffer setup
    glEnable GL_DEPTH_TEST          ; # Enable depth testing
}

proc tclReshapeFunc { toglwin w h } {
    glViewport 0 0 $w $h          ; # Reset the current viewport
    glMatrixMode GL_PROJECTION    ; # Select the projection matrix
    glLoadIdentity                ; # Reset the projection matrix

    # Calculate the aspect ratio of the window
    gluPerspective 45.0 [expr double($w)/double($h)] 0.1 100.0

    glMatrixMode GL_MODELVIEW     ; # Select the modelview matrix
    glLoadIdentity                ; # Reset the modelview matrix
}

proc tclDisplayFunc { toglwin } {
    # Clear color and depth buffer
    glClear [expr $::GL_COLOR_BUFFER_BIT | $::GL_DEPTH_BUFFER_BIT]

    glLoadIdentity                  ; # Reset the current modelview matrix

    glTranslatef 0.0 0.0 -5.0       ; # Transformations
    glRotatef $::xrot 1.0 0.0 0.0
    glRotatef $::yrot 0.0 1.0 0.0
    glRotatef $::zrot 0.0 0.0 1.0

    drawGeometry                    ; # Draw the actual geometry

    $toglwin swapbuffers            ; # Swap front and back buffer
}

frame .fr
pack .fr -expand 1 -fill both
# Create a Togl widget with a depth buffer and doublebuffering enabled.
```

```
togl .fr.toglwin -width 250 -height 250 \
                 -double true -depth true \
                 -createproc  tclCreateFunc \
                 -reshapeproc tclReshapeFunc \
                 -displayproc tclDisplayFunc
grid .fr.toglwin -row 0 -column 0 -sticky news
```

Note

- Option `-createproc` is not effective, when specified in the configure subcommand. It has to be specified at widget creation time.

4.2 tcl3dOgl->OpenGL: Wrapper for OpenGL functionality

This module wraps OpenGL functionality up to OpenGL Version 3.0, GLU library functions based on Version 1.2 and several OpenGL extensions.
It is implemented with the help of the ***GLEW*** [13] library.
Standard shapes (box, sphere, cylinder, teapot, …) with a GLUT compatible syntax are supplied in this module, too.

Requirements for this module: An OpenGL driver suitable for your graphics card. It is recommend to download and install an up-to-date OpenGL driver from the manufacturer of your graphics card, especially if intending to write shader programs in GLSL or Cg.

The master SWIG file for wrapping the OpenGL library is ***tcl3dOgl.i***.

OpenGL library

Implementation files:	***tcl3dOglQuery.tcl, tcl3dOglUtil.tcl, tcl3dOglHelp.tcl***
Header files:	***glew.h, glu.h***
Wrapper files:	***glew.i, glewautogen.i, glu.i***

The wrapping for this module is based on the header files ***glew.h*** and ***glu.h***.

Note

- The original GLEW header file is not usable for direct wrapping with Swig, so it's information is used for generating the wrapper file ***glewautogen.i*** during the build process with Tcl script ***createGlewSwigFile.tcl***.
- File ***tcl3dOglHelp.tcl*** is also automatically generated by script ***createGlewScriptFile.tcl***.

The following Tcl3D specific commands are implemented in this module:

Tcl command	Description
`tcl3dOglGetVersion`	Get the version of the wrapped OpenGL library.
`tcl3dOglHaveFunc`	Check availability of an OpenGL function in the OpenGL driver.
`tcl3dOglHaveExtension`	Check, if a given OpenGL extension is provided by the OpenGL implementation.
`tcl3dOglHaveVersion`	Check, if a specific OpenGL version is available.
`tcl3dOglGetVersions`	Query the OpenGL library with the keys `GL_VENDOR`, `GL_RENDERER`, `GL_VERSION`, `GLU_VERSION` and return the results as a list of key-value pairs.
`tcl3dOglGetExtensions`	Query the OpenGL library with the keys `GL_EXTENSIONS` and `GLU_EXTENSIONS` and return the results as a list of key-value pairs.
`tcl3dOglGetStates`	Query all state variables of the OpenGL library and return the results as a list of sub-lists. Each sublist contains a flag indicating the sucess of the query, the querying command used, the key and the value(s).
`tcl3dOglGetIntState`	Get OpenGL integer state variable.
`tcl3dOglGetFloatState`	Get OpenGL float state variable.
`tcl3dOglGetDoubleState`	Get OpenGL double state variable.
`tcl3dOglGetMaxTextureSize`	Get maximum texture size.
`tcl3dOglGetMaxTextureUnits`	Get maximum number of texture units.
`tcl3dOglGetViewport`	Get current viewport as a 4-element Tcl list.
`tcl3dOglGetShaderInfoLog`	Utility function for easier use of OpenGL function `glGetShaderInfoLog`.
`tcl3dOglGetProgramInfoLog`	Utility function for easier use of OpenGL function `glGetProgramInfoLog`.
`tcl3dOglGetShaderSource`	Utility function for easier use of OpenGL function `glGetShaderSource`.
`tcl3dOglGetInfoLogARB`	Utility function for easier use of OpenGL function `glGetInfoLogARB`.
`glMultiDrawElements`	Procedure to implement the OpenGL function `glMultiDrawElements`.
`tcl3dOglGetGlError`	Check, if an OpenGL related error has been occurred.
`tcl3dOglShaderSource`	Utility function for easier use of OpenGL function `glShaderSource`.
`tcl3dOglGetFuncList`	Return a list of the names of all wrapped OpenGL functions.
`tcl3dOglGetFuncSignatureList`	Return a list of the C-signatures of all wrapped OpenGL functions.
`tcl3dOglGetFuncVersionList`	Return a list of the OpenGL versions or extensions of all wrapped OpenGL functions.

Table 4.1: tcl3dOgl helper commands

Note

- The functions `glGetString` and `gluGetString` as well as the corresponding high-level functions `tcl3dOglGetVersions` and `tcl3dOglGetExtensions` only return correct values, if a Togl window has been created, i.e. a rendering context has been established. This holds true for function `tcl3dOglHaveFunc`, too.
- See Hint 6 in chapter 5.2 for the differences between the GLEW extension library and the previously used OglExt extension library.

GLUT shapes library

Implementation files:	***tcl3dShapesGlut.c, tcl3dShapesTeapot.c, tcl3dShapesGlut.tcl***
Header files:	***tcl3dShapesGlut.h***
Wrapper files:	***tcl3dOgl.i***

The shapes library consists of C files (***tcl3dShapesTeapot.c*** for the teapot, ***tcl3dShapesGlut.c*** for all other GLUT shapes and the common header file ***tcl3dShapesGlut.h***) and the Tcl file ***tcl3dShapesGlut.tcl***.

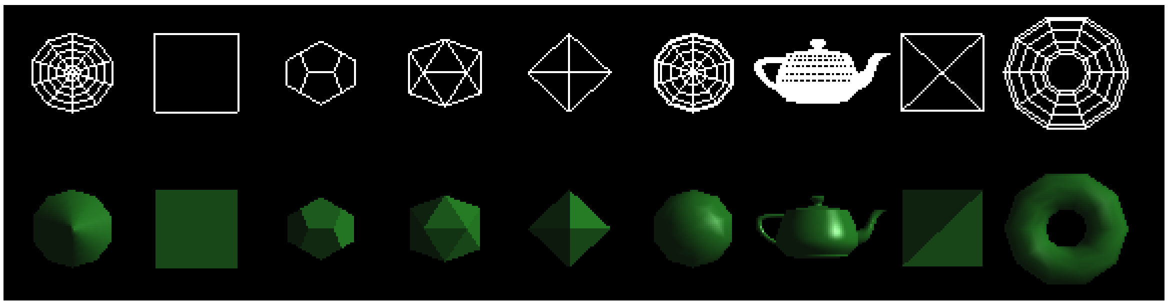
The GLUT shape objects are available under identical names for porting test and demonstration programs to Tcl3D. These shapes are used extensively in the examples of the OpenGL redbook [25]. See there for a description of the functions and its parameters.

Solid shapes	**Wire shapes**
`glutSolidCone`	`glutWireCone`
`glutSolidCube`	`glutWireCube`
`glutSolidDodecahedron`	`glutWireDodecahedron`
`glutSolidIcosahedron`	`glutWireIcosahedron`
`glutSolidOctahedron`	`glutWireOctahedron`
`glutSolidSphere`	`glutWireSphere`
`glutSolidTeapot`	`glutWireTeapot`
`glutSolidTetrahedron`	`glutWireTetrahedron`
`glutSolidTorus`	`glutWireTorus`

Table 4.2: tcl3dOgl GLUT shape commands

Note

- The teapot implementation differs in the original GLUT and the freeglut implementation. If using the teapot in a benchmark application, note that:
  Freeglut uses 7 for the grid parameter.
  Original GLUT and Tcl3D use 14 as grid parameter.


All supported GLUT shapes (Demo ***glutShapes.tcl***)

Examples

The following code snippet shows how to call `tcl3dOglGetVersions`.

```
foreach glInfo [tcl3dOglGetVersions] {
    puts "[lindex $glInfo 0]: [lindex $glInfo 1]"
}

GL_VENDOR: NVIDIA Corporation
GL_RENDERER: GeForce FX Go5600/AGP/SSE2
```

```
GL_VERSION: 1.4.0
GLU_VERSION: 1.2.2.0 Microsoft Corporation
```

The following code snippet shows how to call `tcl3dOglGetExtensions`.

```
foreach glInfo [tcl3dOglGetExtensions] {
    puts "[lindex $glInfo 0]:"
    foreach ext [lsort [lindex $glInfo 1]] {
        puts "\t$ext"
    }
}

GL_EXTENSIONS:
     GL_ARB_depth_texture
     GL_ARB_fragment_program
     GL_ARB_imaging
     …
GLU_EXTENSIONS:
     GL_EXT_bgra
```

The following code snippet shows how to call `tcl3dOglGetStates`.

