

## glman, a Better View into GLSL

*glman* is a program to allow a better view into the OpenGL Shading Language (GLSL). It does not take the place of an OpenGL program for real shader applications, but it is a nice OpenGL program substitute for running experiments as you learn about shaders.

You start *glman* by double-clicking on its executable's icon. In the Oregon State University Computer Graphics Education Lab, *glman* is started with:

**Start** → **All Programs** → **Shaders** → **glman.exe**

The starting user interface window looks like this. At the same time, a console window pops up. There are, at times, useful messages that are displayed there. Most of the time, you can ignore it. Iconify it if you want.

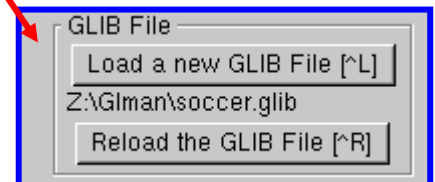
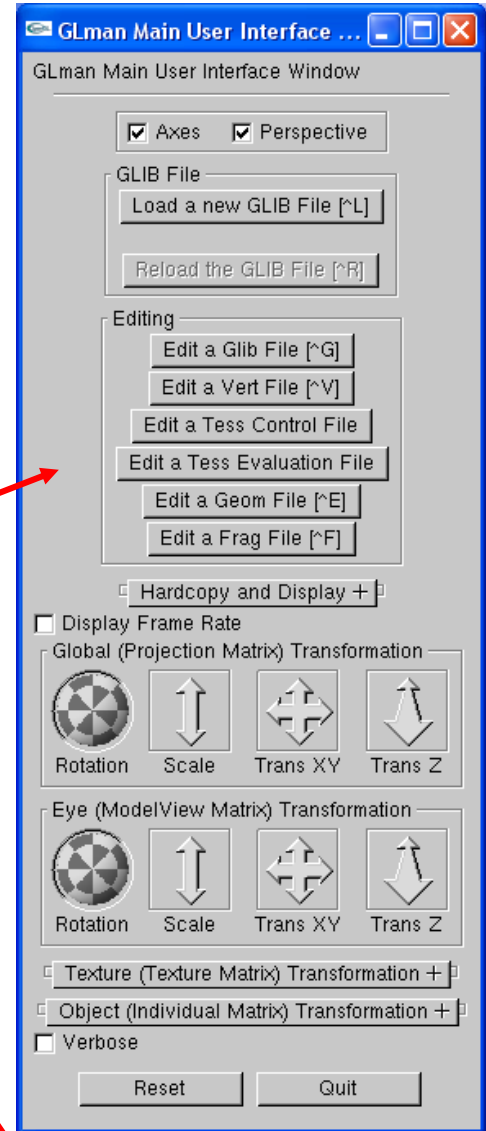
### Loading a GLIB File

*GLIB* stands for *GL Interface Bytestream*. It is an ASCII-encoded input file inspired by the Photorealistic RenderMan RIB file. The GLIB portion of the *glman* menu looks like this.

**Load a new GLIB File** This brings up a dialog box that allows you to select a GLIB file. *glman* parses your GLIB file and creates a scene in a new graphics window.

**Reload the GLIB File** Reloads the currently-loaded GLIB file.

The following commands are allowed in a GLIB file. The command itself is *case-insensitive*, but any text arguments are *case-sensitive*. Numbers in square brackets [ ] show the default values if the parameters are not set. If no default is given, then this command does not do anything without parameters.



***If you read nothing else in this document, read this. Some shaders expect to find the default OpenGL viewing situation, that is, the eye at the origin looking in -Z. So, glman provides that situation when your scene is first displayed. Unfortunately, this often leaves you seeing little or nothing of your scene because you're inside it. Thus, usually your first move upon opening up a new .glib scene should be to use the Eye Transformation "Trans Z" widget to push the scene back into the viewing volume where it is more visible.***

## GLIB Scene Creation

### Window and Viewing Volume

WindowSize wx wy	Specifies the initial graphics window size. [600. 600.]
Ortho xl xr yb yt	Set the current projection to orthographic with the given parameters. [-3. 3. -3. 3.]
Perspective fov	Set the current projection to perspective with the given field of view angle (degrees). [50.]