```
foreach glState [tcl3dOglGetStates] {
    set msgStr "[lindex $glState 2]: [lrange $glState 3 end]"
    if { [lindex $glState 0] == 0 } {
        set tag "(Unsupported)"
    } else {
        set tag ""
    }
    append msgStr $tag
    puts $msgStr
}

GL_VERTEX_ARRAY_SIZE: 4
GL_VERTEX_ARRAY_TYPE: 5126
GL_VERTEX_ARRAY_STRIDE: 0
GL_VERTEX_ARRAY_POINTER: --(Unsupported)
GL_NORMAL_ARRAY: 0
GL_NORMAL_ARRAY_TYPE: 5126
```

See the demo program ***tcl3dInfo.tcl*** for other examples, on how to use these procedures.

4.3 tcl3dOgl->Util: Tcl3D utility library

This module implements several utilities in C and Tcl offering functionality needed for 3D programs. It currently contains the following sub-modules:

- 3D vector and transformation matrix module
- Information module
- File utility module
- Color names module
- Large data module (tcl3dVector)
- Image utility module
- Screen capture module
- Timing module
- Random number module

- 3D-model and shapes module
- Virtual trackball and arcball module
- C/C++ based utilities for demo applications

Requirements for this module: None, all files are contained in the Tcl3D distribution.

The master SWIG file for wrapping the utility library is ***util.i***.

4.3.1 3D vector and transformation matrix module

This module provides miscellaneous 3D vector and 4x4 transformation matrix functions.

Overview

The following tables list the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dVec3fPrint`	Print the contents of a 3D vector onto standard output.
`tcl3dVec3fCompare`	Compare two 3D vectors.
`tcl3dVec3fIdentity`	Fill a 3D vector with (0.0, 0.0, 0.0).
`tcl3dVec3fCopy`	Copy a 3D vector.
`tcl3dVec3fLength`	Calculate the length of a 3D vector.
`tcl3dVec3fNormalize`	Normalise a 3D vector.
`tcl3dVec3fDistance`	Calculate the distance between two 3D vectors.
`tcl3dVec3fDotProduct`	Calculate the dot product of two 3D vectors.
`tcl3dVec3fCrossProduct`	Calculate the cross product of two 3D vectors.
`tcl3dVec3fAdd`	Add two 3D vectors.
`tcl3dVec3fSubtract`	Subtract two 3D vectors.
`tcl3dVec3fScale`	Scale a 3D vector by a scalar value.
`tcl3dVec3fPlaneNormal`	Create a plane normal defined by three points.

Table 4.3: tcl3dUtil: 3D vector commands

Tcl command	Description
`tcl3dMatfPrint`	Print the contents of a matrix onto standard output.
`tcl3dMatfCompare`	Compare two transformation matrices.
`tcl3dMatfIdentity`	Build the identity transformation matrix.
`tcl3dMatfCopy`	Copy a transformation matrix.
`tcl3dMatfTranslatev`	Build a translation matrix based on a 3D vector.
`tcl3dMatfTranslate`	Build a translation matrix based on 3 scalar values.
`tcl3dMatfRotate`	Build a rotation matrix based on angle (°) and axis.
`tcl3dMatfRotateX`	Build a rotation matrix based on angle (°) around x axis.
`tcl3dMatfRotateY`	Build a rotation matrix based on angle (°) around y axis.
`tcl3dMatfRotateZ`	Build a rotation matrix based on angle (°) around z axis.
`tcl3dMatfScalev`	Build a scale matrix based on a 3D vector.
`tcl3dMatfScale`	Build a scale matrix based on 3 scalar values.
`tcl3dMatfTransformPoint`	Transform a point by a given matrix.
`tcl3dMatfTransformVector`	Transform a 3D vector by a given matrix.
`tcl3dMatfMult`	Multiply two transformation matrices.
`tcl3dMatfInvert`	Invert a transformation matrix.
`tcl3dMatfTranspose`	Transpose a transformation matrix.

Table 4.4: tcl3dUtil: Matrix commands

Examples

See the test programs ***matmathtest.tcl* and *vecmathtest.tcl*** for examples, on how to use these procedures. Also take a look at the demo program ***ogl_fps_controls.tcl*** for a real-world example.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dVecMath.c, tcl3dVecMath.tcl***
Header files:	***tcl3dVecMath.h***
Wrapper files:	***util.i***

4.3.2 Information module

This module provides convenience functions for querying Tcl3D package related information.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dHavePackage`	Check, if a Tcl package is available in a given version.
`tcl3dGetLibraryInfo`	Return the library version corresponding to supplied Tcl3D package name.
`tcl3dGetPackageInfo`	Return a list of sub-lists containing Tcl3D package information. Each sub-list contains the name of the Tcl3D sub-package, the availability flag (0 or 1), the sub-package version as well as the version of the wrapped library.
`tcl3dShowPackageInfo`	Display the version info returned by `tcl3dGetPackageInfo` in a toplevel window.
`tcl3dHaveCg`	Check, if the Cg library has been loaded successfully.
`tcl3dHaveSDL`	Check, if the SDL library has been loaded successfully.
`tcl3dHaveFTGL`	Check, if the FTGL library has been loaded successfully.
`tcl3dHaveGl2ps`	Check, if the GL2PS library has been loaded successfully.
`tcl3dHaveOde`	Check, if the ODE library has been loaded successfully.

Table 4.5: tcl3dUtil: Information commands

Examples

The following code snippet shows how to call `tcl3dGetPackageInfo`.

```
foreach pkgInfo [tcl3dGetPackageInfo] {
    puts "[lindex $pkgInfo 0]: [lindex $pkgInfo 1]"
}

{tcl3dcg     1 0.4.0 1.5.0015}
{tcl3dftgl   1 0.4.0 2.1.2}
{tcl3dgauges 1 0.4.0 {}}
```

```
{tcl3dgl2ps  1 0.4.0 1.3.2}
{tcl3dode    1 0.4.0 0.7.0}
{tcl3dogl    1 0.4.0 {1.2 APPLE-1.4.56}}
{tcl3dsdl    1 0.4.0 1.2.9}
```

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilInfo.tcl***
Header files:	None
Wrapper files:	None

4.3.3 File utility module

This module provides miscellaneous functions for file related tasks: Handling of temporary directories and file access from a Starpack.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dGetTmpDir`	Get the name of a temporary directory.
`tcl3dCreateTmpDir`	Create a unique temporary directory.
`tcl3dGenExtName`	Create a name on the file system. Use this function, if writing to a file from a script, which may be running from within a Starpack.
`tcl3dGetExtFile`	Get a name on the file system. Use this function, if a file is needed for reading from an external Tcl3D library, like font files used by FTGL, or shader files, and the script may be executed from within a Starpack.

Table 4.6: tcl3dUtil: File utility commands

Examples

See the demo program ***Lesson02.tcl*** for an example usage of `tcl3dGenExtName`, and demo ***ftglTest.tcl*** for an example usage of `tcl3dGetExtFile` .

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilFile.tcl***
Header files:	None
Wrapper files:	None

4.3.4 Color names module

This module provides miscellaneous functions for handling color specifications in Tcl and OpenGL style.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dGetColorNames`	Return a list of all supported Tcl color names.
`tcl3dFindColorName`	Check, if supplied color name is a valid Tcl color name.
`tcl3dName2Hex`	Convert a Tcl color name into the corresponding hexadecimal representation: #RRGGBB
`tcl3dName2Hexa`	Convert a Tcl color name into the corresponding hexadecimal representation: #RRGGBBAA
`tcl3dName2rgb`	Convert a Tcl color specification into the corresponding OpenGL representation. OpenGL colors are returned as a list of 3 unsigned bytes: r g b
`tcl3dName2rgbf`	Convert a color specification into the corresponding OpenGL representation. OpenGL colors are returned as a list of 3 floats in the range [0..1]: r g b
`tcl3dName2rgba`	Convert a color specification into the corresponding OpenGL representation. OpenGL colors are returned as a list of 4 unsigned bytes: r g b a
`tcl3dName2rgbaf`	Convert a color specification into the corresponding OpenGL representation. OpenGL colors are returned as a list of 4 floats in the range [0..1]: r g b a
`tcl3dRgb2Name`	Convert an OpenGL RGB color representation into a hexadecimal Tcl color name string. OpenGL colors are specified as unsigned bytes in the range [0..255].
`tcl3dRgba2Name`	Convert an OpenGL RGBA color representation into a hexadecimal Tcl color name string. OpenGL colors are specified as unsigned bytes in the range [0..255].
`tcl3dRgbf2Name`	Convert an OpenGL RGB color representation into a hexadecimal Tcl color name string. OpenGL colors are specified as floats in the range [0..1].
`tcl3dRgbaf2Name`	Convert an OpenGL RGBA color representation into a hexadecimal Tcl color name string. OpenGL colors are specified as floats in the range [0..1].

Table 4.7: tcl3dUtil: Color utility commands

Examples

See the test program ***colorNames.tcl*** for examples, on how to use these procedures.