### Transformations

**Like OpenGL itself, these transformations take effect in the reverse order in which they are listed.**

Translate tx ty tz	Pre-concatenate a translation onto the current matrix
Rotate angle ax ay az	Pre-concatenate a rotation onto the current matrix (angle in degrees)
Scale s	Pre-concatenate a uniform scale onto the current matrix
Scale sx sy sz	Pre-concatenate a non-uniform scale onto the current matrix
PushMatrix	Push the current matrix on the matrix stack
TransformBegin	Same as PushMatrix
PopMatrix	Pop the current matrix from the matrix stack
TransformEnd	Same as PopMatrix

### Creating Geometry

Box dx dy dz	Creates a 3D box. If specified, (dx,dy,dz) are the lengths of the sides. [2. 2. 2.]
Cylinder radius height	Draw a solid cylinder. [1. 1.]
Cone radius height	Draw a solid cone. [1. 1.]
DiskXY	Creates a unit disk parallel to the XY plane and passing through Z=0.
JitterCloud numx numy numz	Creates a jittered 3D point cloud. If specified, num* are the number of points to use in each direction. See <i>PointCloud</i> .

LinesAdjacency [v0] [v1] [v2] [v3]	Creates an instance of the new OpenGL GL_LINES_ADJACENCY primitive. This works with geometry shaders and only makes sense if they are available on your system. Each vertex consists of an x, y, and z, given in square brackets. So, for instance, [v0] might be: [1. 2. 3.]
Obj filename	Reads in a .obj geometry filename into lists of GL_TRIANGLES. If <i>filename</i> is not given, <i>glman</i> will prompt you for it. The true .obj format can be quite complex. This feature, however, just supports vertices, normals, texture coordinates, and faces. If you don't have a real need, use Obj instead of ObjAdj. The file will read faster and the resulting geometry will display faster. Any face with more than 3 vertices is converted automatically into triangles.
ObjAdj filename	Reads in a .obj geometry filename into a list of GL_TRIANGLES_ADJACENT. This is useful for use with Geometry Shaders for applications such as smoothing and silhouettes. If <i>filename</i> is not given, <i>glman</i> will prompt you for it. The true .obj format can be quite complex. This feature, however, just supports vertices, normals, texture coordinates, and faces. Any face with more than 3 vertices is converted automatically into triangles.
PointCloud numx numy numz	Creates a regular 3D point cloud. If specified, numx, numy, and numz are the number of points to use in each direction. See <i>JitterCloud</i> .
QuadBox numquads	Draws a series of 'numquads' quadrilaterals (default=10) parallel to the XY plane. The XYZ coordinates run from (-1.,-1.,-1.) to (1.,1.,1.). The 3D texture coordinates run from (0.,0.,0.) to (1.,1.,1.). This is a good way to test 3D textures.
QuadXY z size nx ny	Creates a quadrilateral parallel to the XY plane, passing through Z=z. If given, size is the quadrilateral's dimension, going from (-size,-size) to (size,size) in X and Y. If given, nx and ny are the number of sub-quads this quadrilateral is broken into. This is a good way to test 2D textures.
QuadXZ y size nx nz	Creates a quadrilateral parallel to the XZ plane, passing through Y=y. If given, size is the quadrilateral's dimension, going from (-size,-size) to (size,size) in X and Z. If given, nx and nz are the number of sub-quads this quadrilateral is broken into.

QuadYZ x size ny nz	Creates a quadrilateral parallel to the YZ plane, passing through X=x. If given, size is the quadrilateral's dimension, going from (-size,-size) to (size,size) in Y and Z. If given, ny and nz are the number of sub-quads this quadrilateral is broken into.
Soccerball radius	Creates a geometric soccer ball from 12 pentagons and 20 hexagons. As part of this, two uniform variables are defined: <ol style="list-style-type: none"> <li>1. <b>FaceIndex</b>: which face are we on right now. 0-11 are the pentagons, 12-31 are the hexagons.</li> <li>2. <b>Tangent</b>: vec3 pointing in a consistent tangent direction, same as the Sphere uses.</li> </ol> <p>In addition, the s and t texture coordinates are filled with good values for mapping an image to each face. The p value is filled with a normalized radius from the center of that face. The seam is located at p=1. [1.]</p>
Sphere radius	Draw a solid sphere. This primitive sets the vertex coordinates, the vertex normals, and the vertex texture coordinates. In order to align bump-mapping, it also sets a vec3 called <b>Tangent</b> at each vertex. The <b>Tangent</b> vectors are all tangent to the sphere surface and always point in a consistent direction, towards the North Pole. [1.]
Teapot	Create a solid teapot.
Torus innerradius outerradius numSides numRings	Create a solid torus. [ .2 1. 20 40 ]
WireBox dx dy dz	Creates a 3D wireframe box. If specified, (dx,dy,dz) are the lengths of the sides. [2. 2. 2.]
WireCylinder radius height	Create a wireframe cylinder. [1. 1.]
WireCone radius height	Create a wireframe cone. [1. 1.]
WireObj filename	Reads in a .obj geometry filename into lists of lines. If <i>filename</i> is not given, <i>glman</i> will prompt you for it. The true .obj format can be quite complex. This feature, however, just supports vertices, normals, texture coordinates, and faces.
WireSphere radius	Create a wireframe sphere. [1.]
WireTorus innerradius outerradius numSides numRings	Create a wireframe torus. [ .2 1. 20 40 ]

WireTeapot	Create a wireframe teapot
Xarrow numslices	Creates an arrow along the X-axis, from X=0. to X=1. If specified, numslices are the number of individual slices to use along the arrow. [100]

## Specifying Textures

Texture2D texture_unit filename	This reads a 2D texture from a file. If the filename ends in a .bmp suffix, a BMP image file is assumed, with red, green, and blue read from the file (no alpha). Any other filename pattern implies a raw format, which consists of two binary 4-byte integers giving the X and Y dimensions of the image, and then 4 components per texel specifying the red, green, blue, and alpha of that texel. The components can be all unsigned bytes or all 32-bit floating point.
Texture2D texture_unit dims dimt	Setup a 2D texture unit for render-to-texture (see below)
Texture3D texture_unit filename	This reads a 3D texture from a file in a raw format, which consists of three binary 4-byte integers giving the X, Y, and Z dimensions of the volume, and then 4 components per texel specifying the red, green, blue, and alpha of that texel. The components can be all unsigned bytes or all 32-bit floating point.
CubeMap texture_unit posxfile negxfile posyfile negyfile poszfile negzfile	Generate a cubemap texture on texture unit texture_unit.

## Specifying Shaders

Vertex file.vert	Specify a vertex shader filename
TessControl file.tcs	Specify a tessellation control shader filename.
TessEvaluation file.tes	Specify a tessellation evaluation shader filename.
Geometry file.geom	Specify a geometry shader filename
Fragment file.frag	Specify a fragment shader filename
Program programname uniformvariables ...	Compile and Link the vertex, fragment, and possibly geometry (see below), shaders into a program and specify the uniform variables for that program (see below) The program command must come last in this group of three or four. It links together the current vertex shader, the current fragment shader, and possibly

the current geometry shader and tessellation shaders. Note that this means that you can re-use a shader in another shader program by simply not redefining another shader of that type.

If you want to un-specify a shader (that is, no longer use it), just give the vertex, fragment, geometry, or tessellation commands with no arguments.

**If you are on a system that is enabled for Geometry Shaders, then you must also use the commands:**

<code>geometryinputtype type</code>	Specify what type of topology this geometry shader expects to find as input. This can be: <code>GL_POINTS</code> , <code>GL_LINES</code> , <code>GL_LINES_ADJACENCY</code> , <code>GL_TRIANGLES</code> , or <code>GL_TRIANGLES_ADJACENCY</code>
<code>geometryoutputtype type</code>	Specify what type of topology this geometry shader will be emitting. This can be: <code>GL_POINTS</code> , <code>GL_LINE_STRIP</code> , or <code>GL_TRIANGLES_STRIP</code> .