```
[tcl3dName2Hex white]  returns "#FFFFFF"
[tcl3dName2Hexa white] returns "#FFFFFFFF"

[tcl3dName2rgb white] returns {255 255 255}
[tcl3dRgb2Name 255 255 255] returns "#FFFFFF"

[tcl3dName2rgba white] returns {255 255 255 255}
```

```
[tcl3dRgba2Name 255 255 255 255] returns "#FFFFFFFF"

[tcl3dName2rgbf white] returns {1.0 1.0 1.0}
[tcl3dRgbf2Name 1.0 1.0 1.0] returns "#FFFFFF"

[tcl3dName2rgbaf white] returns {1.0 1.0 1.0 1.0}
[tcl3dRgbaf2Name 1.0 1.0 1.0 1.0] returns "#FFFFFFFF"

[tcl3dName2rgb "#0a0c0e"] returns {10 12 14}
```

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilColors.tcl***
Header files:	None
Wrapper files:	None

4.3.5 Large data module

This module provides miscellaneous functions for handling large data like textures and vertex arrays.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	**Description**
`tcl3dVector`	Create a new Tcl3D Vector by calling the low-level memory allocation routine new_TYPE and create a new Tcl procedure. (See example below).
`tcl3dVectorInd`	Get index of a Tcl3D Vector.
`tcl3dVectorPrint`	Print the contents of a Tcl3D Vector onto standard output.
`tcl3dVectorFromArgs`	Create a new Tcl3D Vector from a variable argument list.
`tcl3dVectorFromList`	Create a new Tcl3D Vector from a Tcl list.
`tcl3dVectorFromString`	Create a new Tcl3D Vector from a Tcl string. *Very slow.*
`tcl3dVectorFromByteArray`	Create a new Tcl3D Vector from a Tcl binary string.
`tcl3dVectorFromPhoto`	Create a new Tcl3D Vector containing the data of a Tk photo image. See next chapter for detailed description.
`tcl3dVectorToList`	Copy the contents of a Tcl3D Vector into a Tcl list. *Very slow.*
`tcl3dVectorToString`	Copy the contents of a Tcl3D Vector into a string. *Very slow.*
`tcl3dVectorToByteArray`	Copy the contents of a Tcl3D Vector into a Tcl binary string.

Table 4.8: tcl3dUtil: tcl3dVector utility commands

Note
- The `tcl3dFromString` and `tcl3dVectorToString` commands can be replaced with the corresponding `ByteArray` commands, which are much faster.
- For functions converting photos into vectors and vice versa, see the next chapter about image manipulation.

The `tcl3dVector` command creates a new Tcl procedure with the following subcommands, which wrap the low-level vector access functions described above:

Subcommand	Description
`get`	Get vector element at a given index. (`TYPE_getitem`)
`set`	Set vector element at a given index to supplied value. (`TYPE_setitem`)
`setvec`	Set range of vector elements to supplied value. (`TYPE_setarray`)
`addvec`	Add supplied value to a range of vector elements. (`TYPE_addarray`)
`mulvec`	Muliply supplied value to a range of vector elements. (`TYPE_mularray`)
`delete`	Delete a tcl3dVector. (`delete_TYPE`)

Table 4.9: tcl3dUtil: tcl3dVector subcommands

Examples

The following example shows the usage of the `tcl3dVector` command.

```
set ind 23
set vec [tcl3dVector GLfloat 123] ; # Create Vector of 123 GLfloats
$vec set $ind 1017.0              ; # Set element at index 23 to 1017.0
set x [$vec get $ind]             ; # Get element at index 23
$vec addvec 33 2 10               ; # Add 33 to ten elements starting at index 2
$vec delete                       ; # Free the allocated memory
```

Note
- Indices start at zero.

See the demo program ***bytearray.tcl*** and ***vecmanip.tcl*** for examples, on how to use the `ByteArray` procedures for generating textures in Tcl.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dVector.tcl***
Header files:	None
Wrapper files:	***vector.i, bytearray.i***

As stated in chapter 3.1.2, some of the OpenGL functions need a pointer to a contiguous block of allocated memory. SWIG already provides a feature to automatically generate wrapper functions for allocating and freeing memory of any type. This SWIG feature `%array_functions` has been extended and replaced with 2 new SWIG commands: `%baseTypeVector` for scalar types and `%complexTypeVector` for complex types like structs. It not only creates setter and getter functions for accessing single elements of the allocated memory, but also adds functions to set ranges of the allocated memory.

Wrapper functions for the following scalar types are defined in file ***tcl3dVectors.i***:

Array of	is mapped to
`short`	`short`
`int`	`int`
`ushort`	`unsigned short`
`uint`	`unsigned int`
`float`	`float`

`double`	`double`
`GLenum`	`unsigned int`
`GLboolean`	`unsigned char`
`GLbitfield`	`unsigned int`
`GLbyte`	`signed char`
`GLshort`	`short`
`GLint`	`int`
`GLsizei`	`int`
`GLubyte`	`unsigned char`
`GLushort`	`unsigned short`
`GLuint`	`unsigned int`
`GLfloat`	`float`
`GLclampf`	`float`
`GLdouble`	`double`
`GLclampd`	`double`

Note

- tcl3dVectors of type `char`, `unsigned char`, `GLchar` and `GLcharARB` are not supported, because the corresponding typemaps would collide with the standard SWIG mapping for C strings. Use types `GLbyte` and `GLubyte`, if you need tcl3dVectors with element sizes of 1 byte.

The generated wrapper code looks like this (Example shown for GLdouble):

```
static double *new_GLdouble(int nelements) {
  return (double *) calloc(nelements,sizeof(double));
}

static void delete_GLdouble(double *ary) {
  free(ary);
}

static double GLdouble_getitem(double *ary, int index) {
    return ary[index];
}

static void GLdouble_setitem(double *ary, int index, double value) {
    ary[index] = value;
}

static void GLdouble_setvector(double *ary, double value,
                               int startIndex, int len) {
    int i;
    int endIndex = startIndex + len;
    for (i=startIndex; i<endIndex; i++) {
        ary[i] = value;
    }
}

static void GLdouble_addvector(double *ary, double value,
                               int startIndex, int len) {
    int i;
    int endIndex = startIndex + len;
    for (i=startIndex; i<endIndex; i++) {
        ary[i] += (double) value;
    }
}

static void GLdouble_mulvector(double *ary, double value,
                               int startIndex, int len) {
    int i;
    int endIndex = startIndex + len;
    for (i=startIndex; i<endIndex; i++) {
        ary[i] *= (double) value;
    }
}

static double *GLdouble_ind(double *ary, int incr) {
    return (ary + incr);
}

static double *GLdouble_convert(void *ary) {
    return (double *)ary;
}
```

These low level functions are typically not used directly. They are accessible via the Tcl command `tcl3dVector`, with the exception of the `TYPE_ind` functions.
An example for the usage of `GLfloat_ind` for optimised access to vectors can be found in NeHe demo ***Lesson37.tcl***.

File ***bytearray.i*** provides the implementation and wrapper definitions to convert Tcl binary strings (ByteArrays) into Tcl3D Vectors (`tcl3dByteArray2Vector`) and vice versa (`tcl3dVector2ByteArray`).

Comparison of the different vector methods

There are 4 different methods of setting vectors.

Method 1: `$vec set $index $val`
Set the elements with the tcl3dVector object method "set". Most elegant way, but also the slowest. Only useful for small vectors.

Method 2: `${type}_setitem $vec $index $val`
Set the elements with the tcl3dVector low-level function "setitem". Not so elegant, because you need to know the type of the vector, but much faster than method 1.

Method 3: `tcl3dListToVector_$type $list $vec $len`
Set the elements with the low level functions "tcl3dListToVector_TYPE" introduced in Tcl3D 0.3.3. Not so elegant, because you need to know the type of the tcl3dVector and you have to build a Tcl list before setting the tcl3dVector. This is the fastest way.

Method 4: `set vec [tcl3dVectorFromList $type $list]`
Set the elements with the utility function "tcl3dVectorFromList", which internally calls the low level functions "tcl3dListToVector_TYPE". You don't have to care about allocating a tcl3dVector of approriate size. This should be only slightly slower than method3.

The test program ***vectorspeed.tcl*** implements the above mentioned four different methods and shows output similar to the following lines:

```
D:\tcl3d\tcl3dOgl\tests> tclsh vectorspeed.tcl
Number of runs : 100
Size of vectors: 1000
Setting 100000 elements per method.
SetMethod1: 25339.3 microseconds per iteration
SetMethod2:  3637.8 microseconds per iteration
SetMethod3:   659.2 microseconds per iteration
SetMethod4:   736.2 microseconds per iteration
```

4.3.6 Image utility module

This module provides access to Tk photo images.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dPhotoChans`	Return the number of channels of a Tk photo.
`tcl3dVectorToPhoto`	Copy from OpenGL raw image format into a Tk photo. The photo image must have been initialized with the appropriate size and type.
`tcl3dPhotoToVector`	Copy a Tk photo into a `tcl3dVector` in OpenGL raw image format. The `tcl3dVector` must have been allocated with the appropriate size and type.
`tcl3dVectorFromPhoto`	Create a new Tcl3D Vector containing the image data of a Tk photo image. Only GL_UNSIGNED_BYTE currently supported.

Table 4.10: tcl3dUtil: Image utility commands

Note
- The Img extension is recommended to have access to lots of image formats.

Examples

Example 1: Read an image into a Tk photo and use it as a texture map.

```
set texture [tcl3dVector GLuint 1] ; # Memory for 1 texture identifier

proc LoadImage { imgName } {
    set retVal [catch {set phImg [image create photo -file $imgName]} err1]
    if { $retVal != 0 } {
        error "Error reading image $imgName ($err1)"
    } else {
        set numChans [tcl3dPhotoChans $phImg]
        if { $numChans != 3 && $numChans != 4 } {
            error "Error: Only 3 or 4 channels allowed ($numChans supplied)"
        }
        set w [image width  $phImg]
        set h [image height $phImg]
        set texImg [tcl3dVectorFromPhoto $phImg $numChans]
        image delete $phImg
    }
    return [list $texImg $w $h]
}

proc CreateTexture {} {
    # Load an image into a tcl3dVector.
    set imgInfo [LoadImage "Wall.bmp"]
    set imgData   [lindex $imgInfo 0]
    set imgWidth  [lindex $imgInfo 1]
    set imgHeight [lindex $imgInfo 2]

    # Create the texture identifiers.
    glGenTextures 1 $::texture

    glBindTexture GL_TEXTURE_2D [$::texture get 0]
    glTexParameteri GL_TEXTURE_2D GL_TEXTURE_MIN_FILTER $::GL_LINEAR
    glTexParameteri GL_TEXTURE_2D GL_TEXTURE_MAG_FILTER $::GL_LINEAR
    glTexImage2D GL_TEXTURE_2D 0 3 $imgWidth $imgHeight \
                 0 GL_RGBA GL_UNSIGNED_BYTE $imgData

    # Delete the image data vector.
    $imgData delete
}
```

Example 2: Read an image from the OpenGL framebuffer and save it with the Img library.

```
proc SaveImg { imgName } {
    set w $::toglWidth
    set h $::toglHeight
    set numChans 4
    set vec [tcl3dVector GLubyte [expr $w * $h * $numChans]]
    glReadPixels 0 0 $w $h GL_RGBA GL_UNSIGNED_BYTE $vec
    set ph [image create photo -width $w -height $h]
    tcl3dVectorToPhoto $vec $ph $w $h $numChans
    set fmt [string range [file extension $imgName] 1 end]
    $ph write $imgName -format $fmt
    image delete $phImg
    $vec delete
}

proc tclReshapeFunc { toglwin w h } {
    set ::toglWidth  $w
    set ::toglHeight $h
    ...
}
```

The actual size of the Togl window (`::toglWidth, ::toglHeight`), which is needed in command `SaveImg`, can be saved in a global variable when the reshape callback is executed.

See the NeHe demo program ***Lesson41.tcl*** or any demo using textures for examples, on how to use the photo image utilities.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dVector.tcl***
Header files:	None
Wrapper files:	***tkphoto.i***

4.3.7 Screen capture module

This module implements functions for capturing window contents into either a photo image, an image file or the clipboard.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dWidget2Img`	Copy contents of a widget and all of its sub-widgets into a photo image.
`tcl3dWidget2File`	Copy contents of a widget and all of its sub-widgets into a photo image and save the image to a file.
`tcl3dCanvas2Img`	Copy the contents of a Tk canvas into a photo image.
`tcl3dCanvas2File`	Copy the contents of a Tk canvas into a photo image and save the image to a file.
`tcl3dClipboard2Img`	Copy the contents of the Windows clipboard into a photo image.
`tcl3dClipboard2File`	Copy the contents of the Windows clipboard into a photo image and save the image to a file.
`tcl3dImg2Clipboard`	Copy a photo into the Windows clipboard.
`tcl3dWindow2Clipboard`	Copy the contents of the top level window (Alt-PrtSc) into the Windows clipboard.
`tcl3dDesktop2Clipboard`	Copy the contents of the whole desktop (PrtSc) into the Windows clipboard.
`tcl3dWindow2Img`	Copy the contents of the top level window (Alt-PrtSc) into a photo image.
`tcl3dWindow2File`	Copy the contents of the top level window (Alt-PrtSc) into a photo image and save the image to a file.

Table 4.11: tcl3dUtil: Capture commands

Note

- All of the functionality requires the help of the ***Img*** extension.
- Some of the functionality requires the help of the ***Twapi*** extension and is therefore available only on Windows.

Examples

See the demo program ***presentation.tcl*** for an example, on how to use these procedures to save screenshots of the available Tcl3D demos by right-clicking on the demo name.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilCapture.tcl***
Header files:	None
Wrapper files:	None

4.3.8 Timing module

This module provides functions for timing purposes.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dNewSwatch`	Create a new stop watch and return it's identifier.
`tcl3dDeleteSwatch`	Delete an existing stop watch.
`tcl3dStopSwatch`	Stop a running stop watch.
`tcl3dStartSwatch`	Start a stop watch.
`tcl3dResetSwatch`	Reset a stop watch, i.e. set the time to zero seconds.
`tcl3dLookupSwatch`	Lookup a stop watch and return the elapsed seconds.

Table 4.12: tcl3dUtil: Stop watch commands

Examples

See the demo program ***spheres.tcl*** for an example, on how to use these procedures to measure the rendering frame rate.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilStopWatch.c***
Header files:	***tcl3dUtilStopWatch.h***
Wrapper files:	***util.i***

4.3.9 Random number module

This module provides functions to generate random numbers.

Overview

The following table lists the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`tcl3dNewRandomGen`	Initialize a new random number generator.
`tcl3dDeleteRandomGen`	Delete a random number generator.
`tcl3dGetRandomInt`	Generate a pseudo-random integer number.
`tcl3dGetRandomFloat`	Generate a pseudo-random floating point number.

Table 4.13: tcl3dUtil: Random number commands

Examples

See the demo program ***mandelbrot.tcl*** for an example, on how to use these procedures to set up random colors for fractal generation.

Implementation details

The functionality of this module is implemented in the following files:

Implementation files:	***tcl3dUtilRandom.c***
Header files:	***tcl3dUtilRandom.h***
Wrapper files:	***util.i***

4.3.10 3D-Model and shapes module

This module provides functions for reading 3D models in Wavefront format and creating basic shapes.

Overview

The following tables list the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

Tcl command	Description
`glmUnitize`	"Unitize" a model by translating it to the origin and scaling it to fit in a unit cube around the origin.
`glmDimensions`	Calculates the dimensions (width, height, depth) of a model.
`glmScale`	Scales a model by a given amount.
`glmReverseWinding`	Reverse the polygon winding for all polygons in this model.
`glmFacetNormals`	Generates facet normals for a model.
`glmVertexNormals`	Generates smooth vertex normals for a model.
`glmLinearTexture`	Generates texture coordinates according to a linear projection of the texture map.
`glmSpheremapTexture`	Generates texture coordinates according to a spherical projection of the texture map.
`glmDelete`	Deletes a GLMmodel structure.
`glmReadOBJ`	Reads a model description from a Wavefront .OBJ file.
`glmWriteOBJ`	Writes a model description in Wavefront .OBJ format to a file.
`glmDraw`	Renders the model to the current OpenGL context using the mode specified.
`glmList`	Generates and returns a display list for the model using the mode specified.
`glmWeld`	Eliminate (weld) vectors that are within an epsilon of each other.

Table 4.14: tcl3dUtil: Wavefront reader commands

Tcl command	Description
`tcl3dCube`	Draw a textured cube with given center and size.
`tcl3dHelix`	Draw a helix with given center, radius and number of twists.
`tcl3dSphere`	Draw a sphere with given radius precision.

Table 4.15: tcl3dUtil: Shape commands

Examples

See the demo program ***gaugedemo.tcl*** for an example, on how to use the Wavefront parser functions.
See NeHe demo program ***Lesson23.tcl*** for an example, on how to use `tcl3dCube`.
See NeHe demo program ***Lesson36.tcl*** for an example, on how to use `tcl3dHelix`.
See demo program ***ogl_benchmark_sphere.tcl*** for an example, on how to use `tcl3dSphere`.

Implementation details

The ***tcl3dModel.* and tcl3dModelFmtObj.**** files provide a parser for reading model files in Alias/Wavefront format. The code to read and draw the models is a modified version of the parser from Nate Robin's OpenGL tutorial [18].
The ***tcl3dShapes.**** files implement a sphere based on an algorithm found at Paul Bourke's excellent pages [21] as well as a cube and a helix based on algorithms found in the NeHe tutorials 23 and 36 [15].

Implementation files:	***tcl3dModel.c, tcl3dModelFmtObj.c, tcl3dShapesMisc.c***
Header files:	***tcl3dModel.h, tcl3dModelFmtObj.h, tcl3dShapesMisc.h***
Wrapper files:	***util.i***

Note

- The standard GLUT shapes are described in chapter 4.2.

4.3.11 Virtual trackball and arcball module

This module provides functions for emulating a trackball and an arcball.

Overview

The following tables list the available functions of this module. For a detailed description of the functions see the Tcl3D Reference Manual [5] or the source code files as listed in section **Implementation details** at the end of this chapter.

The trackball module implements the following commands:

Tcl command	Description
`tcl3dTbInit`	Call this initialization procedure before any other trackball procedure.
`tcl3dTbReshape`	Call this procedure from the reshape callback.
`tcl3dTbMatrix`	Get the trackball matrix rotation.
`tcl3dTbStartMotion`	Begin trackball movement.
`tcl3dTbStopMotion`	Stop trackball movement.
`tcl3dTbMotion`	Call this procedure from the motion callback.
`tcl3dTbAnimate`	Call with parameter `1` (or `$::GL_TRUE`), if you want the trackball to continue spinning after the mouse button has been released. Call with parameter `0` (or `$::GL_FALSE`), if you want the trackball to stop spinning after the mouse button has been released.

Table 4.16: tcl3dUtil: Trackball commands

The arcball module implements the following commands:

Tcl command	Description
`tcl3dNewArcBall`	Create new ArcBall with given width and height.
`tcl3dDeleteArcBall`	Delete an ArcBall.
`tcl3dSetArcBallBounds`	Update mouse bounds for ArcBall. Call this procedure from the reshape callback.
`tcl3dArcBallClick`	Update start vector and prepare for dragging.
`tcl3dArcBallDrag`	Update end vector and get rotation as Quaternion.

Table 4.17: tcl3dUtil: ArcBall commands

Examples

See the demo program ***ftglDemo.tcl*** for an example, on how to use the trackball procedures.
See the NeHe demo program ***Lesson48.tcl*** for an example, on how to use the ArcBall procedures.

Implementation details

The functionality of the trackball module is implemented in the following files:

Implementation files:	***tcl3dUtilTrackball.c, tcl3dUtilTrackball.tcl***
Header files:	***tcl3dUtilTrackball.h***
Wrapper files:	***util.i***

The functionality of the ArcBall module is implemented in the following files:

Implementation files:	***tcl3dUtilArcBall.c***
Header files:	***tcl3dUtilArcBall.h***
Wrapper files:	***util.i***

4.3.12 C/C++ based utilities for demo applications

This sub-module implements C/C++ based utility functions for some of the demo applications.

Overview

tcl3dDemoOglLogo implements an animated 3-dimensional OpenGL logo.
It is used in demo ***animlogo.tcl*** in directory ***LibrarySpecificDemos/tcl3dOgl***.

tcl3dDemoReadRedBookImg implements a parser for the simple image file format used in some of the RedBook demos.