**Like the vertex, geometry, and fragment commands, these must come *before* the program command.**

### Miscellaneous

<code>Background r g b</code>	Sets the current background color
<code>Color r g b</code>	Set the current rendering color to (r,g,b) $0. \leq r,g,b \leq 1.$
<code>Flat</code>	Sets the current shading mode to <code>GL_FLAT</code> .
<code>LineWidth size</code>	Sets the current line width.
<code>LookAt ex ey ez lx ly lz ux uy uz</code>	Calls the OpenGL <code>gluLookAt( )</code> routine. (ex,ey,ez) are the eye position. (lx,ly,lz) are the look-at position. (ux,uy,uz) are the up-vector.
<code>Noise2D res</code>	Specify the resolution of glman's built-in 2D noise texture (see below)
<code>Noise3D res</code>	Specify the resolution of glman's built-in 3D noise texture (see below).
<code>PointSize size</code>	Sets the current point size.
<code>Smooth</code>	Sets the current shading mode to <code>GL_SMOOTH</code> .
<code>Timer numsecs</code>	Sets the timer period from the default of 10 seconds per cycle to numsecs per cycle

MessageBox An informative text message Puts up a Message Box with the text message in it. This is useful if you want to tell the user something about what this .glib file is about and what to do with this scene display.

In GLIB files:

- Multiple whitespace characters in a row are treated as a single whitespace character.
- A # causes the rest of the line to be treated as a comment and ignored
- A / causes the rest of the line to be treated as a comment and ignored (so that // will act as expected)
- A backslash (\) at the end of a line causes the carriage return to be ignored. The current line is continued onto the next line.

## Using Textures

As indicated above, there are two ways of inputting a 2D texture: as a 24-bit uncompressed BMP file or as a raw texture file. If you want this to work on any graphics system, be sure the image dimensions are powers of two. The NVIDIA cards in the OSU Computer Graphics Education Lab quietly don't require this to be true, but for now, many systems do.

The 2D texture raw format is very simple. The first 8 bytes are two 4-byte integers, declaring the S and T image dimensions. The following bytes are the RGBA values for each texel. These RGBA values can be unsigned bytes or floats. *glman* will look at the size of the file and do the right thing.

When writing a raw 2D texture file, the order of writing should be:

```
FILE *fp = fopen( "example.tex", "wb" );
if( fp == NULL )
{
    . . . Print message and exit . . .
}
fwrite( &nums, 4, 1, fp );
fwrite( &numt, 4, 1, fp );

for( int t = 0; t < numt; t++ )
{
    for( int s = 0; s < nums; s++ )
    {
        fwrite( &red, 4, 1, fp );
        fwrite( &green, 4, 1, fp );
        fwrite( &blue, 4, 1, fp );
        fwrite( &alpha, 4, 1, fp );
    }
}
```

The 3D texture raw format is just as simple. The first 12 bytes are three 4-byte integers, declaring the S, T, and P volume dimensions. The following bytes are the RGBA values for each texel. These RGBA values can be unsigned bytes or floats. *glman* will look at the size of the file and do the right thing.

When writing a raw 3D texture file, the order of writing should be:

```
fwrite( &nums, 4, 1, fp );
fwrite( &numt, 4, 1, fp );
fwrite( &nump, 4, 1, fp );

for( int p = 0; p < nump; p++ )
{
    for( int t = 0; t < numt; t++ )
    {
        for( int s = 0; s < nums; s++ )
        {
            fwrite( &red, 4, 1, fp );
            fwrite( &green, 4, 1, fp );
            fwrite( &blue, 4, 1, fp );
            fwrite( &alpha, 4, 1, fp );
        }
    }
}
```

*glman* expects raw texture binary byte-ordering to be consistent with an Intel x86 architecture. If you write raw texture files from a UNIX box (e.g., Sun or SGI), you must reverse the byte ordering yourself.

The second argument on the Texture2D and Texture3D lines is the OpenGL texture unit to assign this texture to. You then need to tell your shaders what that texture uniform number is. For example, the GLIB line might be:

```
Program Texture TexUnit 7
```

And your fragment shader might look like:

```
uniform sampler2D TexUnit;

void
main( void )
{
    vec4 rgb = texture2D( TexUnit, gl_TexCoord[0] ).rgb;
    gl_FragColor = vec4( rgb, 1. );
}
```

**BTW, don't use texture units 2 and 3 yourself. *glman* uses these already to tell your shaders about its built-in 2D and 3D noise textures.**

Interestingly enough, a limitation of GLSL is that you cannot hardcode the texture unit number in the call to texture2D( ). For example, you *cannot* say:

```
vec4 rgb = texture2D( 7, gl_TexCoord[0] ).rgb;
```



## Rendering to a Texture

You can use `glman` to render to a texture, and then read that texture (or textures) back into another shader program. You first need to setup the texture(s) to be rendered to by defining their storage size:

```
Texture2D texture_unit dims dimt
```

This is the resolution of the “texture framebuffer” that you will be rendering into. Don’t make this too small – the resulting texture will look chunky. 1024x1024 is a good nominal resolution, if you have no other preference.