It is used in demos ***colormatrix.tcl***, ***colortable.tcl***, ***convolution.tcl***, ***histogram.tcl*** and ***minmax.tcl*** in directory ***TutorialsAndBooks/RedBook***.

tcl3dHeightmap implements a converter from a Tk photo image into a heightmap.
It is used in NeHe demo ***Lesson45.tcl*** in directory ***TutorialsAndBooks/NeHe***.

Implementation details

The functionality of the OpenGL logo animation is implemented in the following files:

Implementation files:	***tcl3dDemoOglLogo.c***
Header files:	***tcl3dDemoOglLogo.h***
Wrapper files:	***util.i***

The functionality of the RedBook image parser module is implemented in the following files:

Implementation files:	***tcl3dDemoReadRedBookImg.c***
Header files:	***tcl3dDemoReadRedBookImg.h***
Wrapper files:	***util.i***

The functionality of the heightmap module is implemented in the following files:

Implementation files:	***heightmap.i, tcl3dDemoHeightMap.tcl***
Header files:	***None***
Wrapper files:	***heightmap.i***

4.4 tcl3dCg: Wrapper for NVidia's Cg shading language

This module wraps NVidia's ***Cg*** [7] library based on version 1.5.0015 and adds some Cg related utility procedures.

This is an optional module.
Requirements for this module: The Cg library and header files.
Runtime libraries are included in the Tcl3D distribution.

The master SWIG file for wrapping the Cg library is ***tcl3dCg.i***.

Implementation files:	***tcl3dCgQuery.tcl, tcl3dCgUtil.tcl***
Header files:	All files in subdirectory ***Cg***
Wrapper files:	***cg.i***

The wrapping for this module is based on the unmodified Cg header files.

Cg utility module

Tcl command	Description
`tcl3dCgGetVersion`	Get the version of the wrapped Cg library.
`tcl3dCgGetError`	Check, if a Cg related error has occured.
`tcl3dCgGetProfileList`	Get a list of Cg profile names.
`tcl3dCgFindProfile`	Find a supported Cg profile by name.
`tcl3dCgFindProfileByNum`	Find a supported Cg profile by it's numerical value.
`tcl3dCgPrintProgramInfo`	Print the Cg program information onto standard output.

Table 4.18: tcl3dCg utility commands

See the demo programs contained in directory ***LibrarySpecificDemos/tcl3dCg*** for examples, on how to use the Cg functions.

4.5 tcl3dSDL: Wrapper for the Simple DirectMedia Library

This module wraps the ***SDL*** [8] library based on version 1.2.9 and adds some SDL related utility procedures.

Note
- Currently only the functions related to joystick and CD-ROM handling have been wrapped and tested.

This is an optional module.
Requirements for this module: The SDL library and header files.
Libraries and header files are included in the Tcl3D distribution.

The master SWIG file for wrapping the Simple DirectMedia library is ***tcl3dSDL.i***.

Implementation files:	***tcl3dSDLQuery.tcl, tcl3dSDLUtil.tcl***
Header files:	All files in subdirectory ***include***
Wrapper files:	***sdl.i***

The wrapping for this module is based on the unmodified SDL header files.

SDL utility module

Tcl command	Description
`tcl3dSDLGetVersion`	Get the version of the wrapped SDL library.
`tcl3dSDLGetFocusName`	Convert a SDL focus state bitfield into a string representation.
`tcl3dSDLGetButtonName`	Convert a SDL button state bitfield into a string representation.
`tcl3dSDLGetHatName`	Convert SDL hat related enumerations into a string representation.
`tcl3dSDLGetEventName`	Convert SDL event related enumerations into a string representation.
`tcl3dSDLFrames2MSF`	Convert CD frames into minutes/seconds/frames.
`tcl3dSDLGetTrackTypeName`	Convert SDL CD track type enumerations into a string representation.
`tcl3dSDLGetCdStatusName`	Convert SDL CD status enumerations into a string representation.

Table 4.19: tcl3dSDL utility commands

See the demo programs contained in directory ***LibrarySpecificDemos/tcl3dSDL*** for examples, on how to use the SDL functions.

4.6 tcl3dFTGL: Wrapper for the OpenGL Font Rendering Library

This module wraps the ***FTGL*** [9] library based on version 2.1.2 and adds some FTGL related utility procedures.
The FTGL library depends on the ***Freetype2*** library [10].

This is an optional module.
Requirements for this module: The FTGL and Freetype2 library and header files.
Libraries and header files are included in the Tcl3D distribution.

The master SWIG file for wrapping the OpenGL Font Rendering library is ***tcl3dFTGL.i***.

Implementation files:	***tcl3dFTGLQuery.tcl, tcl3dFTGLUtil.tcl***
Header files:	All files in subdirectory ***include***
Wrapper files:	***ftgl.i***

The wrapping for this module is based on the unmodified FTGL header files.

FTGL utility module

Tcl command	Description
`tcl3dFTGLGetVersion`	Get the version of the wrapped FTGL library.
`tcl3dFTGLGetBBox`	Get bounding box of a string.

Table 4.20: tcl3dFTGL utility commands

See the demo programs contained in directory ***LibrarySpecificDemos/tcl3dFTGL*** for examples, on how to use the FTGL functions.

4.7 tcl3dGl2ps: Wrapper for the OpenGL To Postscript Library

This module wraps Christophe Geuzaine's ***GL2PS*** [11] library based on version 1.3.2 and adds some GL2PS related utility procedures.

Note

- Gl2PS currently does not support textures.

This is an optional module.
Requirements for this module: None, all files are contained in the Tcl3D distribution.

The master SWIG file for wrapping the Gl2ps library is ***tcl3dGl2ps.i***.

Implementation files:	***gl2ps.c, tcl3dGl2psQuery.tcl, tcl3dGl2psUtil.tcl***
Header files:	***gl2ps.h***
Wrapper files:	***gl2ps.i***

The wrapping for this module is based on the unmodified GL2PS implementation and header files.

Gl2ps utility module

Tcl command	**Description**
`tcl3dGl2psGetVersion`	Get the version of the wrapped GL2PS library.
`tcl3dGl2psCreatePdf`	Create a PDF file from current Togl window content.

Table 4.21: tcl3dGl2ps utility commands

See NeHe demo ***Lesson02.tcl*** or the benchmarking demo ***sphere.tcl*** in directory ***LibrarySpecificDemos/tcl3dOgl*** for an example, on how to use the GL2PS functions for PDF export.

4.8 tcl3dOde: Wrapper for the Open Dynamics Engine

This module wraps the ***ODE*** [12] library based on version 0.7 and adds some ODE related utility procedures.

Note

- This module is still work in progress. It's interface may change in the future.

This is an optional module.
Requirements for this module: The ODE library and header files.
Libraries and header files are included in the Tcl3D distribution.

The master SWIG file for wrapping the Open Dynamics Engine library is ***tcl3dOde.i***.

Implementation files:	***tcl3dOdeQuery.tcl, tcl3dOdeUtil.tcl***
Header files:	All files in subdirectory ***ode***
Wrapper files:	***ode.i***

The wrapping for this module is based on the unmodified ODE header files.

ODE utility module

Tcl command	Description
`tcl3dOdeGetVersion`	Get the version of the wrapped ODE library.

Table 4.22: tcl3dOde utility commands

See the demo programs contained in directory ***LibrarySpecificDemos/tcl3Ode*** for examples, on how to use the ODE functions.

4.9 tcl3dGauges: Tcl3D package for displaying gauges

This package implements the following gauges: airspeed, altimeter, compass, tiltmeter.

This is an optional module.
Requirements for this module: None, all files are contained in the Tcl3D distribution.

The gauge package has been implemented by Victor G. Bonilla.

See the demo programs ***gaugedemo.tcl*** and ***gaugetest.tcl*** for examples, on how to use the gauges.

5 Miscellaneous Tcl3D information

This chapter contains miscellaneous information about Tcl3D:

- License information
- Programming hints
- Open issues
- Known bugs
- Starpack internals

5.1 License information

The Tcl3D utility library files (see below for exceptions) are copyrighted by Paul Obermeier and distributed under the BSD license.
The following files of the Tcl3D utility library have differing copyrights:

- The original Wavefront parser code is copyrighted by Nate Robins.
- The original GLUT shape code is copyrighted by Mark Kilgard.
- The original code of tcl3dSphere is copyrighted by Paul Bourke.
- The original code of tcl3dHelix is copyrighted by Dario Corno.
- The original code of tcl3dArcBall is copyrighted by Tatewake.com.
- The original code of tcl3dTrackball is copyrighted by Gavin Bell et al.

The Tcl3D gauge library is copyrighted by Victor G. Bonilla and distributed under the BSD license.

The original Togl widget is copyrighted by Brian Paul and Benjamin Bederson. The modified Tcl3D version is copyrighted by Paul Obermeier and distributed under the BSD license.

The SWIG wrapper files and supporting Tcl files of all modules are copyrighted by Paul Obermeier and distributed under the BSD license.

See the homepages of the wrapped libraries for their license conditions.

5.2 Programming hints

Hint 1:
Most OpenGL examples written in C use the immediate mode. As Tcl is a scripted language and each OpenGL call has to go through the wrapper interface, it's almost always a bad idea (in terms of speed) to translate these examples one-by-one. Using display lists or vertex arrays does not add much complexity to your Tcl3D program, but enhances performance significantly. Try the ***Spheres.tcl*** or ***ogl_benchmark_sphere.tcl*** demo for an example, how display lists or vertex arrays can speed up your Tcl3D application.

Hint 2:
Do not use global variables `GL_VERSION_X_Y` (ex. `[info exists GL_VERSION_1_3]`) to check the OpenGL version supported on your computer. This does not work, because these variables are all defined independently of the underlying OpenGL implementation. Use the utility function `tcl3dHaveExtension` instead.

Hint 3:
```
Error: expected integer but got "GL_REPEAT"
```

Some OpenGL functions expect an integer or floating point value, which is often given in C code examples with an enumeration, as shown in the next example:

```
extern void glTexParameteri ( GLenum target, GLenum pname, GLint param );
```

It is called in C typically as follows:

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_REPEAT);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
```

As the 3rd parameter is not of type `GLenum`, you have to specify the numerical value in Tcl:

```
glTexParameteri GL_TEXTURE_2D GL_TEXTURE_WRAP_S $::GL_REPEAT
glTexParameteri GL_TEXTURE_2D GL_TEXTURE_MAG_FILTER $::GL_NEAREST
```

If called with the enumeration name:

```
glTexParameteri GL_TEXTURE_2D GL_TEXTURE_WRAP_S GL_REPEAT
```

you will get the above error message.

Hint 4:

```
Error: expected floating-point number but got "_08201905_p_float".
```

This error message indicates, that a `tcl3dVector` has been specified as parameter to a function, which expects a Tcl list. This often happens, when using one of the `glMultMatrix` commands. Use a sequence like shown below to convert the `tcl3dVector` into a Tcl list before supplying it to the function:

```
set matAsList [tcl3dVectorToList $mat 16]
glMultMatrixf $matAsList
```

Hint 5:

```
Error: Package tcl3dcg: couldn't load library "C:/Tcl/lib/tcl3d/tcl3dCg/tcl3dCg.dll":
this library or a dependent library could not be found in library path
```

This typically indicates that the dependent library or libraries (ex. ***cg.dll*** or ***cgGL.dll***) are not found, i.e. they are not in a directory contained in your Path environment variable.

```
Error: Package tcl3dcg: couldn't load library "C:/Tcl/lib/tcl3d/tcl3dCg/tcl3dCg.dll":
 permission denied
```

This typically indicates that the dependent library or libraries (ex. ***cg.dll*** or ***cgGL.dll***) were found, but you do not have the permissions to execute the library.

These errors may occur with the following Tcl3D modules:

Tcl 3D module	**Affected libraries**
`tcl3dCg`	***cg.dll cgGL.dll***
`tcl3dFTGL`	***libftgl.dll freetype6.dll***
`tcl3dOde`	***ode.dll***
`tcl3dSDL`	***SDL.dll***

Although the examples shown in this hint use Windows specific library names, the above mentioned errors may occur on Unix systems as well.

Hint 6:

The OpenGL extension library ***OglExt*** used in Tcl3D versions before 0.4 for wrapping OpenGL functions and the currently used ***GLEW*** library have an important difference:
OpenGL functions not available in the installed OpenGL driver have been ignored by the OglExt library, i.e. transformed into a no-op. The disadvantage of this behaviour was, that you did not get any feedback about not available functions in your OpenGL driver implementation.

With GLEW you will get a core dump, when trying to use such a function, because the function pointer is NULL. You should therefore always check either the OpenGL version implemented in your driver (`tcl3dOglHaveVersion`), the availability of the extensions you intend to use (`tcl3dOglHaveExtension`), or to be absolutely sure, check the availability of each OpenGL function in your initialization code (`tcl3dOglHaveFunc`).
Use the demo ***tcl3dInfo.tcl*** to get information about the supported OpenGL functions of your installed OpenGL driver.

5.3 Open issues

- GLU callbacks are currently not supported. This implies, that tesselation does not work, because this functionality relies heavily on the usage of C callback functions.
- There is currently no possibility to specify a color map for OpenGL indexed mode. As color maps depend on the underlying windowing system, this feature must be handled by the Togl widget.

5.4 Known bugs

- The tiltmeter widget from the tcl3dGauge package is not working correctly with Tcl versions less than 8.4.7, because of a bug in the namespace implementation.
- Picking with depth values does not work correctly, as depth is returned as an unsigned int, mapping the internal floating-point depth values [0.0 .. 1.0] to the range [0 .. 2^{32} –1]. As Tcl only supports signed integers, some depth values are incorrectly transferred into the Tcl commands.
- SWIG versions up to 1.3.24 had an annoying (but not critical) bug in the Tcl library file ***swigtcl8.swg***: Please check, if your version has a line “`printf ("Searching %s\n", key);`” in function `SWIG_Tcl_GetConstant`, and delete this line, if existent. ***swigtcl8.swg*** can be found in ***/usr/lib/swig1.3/tcl*** or ***/usr/share/swig/VERSION/tcl*** on Linux or in the ***lib/tcl*** subdirectory of your SWIG Windows installation.
- SWIG version 1.3.21 (as delivered with SuSE 9.3) does not correctly wrap the ODE library.
- The PDF files generated with Gl2ps are not displayed correctly with the Preview program on a Mac. Acrobat Reader displays them correctly.
- `tcl3dOglGetVersion` and `tcl3dOglGetPackageInfo` dump core on Mac OSX, if no Togl window has been created. On other systems, the function returns an empty string in that case. See also the note about glGetString in chapter 4.2.

5.5 Starpack internals

For an introduction to Tclkits, Starkits and Starpacks see Jean-Claude Wippler’s homepage at http://www.equi4.com/.

5.5.1 Starpack issue #1

If shipping external libraries with your Starpack, you have to copy them to the file system, before they can be used. A convenient place is the directory containing the Starpack.

```
# Check if all necessary external libraries exists in the directory
# containing the Starpack. Copy them to the filesystem, if necessary.
set __tcl3dExecDir [file dirname $::starkit::topdir]
set __tcl3dDllList [glob -nocomplain -dir [file join $starkit::topdir extlibs] \
                   *[info sharedlibextension]*]

foreach starkitName $__tcl3dDllList {
    set osName [file join $__tcl3dExecDir [file tail $starkitName]]
    if { ! [file exists $osName] } {
        set retVal [catch { file copy -force -- $starkitName $__tcl3dExecDir }]
        puts "Copying DLL $starkitName to directory $__tcl3dExecDir"
        if { $retVal != 0 } {
            error "Error copying DLL $starkitName to directory $__tcl3dExecDir"
        }
    }
}
```

This aforementioned solution seems to be the best possible solution today, but has the following two disadvantages:

- Windows user will typically place the Starpack onto the desktop. Starting the Starpack inflates the desktop with lots of DLL‘s.
- On Linux/Unix the current directory typically is not included in the LD_LIBRARY_PATH variable.

That's why the starpacks are distributed in it's own folder, and the Unix distributions come with an additional start shell script: `tcl3dsh-OS-VERSION.sh`

```
#!/bin/sh
# Startup script for tcl3dsh, the Tcl3D Starpack.

LD_LIBRARY_PATH=".:$LD_LIBRARY_PATH"
LD_LIBRARYN32_PATH=".:$LD_LIBRARYN32_PATH"
export LD_LIBRARY_PATH
export LD_LIBRARYN32_PATH

./tcl3dsh-Linux-0.4.0 $*
```

5.5.2 Starpack issue #2

Some of the external libraries need files for initialization, ex. the FTGL library needs the name of a TrueType font file to construct it‘s OpenGL commands. This font file has to be on the real filesystem, so that the FTGL library can find it, and not in the virtual filesystem of the starpack.

Tcl3D supports a utility procedure `tcl3dGetExtFile`, which you should use, if intending to use a Tcl3D script - depending on such a library - in a Starpack. See chapter 4.3.3 for a description of the Starpack related file utilities.

A typical usage is shown in the following code segment:

```
set fontfile [file join [file dirname [info script]] "Vera.ttf"]
# tcl3dGetExtFile is available only in versions 0.3.1 and up.
# You may check availability of command first, if running scripts with older
# Tcl3D versions.
if { [info proc tcl3dGetExtFile] eq "tcl3dGetExtFile" } {
    # Get the font file in a Starpack independent way.
    set fontfile [tcl3dGetExtFile $fontfile]
}
```

6 Demo applications

More than 180 Tcl3D applications for testing and demonstration purposes are currently available. Most of these applications were converted from existing demonstration programs written in C/C++ found on the web. A detailed list of all demos is available online on the Tcl3D homepage at http://www.tcl3d.org/demos/ or in the Tcl3D Demo Manual.

The Tcl3D demo applications are divided into 3 categories:

- Category **Tutorials and books** contains scripts, which have been converted from C/C++ to Tcl3D, coming from the following sources:
  OpenGL Red Book [19]
  NeHe tutorials [15]
  Kevin Harris CodeSampler web site [16]
  Vahid Kazemi's GameProgrammer page [17]
- Category **Library specific demos** contains scripts showing features specific to the wrapped library.
- Category **Tcl3D specific demos** contains scripts demonstrating and testing Tcl3D specific features.

The next figure shows an excerpt from the demo hierarchy.

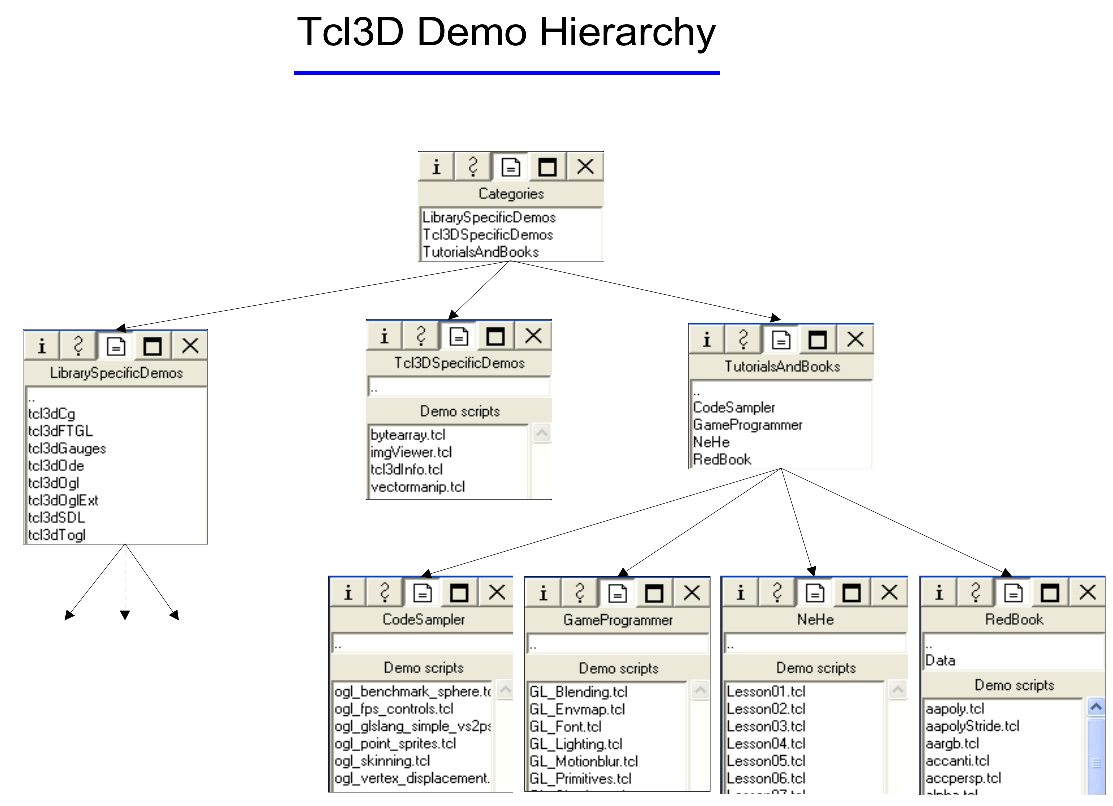


Figure 6.1: Tcl3D demo hierarchy

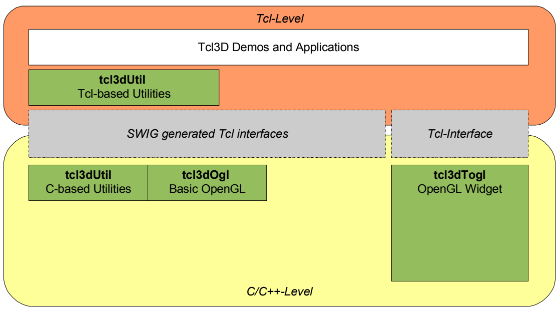
7 Release notes

This chapter shows the release and feature history of Tcl3D both graphically and in text form. It also contains a list of obsolete functions.