Then, to render into this texture, use the `glib` command

```
RenderToTexture texture_unit [texture_unit] [texture_unit] . . .
```

This switches the output from the screen framebuffer to the texture framebuffer. To go back to using the screen framebuffer as the output, use:

```
RenderToTexture
```

You can then pass in the texture unit to the next shader program as you would any other texture unit input.

An example of using render-to-texture is to use the second pass to filter the first pass’s rendered scene:

```
##OpenGL GLIB
Perspective 90

Texture2D 6 1024 1024

RenderToTexture 6

Background 0. 0. 0.
Clear

Vertex filter.vert
Fragment filter.frag
Program Filter1 \
    Ad <.05 .1 .5> Bd <.05 .1 .5> \
    Tol <0. 0. .25> \
    NoiseAmp <0. 0. 3.> NoiseFreq <0. 1. 10.>

Color [1. .9 0]
Teapot

RenderToTexture

Background .2 0 0
Clear
```

```

Vertex    image.vert
Fragment image.frag
Program  Filter2 InUnit 6
          EdgeDetect <false>
          TEdge <0. 1. 1.>
          TSharp <0. 1. 10.>
          ResS 1024  ResT 1024

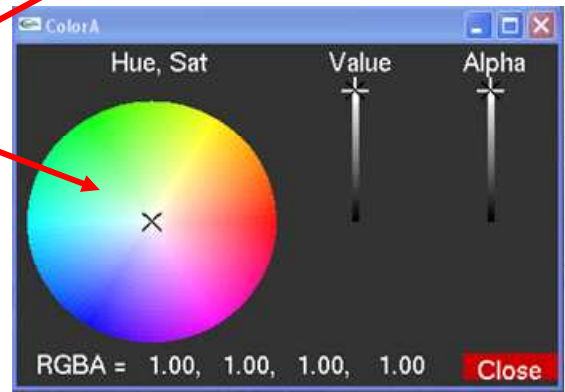
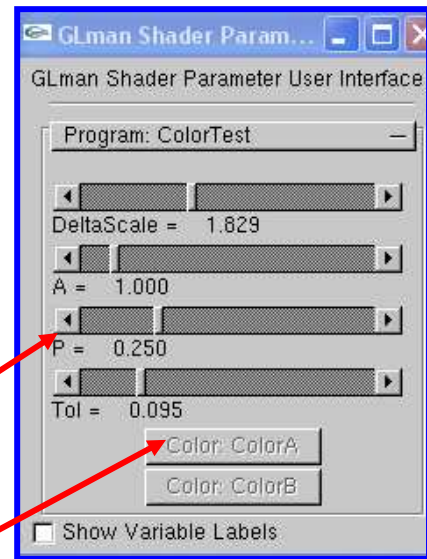
Translate 0 0 0.
QuadXY .2 2.

```

## Specifying Uniform Variables

Uniform variables are specified on the Program command line in a tag-value pair format:

- Scalar variables are just listed as numbers.
- Array variables are enclosed in square brackets. [ ]
- Range variables are enclosed in angle brackets. < > These are scalar variables, but will generate a slider in the Uniform Variable user interface so that the you can then change this value on the fly. The 3 values in the brackets are : <min current max>. This can be used for variables that are type *int* or *float*. *glman* will look at your symbol table and do the right thing.
- Color variables are enclosed in curly brackets. { } They are:
  - {red green blue alpha}
  - and will generate a button in the UI that, when clicked, brings up a color selector window. The color selector allows you to change this color variable on-the-fly.
- The < > angle brackets can also be used for Boolean variables. Enclose a single number in the angle bracket: 0 for false and non-zero for true. (The words <true> and <false> can also be used in the angle brackets for readability.) This will generate a checkbox in the user interface. This must be used only for variables in your shader that are type *bool*. *glman* will look at your symbol table to confirm this.
- Multiple vertex-tessellation-geometry-fragment-program combinations are allowed in the same GLIB file. If there is more than one combination, then they will appear as separate rollout panels in the user interface. The first program rollout will be open, and all the others will be closed. Open the ones you need when you need them.



For example, the user interface window shown above was created as a result of these lines in the GLIB file:

```
Vertex    colortest.vert
Fragment  colortest.frag
Program   ColorTest  DeltaScale <0. 0. 5.>  A <0 1. 10>  P <0. .25 1.>  \
          Tol <0. 0. .5>  ColorA {1. 1. 1. 1.}  ColorB {1. .5 0. 1.}
```

## Timer Variable

If you would like to add programmed motion to your scene, *glman* automatically updates a uniform floating point variable called **Timer** by stepping it from 0. up to 1. and back to 0. in a certain number of seconds. The default is 10 seconds, although this can be changed using the Glib *Timer* command, or by scaling it in your shader code.

For example, if *n* is a noise value between -1. and 1., you could oscillate the use of that noise value by:

```
uniform float Timer;
. . .
float newrad = oldrad + NoiseAmp*n*sin(2.*PI*NoiseSpeed*Timer);
```

Note that the *sin* function is used to turn the **Timer** saw tooth function into something that oscillates, and that *NoiseSpeed* is used to scale the speed.

*glman* only bothers enabling timer interrupts if it spots the use of **Timer** in one of your shader symbol tables, so you don't end up incurring the overhead unless you actually need to.

## Noise

*glman* automatically creates a 3D noise texture and places it into Texture Unit 3. Your vertex or fragment shader can get at it through the pre-created uniform variable called `Noise3`. Reference it in your shader as:

```
uniform sampler3D Noise3;
. . .
vec3 stp = ...
vec4 nv = texture3D( Noise3, stp );
```

The noise texture is a `vec4`. The [0] component is the low frequency noise. The [1] component is twice the frequency and half the amplitude of the [0] component, and so on for the [2] and [3] components. Each component is centered on a value of .5, so that if you want a plus-or-minus-from-zero effect, subtract .5 from each component. To get a nice 4-octave noise value between 0. and 1. (useful for noisy mixing), add up all four components, subtract 1., and divide the whole thing by 2.

Component	Term	Term Range
0	nv[0]	0.5 ± .5000
1	nv[1]	0.5 ± .2500
2	nv[2]	0.5 ± .1250
3	nv[3]	0.5 ± .0675
	<b>sum</b>	<b>2.0 ± ~ 1.0</b>
	<b>sum - 1</b>	<b>1.0 ± ~ 1.0</b>
	<b>(sum - 1) / 2</b>	<b>0.5 ± ~ 0.5</b>

```
float sum = nv[0] + nv[1] + nv[2] + nv[3]; // range is 1. -> 3.
sum = ( sum - 1. ) / 2.; // range is now 0. -> 1.
```

If you would like to have a 4-octave noise function that ranges from -1. to 1., then do this instead:

```
float sum = nv[0] + nv[1] + nv[2] + nv[3]; // range is 1. -> 3.
sum = sum - 2.; // range is now -1. -> 1.
```

Accessing the 2D noise texture works the same as the 3D one, except you use:

```
uniform sampler2D Noise2;
. . .
vec2 st = ...
vec4 nv = texture2D( Noise2, st );
```

By default, the noise textures are 64x64 and 64x64x64. You can change this by putting a command in your GLIB file of the form:

```
Noise2D 128
or
Noise3D 128
```

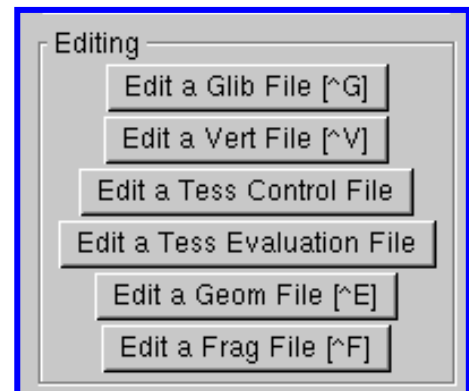
or whatever resolution you want (up to around 400). The first time *glman* creates a 2D or 3D noise texture for you, it will take a few seconds. But, it then writes it to a file in the current folder. The next time *glman* needs this noise texture, it will read it directly from the file, which is a lot faster.

## Editing Files

The .glib, .vert, .frag, .geom, .tcs, and .tes files can be edited any way you want. If you want to easily open a WordPad editing window on a file, click on one of these buttons and then select the file. You can have as many of these WordPad windows open at one time as you want.