7.1 Release history

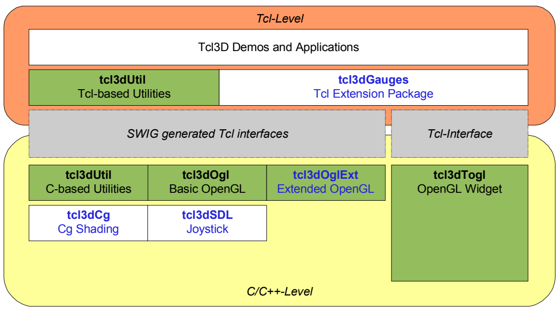
Tcl3D Version 0.1

Released 2005/05/29 as TclOgl: Basic OpenGL wrapping, Togl widget with Tcl callbacks.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dTogl OpenGL Widget
C/C++-Level

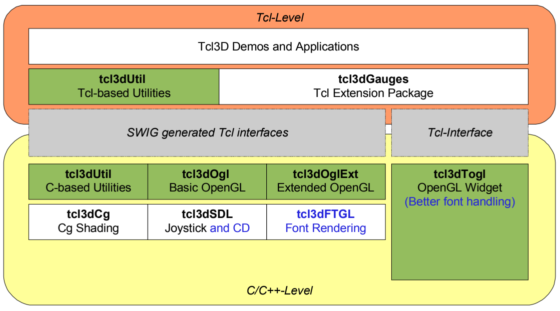
Tcl3D Version 0.2

Released 2006/01/07: Major rewrite and support of new libraries: OpenGL 2.0, OpenGL extensions, Cg, SDL, gauges. Domain www.tcl3d.org created.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dOglExt Extended OpenGL
tcl3dCg Cg Shading
tcl3dSDL Joystick
tcl3dTogl OpenGL Widget
C/C++-Level

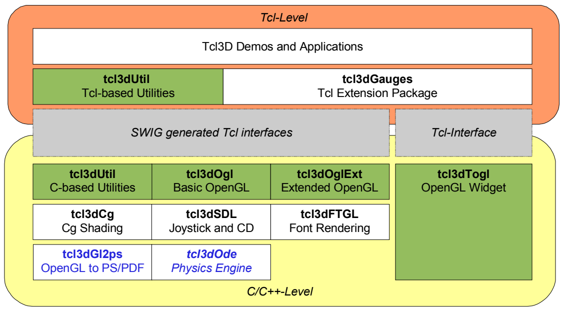
Tcl3D Version 0.3

Released 2006/02/12: Enhanced font handling in Togl. Library FTGL added. Mac OS X support supplied by Daniel Steffen.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dOglExt Extended OpenGL
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dTogl OpenGL Widget (Better font handling)
C/C++-Level

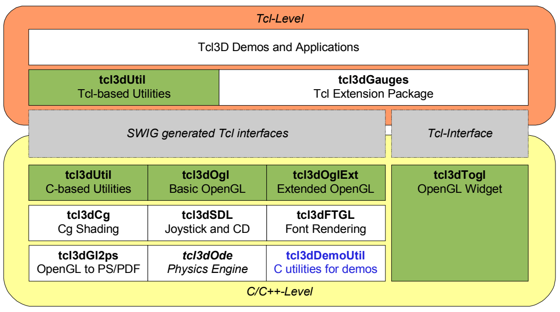
Tcl3D Version 0.3.1

Released 2006/06/16: Support for GL2PS and ODE (alpha) added. Starpack versions.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dOglExt Extended OpenGL
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dGl2ps OpenGL to PS/PDF
tcl3dOde Physics Engine
tcl3dTogl OpenGL Widget
C/C++-Level

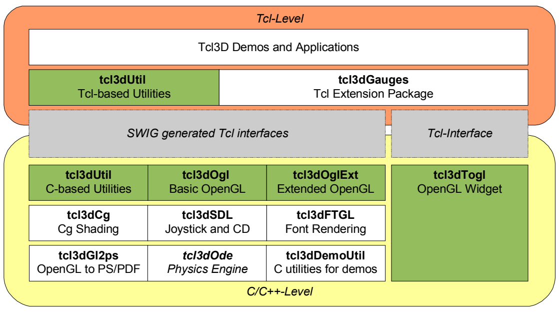
Tcl3D Version 0.3.2

Released 2007/02/25: Demo cleanup and first official Mac OS X support. Windowing system specifics incorporated into Togl widget. New module tcl3dDemoUtil.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dOglExt Extended OpenGL
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dGl2ps OpenGL to PS/PDF
tcl3dOde Physics Engine
tcl3dDemoUtil C utilities for demos
tcl3dTogl OpenGL Widget
C/C++-Level

Tcl3D Version 0.3.3

Released 2008/09/14: Bug fixes, minor enhancements and several new demos.


Tcl-Level
Tcl3D Demos and Applications
tcl3dUtil Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dUtil C-based Utilities
tcl3dOgl Basic OpenGL
tcl3dOglExt Extended OpenGL
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dGl2ps OpenGL to PS/PDF
tcl3dOde Physics Engine
tcl3dDemoUtil C utilities for demos
tcl3dTogl OpenGL Widget
C/C++-Level

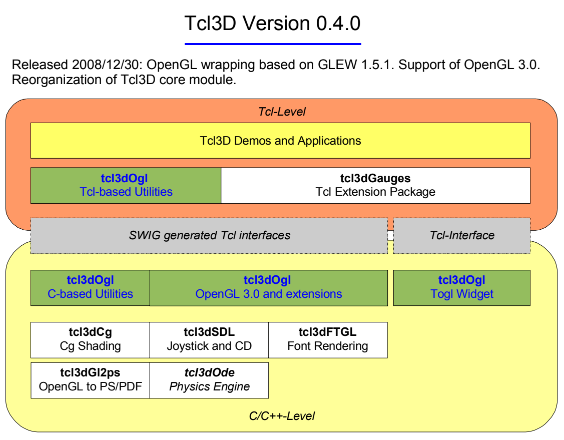

Tcl3D Version 0.4.0
Released 2008/12/30: OpenGL wrapping based on GLEW 1.5.1. Support of OpenGL 3.0. Reorganization of Tcl3D core module.
Tcl-Level
Tcl3D Demos and Applications
tcl3dOgl Tcl-based Utilities
tcl3dGauges Tcl Extension Package
SWIG generated Tcl interfaces
Tcl-Interface
tcl3dOgl C-based Utilities
tcl3dOgl OpenGL 3.0 and extensions
tcl3dOgl Togl Widget
tcl3dCg Cg Shading
tcl3dSDL Joystick and CD
tcl3dFTGL Font Rendering
tcl3dGl2ps OpenGL to PS/PDF
tcl3dOde Physics Engine
C/C++-Level

Figure 7.1: Tcl3D graphical release history

Version 0.4.0 (2008/12/30): OpenGL wrapping now based on GLEW

```
 - Enhancements / New features:
  + CAUTION: Possibly incompatible changes.
    OpenGL wrapping is now based on GLEW, because the previously used OglExt
    extension library is no longer supported.
    OpenGL version now supported is 3.0, based on GLEW version 1.5.1.
    No C++ dependency anymore in the core modules.
  + No more initialization (tcl3dOglExtInit) of the extended OpenGL
    functionality needed. This is done now when creating the Togl widget.
    The old OpenGL extension library OglExt automatically detected, if
    OpenGL functions are not implemented in the OpenGL driver, and did
    nothing in that case. This had the disadvantage, that programs seem
    to run, but indeed were missing an extension function.
  + New OpenGL utility procedures:
    tcl3dOglHaveFunc, tcl3dOglGetFuncList,
    tcl3dOglGetFuncSignatureList, tcl3dOglGetFuncVersionList.
  + CAUTION: Possibly incompatible change.
    Togl's command line parameter "-swapinterval" is set to zero by default, so
    that demos always run with maximum framerate, instead of being fixed to
    the display's refresh rate.
    Removed now obsolete "-swapinterval 0" statements in several demos.
  + Demo tcl3dInfo.tcl updated to display OpenGL version information,
    function signature and availability of all wrapped OpenGL functions.
  + User and reference manuals updated.

- Bug fixes:
  + GLEW has wrong glPointParameterfv* functions signatures:
    "float *" instead of "const float *" according to OpenGL standard.
    Changed in glew.h file.
  + tcl3dVecMath.c had incorrect tcl3dMatfRotate function.
    Thanks to Stefan Augustiniack for patch.

- Removed features:
  + Removed obsolete versions 0.1 and 0.2 from Tcl3D homepage.
  + Removed compatibility function for version 0.1.
  + CAUTION: Possibly incompatible change.
    Removed wrapping of Windows specific OpenGL functions (wgl*).
    Operating system specific functions should only be used in the Togl code.

- New demos:
  + 4 new demos added since release 0.3.3.
    These have been previously released as Tcl3D Demo of the month.
```