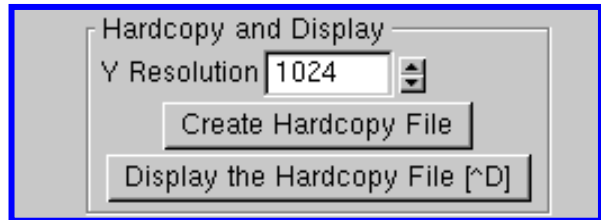
If your system does not support Geometry Shaders, then the “Edit a Geom File” button will not appear.

If your system does not support Tessellation Shaders, then the “Edit a Tess Control File” and “Edit a Tess Evaluation File” buttons will not appear.



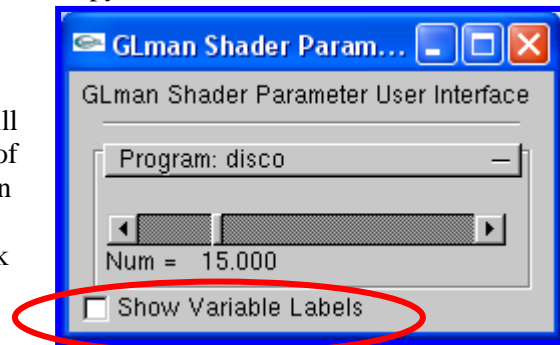
## Generating and Displaying an Image Hardcopy of the Screen

**Create Hardcopy File** As you will be doing cool things with *glman*, you will often want to copy the graphics window to an image file. The Create Hardcopy button will do that, and will let you specify the name of the .bmp file it will be written into. Because *glman* does this by rendering to an internal off-screen framebuffer, the resolution can be (almost) arbitrary. This is useful if you need more pixels in your hardcopy image than you have on your physical screen, as you might need for a high-quality print image or for a large poster.



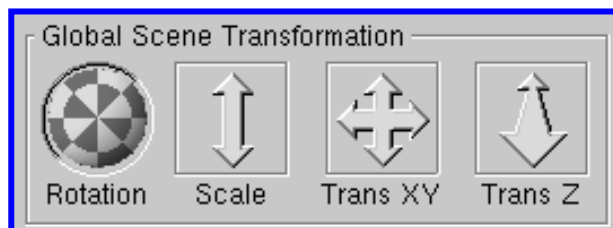
**Display the Hardcopy File** To confirm what you got, and to perhaps send the image to a printer, click here. This will be grayed out until you actually create a Hardcopy.

**Show Variable Labels** This checkbox shows up in the Uniform Variable user interface window. Clicking it will superimpose the values of the uniform variables on top of your graphics scene. This is very handy for doing screen captures of the graphics scene and being able to later recall what uniform variable values made this scene look like what it did.



## Global Scene Transformation

This row of widgets allows you to transform the entire scene in the graphics window. The scene can also be rotated by holding down the left mouse button with the cursor in the graphics window. The scene can also be scaled by holding down the middle mouse button in the graphics window.

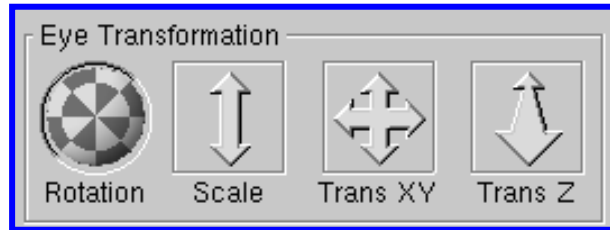


It is important to realize that, unlike what is normally done in an OpenGL program, these transformations *do not end up in the ModelView matrix*. This row of transformations ends up in the *Projection matrix* so that they will have no impact on anything your shaders do in Eye Coordinates. That is, these scene transformations can be used to see the back of a scene, without changing the Eye Coordinate behavior of the shaders.

## Eye Transformation

This row of widgets also allows you to transform the scene in the graphics window.

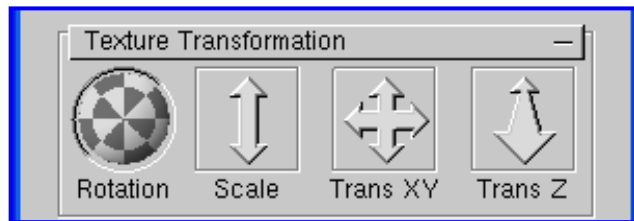
It is important to realize that these transformations *do* end up in the ModelView matrix, just as if the OpenGL `gluLookAt()` routine had been called. That is, these scene transformations will change the Eye Coordinate behavior of the shaders.