Version 0.3.3 (2008/09/14): Bug fix and maintenance release

```
- Enhancements:
    + Added 64-bit Linux to the supported list of platforms.
    + Improved Mac OS X support:
      Fixed resize problems in presentation framework.
      Consistent mouse button behaviour across operating systems.
    + Trackball module supports multiple windows.
      CAUTION: Incompatible change. Additional Togl window parameter in
               procedures tcl3dTbAnimate, tcl3dTbInit, tcl3dTbMatrix.
      Thanks to Michael Magoga for this patch.
    + New OpenGL utility procedures:
      tcl3dOglGetIntState, tcl3dOglGetFloatState, tcl3dOglGetDoubleState.
      tcl3dOglGetMaxTextureSize, tcl3dOglGetMaxTextureUnits,
      tcl3dOglGetViewport, tcl3dOglGetShaderInfoLog, tcl3dOglGetProgramInfoLog,
      tcl3dOglGetShaderSource, tcl3dOglShaderSource, tcl3dOglGetInfoLogARB.
    + New low-level routines for copying Tcl lists into a vector:
      tcl3dListToVector_TYPE
      Tcl utility procedure tcl3dVectorFromList updated to transparently use the
      new low-level routines.
    + Starpacks now allow drag-and-drop of TclKit files.
    + tcl3dGetExtFile not constrained to Starkits anymore.
      Thanks to Jean-Claude Gohard for supplying a vfs and zvfs enabled version.
    + New utility functions for random number generation (same algorithm at C
      and Tcl level).
  - Bug fixes:
    + Bug fix in tcl3dGauges: Eliminated bgerror procedures.
      Thanks to Alexandre Ferrieux and Synic for hints on this bug.
    + Several bug fixes in the presentation framework.
      Thanks to Philip Quaiffe for hints and other useful discussions.
    + Several other minor bug fixes.
  - New demos:
    + 19 new demos added since release 0.3.2.
      These have been previously released as Tcl3D Demo of the month.
```

Version 0.3.2 (2007/02/25): Demo cleanup and first official Mac OS X support

```
  - Unification of demo applications and presentation framework.
  - New module tcl3dDemoUtil for C/C++ based utility functions needed by
    some of the demos for speed issues.
  - More NeHe tutorials added: Lessons 14, 22-24, 26, 28, 33, 36, 37, 41, 45-48.
  - Nine demos from www.GameProgrammer.org added.
  - Updated Tcl3D manual. Created separate demo overview document.
  - Added support to capture screenshots (Module tcl3dCapture).
  - Added new functionality to tcl3dUtil: ArcBall emulation.
  - Added windowing system specifics (SwapInterval, Multisampling) to the
    tcl3dTogl widget.
  - Added support for Visual Studio 2003 (7.1) and 2005 (8.0).
  - Enhanced tcl3dVector functionality.
    + Utility functions for manipulation of image data stored in tcl3dVectors:
        tcl3dVectorCopy, tcl3dVectorCopyChannel,
        tcl3dVectorManip, tcl3dVectorManipChannel
    + tcl3dVector member functions for content independent manipulation:
        setvec, addvec, mulvec
  - tcl3dOde now uses ODE version 0.7 and is available for Windows, Linux,
    Mac OS X and Irix. Wrapper still in alpha version and not complete.
  - tcl3dGl2ps now uses GL2PS version 1.3.2.
  - tcl3dCg now uses Cg version 1.5.0015.
    The 1.4 versions of Cg did not work with OS X on Intel platforms.
```

Version 0.3.1 (2006/06/19): Starpack support for Tcl3D

```
  - Starpack version of Tcl3D, including demos and external libraries.
    First shown at TclEurope 2006.
  - New optional module tcl3dGl2ps, wrapping the OpenGL To Postscript library.
    (Thanks to Ian Gay for idea and first implementation)
  - New optional module tcl3dOde, wrapping the Open Dynamics Engine.
    Very alpha preview, Windows only !!!
  - More NeHe tutorials added: Lessons 19-21.
```

Version 0.3 (2006/02/12): MacOS X and enhanced font support

```
  - Support for Mac OS X added.
    (Thanks to Daniel A. Steffen for supplying patches and binaries)
  - New optional module tcl3dFTGL, wrapping the OpenGL font rendering
```

```
    library FTGL, based on freetype fonts.
  - Corrected and enhanced font handling under Windows in the tcl3dTogl widget.
    No more private Tcl header files needed.
  - Added new font related demo programs:
    tcl3dFont.tcl, tcl3dToglFonts.tcl, ftglTest.tcl, ftglDemo.tcl.
  - Added new SDL demo related to CD-ROM handling: cdplayer.tcl
  - Added some of NeHe's OpenGL tutorials.
  - If an optional library is not installed, no error message is created.
    New procedures to check existence of optional modules:
    tcl3dHaveCg, tcl3dHaveSDL, tcl3dHaveFTGL.
  - Get information on Tcl3D subpackages with tcl3dGetPackageInfo
    and tcl3dShowPackageInfo.
  - Information program tcl3dInfo.tcl enhanced to support commands
    and enums of SDL and FTGL modules.
  - Added new functionality to tcl3dUtil: Simple, scrollable Tk widgets
    for demo programs, trackball emulation (used in FTGLdemo.tcl).
  - Added new functionality to tcl3dUtil:
    tcl3dVectorFromByteArray, tcl3dVectorToByteArray.
    Convert Tcl binary strings to tcl3dVectors and vice versa
    (see demo bytearray.tcl).
  - Bug fix in OglExt wrapping: Parameters of type "float *"
    and "double *" were wrapped incorrectly.
```

Version 0.2 (2006/01/07): Major rewrite of TclOgl

```
  - Major rewrite and inclusion of several new 3D libraries:
      + OpenGL 2.0 and extensions
      + NVidia's Cg library
      + SDL, the Simple Direct Media Library
      + 4 gauge widgets (Thanks to Victor G. Bonilla for supplying this library)
      + Utility library
  - Renamed from tclogl to Tcl3D
  - Created domain tcl3d.org
```

Version 0.1 (2005/05/29): Initial version

```
  - First version (called TclOgl) introduced at the Tcl Europe 2005 conference.
  - Supported features include basic OpenGL wrapping.
```

7.2 Obsolete functions

The following table shows all obsolete functions. Most of these functions have just been renamed to get a more consistent naming scheme.
The obsolete functions are still available, but may be removed in future versions.

Version	Old Name	New Name
0.3.2	`tcl3dCheckCgError`	`tcl3dCgGetError`
	`tcl3dGetCgProfileList`	`tcl3dCgGetProfileList`
	`tcl3dFindCgProfile`	`tcl3dCgFindProfile`
	`tcl3dFindCgProfileByNum`	`tcl3dCgFindProfileByNum`
	`tcl3dPrintCgProgramInfo`	`tcl3dCgPrintProgramInfo`
	`tcl3dHeightMapFromPhoto`	`tcl3dDemoUtilHeightMapFromPhoto`
	`tcl3dReadImage`	`tcl3dReadRedBookImage`
	`tcl3dCreatePdf`	`tcl3dGl2psCreatePdf`
	`tcl3dInit`	`tcl3dOglExtInit`
	`tcl3dCheckGlError`	`tcl3dOglGetError`
	`tcl3dPhoto2Vector`	`tcl3dPhotoToVector`
0.3.3	`tcl3dHaveExtension`	`tcl3dOglHaveExtension`
	`tcl3dHaveVersion`	`tcl3dOglHaveVersion`
	`tcl3dGetVersions`	`tcl3dOglGetVersions`
	`tcl3dGetExtensions`	`tcl3dOglGetExtensions`
	`tcl3dGetStates`	`tcl3dOglGetStates`
	`tcl3dVector2Photo`	`tcl3dVectorToPhoto`
0.4.0	`tcl3dOglExtInit`	`Still existent for backwards compatibility, but functionality not needed anymore.`

Table 7.1: List of obsolete functions

8 References

Tcl3D specific references:

[1] Tcl3D homepage: http://www.tcl3d.org/

[2] Tcl3D page on the Tclers Wiki: http://wiki.tcl.tk/15278

[3] Tcl3D discussion page on the Tclers Wiki: http://wiki.tcl.tk/16057

[4] Tcl3D “Demo of the month” page on the Tclers Wiki: http://wiki.tcl.tk/17771

[5] Tcl3D Reference Manual: http://www.tcl3d.org/html/docs.html

Libraries wrapped with Tcl3D:

[6] Togl page at SourceForge: http://sourceforge.net/projects/togl/

[7] Cg download: http://developer.nvidia.com/object/cg_toolkit.html

[8] SDL download: http://www.libsdl.org/

[9] FTGL download: http://homepages.paradise.net.nz/henryj/code/index.html

[10] Freetype download: http://www.freetype.org/

[11] GL2PS download: http://www.geuz.org/gl2ps/

[12] ODE download: http://www.ode.org/

[13] GLEW: http://glew.sourceforge.net/

[14] GLsdk library: http://oss.sgi.com/projects/ogl-sample/sdk.html

Demos used in Tcl3D:

[15] NeHe’s tutorials: http://nehe.gamedev.net/

[16] Kevin Harris’ code samples: http://www.codesampler.com/oglsrc.htm

[17] Vahid Kazemi’s GameProgrammer page: http://www.gameprogrammer.org/

[18] Nate Robins OpenGL tutorials: http://www.xmission.com/~nate/tutors.html

[19] The Redbook sources: http://www.opengl-redbook.com/source/

[20] OpenGL GLUT demos: http://www.opengl.org/resources/code/samples/glut_examples/demos/demos.html

[21] Paul Bourke’s textured sphere: http://local.wasp.uwa.edu.au/~pbourke/texture/spheremap/

Tools needed for Tcl3D development:

[22] SWIG (Simplified Wrapper and Interface Generator): http://www.swig.org/

[23] ActiveTcl (Batteries included distribution): http://www.activestate.com/

[24] Starpack Wiki page: http://wiki.tcl.tk/3663

Documentation:

[25] Woo, Neider, Davis: OpenGL Programming Guide, Addison-Wesley, **“The Redbook”**

[26] OpenGL Wiki page: http://wiki.tcl.tk/2237

[27] OpenGL Extension Registry: http://www.opengl.org/registry/

Miscellaneous:

[28] Roger E Critchlow's Frustum: http://www.elf.org/pub/frustum01.zip

[29] Paul Obermeier's Portable Software: http://www.posoft.de/