**Usually your first move upon opening up a new .glib scene is to use this "Trans Z" widget to push the scene back into the viewing volume where it is more visible.**

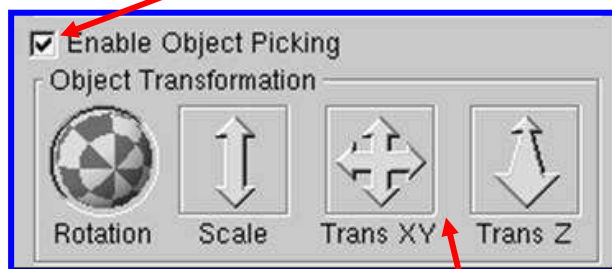
## Texture Transformation

This row of widgets allows you to put a transform into the built-in texture matrix `gl_TextureMatrix[0]`. Note that, once you are no longer using the fixed-function pipeline, the texture matrix does not automatically take effect. You must do this yourself in your shader.

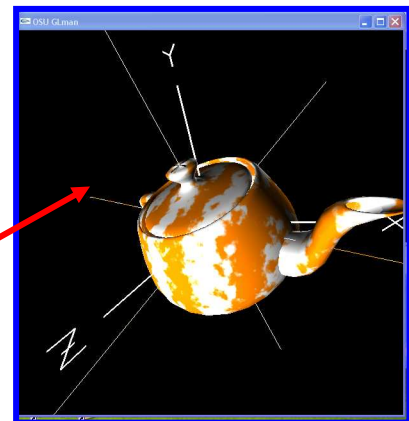


## Object Picking and Transformation

Individual objects in the scene can be picked and independently transformed. This is a good way to test shaders that operate in Eye Coordinates rather than Model Coordinates. To do this, you must first enable object picking by turning on this checkbox.



Then, clicking on a 3D object in the scene with the left mouse button will cause that object to be selected. A large 3D cursor becomes centered on the object to show that it is selected. The 3D cursor will be drawn using the same shaders as the selected object is, so its appearance might look a little weird.



At that time, the Object Transformation row of widgets will become active. These widgets allow you to transform the selected object. The object transformations go into the ModelView matrix, where they will impact any shader that performs operations in Eye Coordinates.

To de-select an object, either click in an open area of the graphics window, or uncheck the Enable Object Picking checkbox

## Monitoring the Frame Rate

It is sometimes useful to get an idea of how much certain shader operations affect the overall speed of the graphics pipeline. For example, certain math functions are implemented in hardware, some in software. If-tests often cause a slowdown. Low count for-loops are often better unrolled. To see what your current frame rate is, click this checkbox on. This causes *glman* to time your display as you interact. After you turn this option on, you will see two things: (1) a frames-per-second (FPS) number will be superimposed on top of the graphics window, and (2) your display speed will drop sharply. This speed drop is because *glman* loops through multiple instances of your display to acquire more precision on the timing. Your speed will go back to normal once you turn this option off.

Display Frame Rate

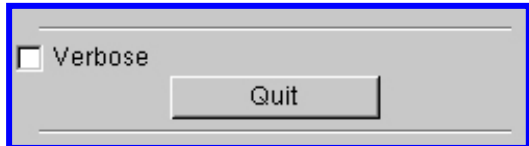
The timing does not include the initial setting and clearing of the frame buffers. Nor does it include the swapping of the double buffers. It just includes the drawing of your scene. Thus, the displayed FPS in this case can exceed the monitor refresh rate. However, when you include the monitor refresh rate (MRR), the actual frames-per-second performance you will get is:

$$FPS' = \left\lceil \frac{MRR}{FPS} \right\rceil$$

where  $\lceil \cdot \rceil$  is the ceiling function.

## Miscellaneous

**Verbose** Normally, If you would like to see more of what is really going on behind the scenes, click this checkbox on. It can be, at times, voluminous. Don't say I didn't warn you.



**Quit** Obvious.

## Questions? Comments?

Send *glman* questions, comments, and suggestions to:

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