The OpenGL Mathematics (GLM) Library

Oregon State University
Mike Bailey
mjb@cs.oregonstate.edu

What is GLM?

GLM is a set of C++ classes and functions that fill in the programming gaps in writing the basic vector and matrix mathematics for computer graphics applications.

GLM isn't a *library* – it is all specified in ***.hpp** header files that get compiled in with your source code.

You can find GLM at:
http://glm.g-truc.net/0.9.8.5/
or you can get a zip file of it on our Class Resources page.

You typically use GLM by putting these lines at the top of your program:

```
#define  GLM_FORCE_RADIANS
#include "glm/vec2.hpp"
#include "glm/vec3.hpp"
#include "glm/mat4x4.hpp"
#include "glm/gtc/matrix_transform.hpp"
#include "glm/gtc/matrix_inverse.hpp"
#include "glm/gtc/type_ptr.hpp"
```


Why are we even talking about this?

The OpenGL overlords have "deprecated" some of the OpenGL functions we have been using to perform transformations. In the desktop world, it means that the use of such functions is ***discouraged***. In Vulkan and in the mobile world of OpenGL-ES, it means those functions are ***gone***. You might as well become familiar with how to live without them. So, instead of saying:

```
gluLookAt( 0., 0., 3.,   0., 0., 0.,   0., 1., 0. );
glRotatef( (GLfloat)Yrot, 0., 1., 0. );
glRotatef( (GLfloat)Xrot, 1., 0., 0. );
glScalef( (GLfloat)Scale, (GLfloat)Scale, (GLfloat)Scale );
```

for OpenGL, you would now say:

```
glm::mat4 modelview;
glm::vec3 eye(0.,0.,3.);
glm::vec3 look(0.,0.,0.);
glm::vec3   up(0.,1.,0.);
modelview = glm::lookAt( eye, look, up );
modelview = glm::rotate( modelview, D2R*Yrot, glm::vec3(0.,1.,0.) );
modelview = glm::rotate( modelview, D2R*Xrot, glm::vec3(1.,0.,0.) );
modelview = glm::scale( modelview, glm::vec3(Scale,Scale,Scale) );
glMultMatrixf(  glm::value_ptr( modelview )  );
```

Exactly the same concept, but a different expression of it. Read on for details …

The Most Useful GLM Variables, Operations, and Functions

// constructor:

```
glm::mat4( 1. );                    // identity matrix
glm::vec4( );
glm::vec3( );
```

GLM recommends that you use the **"glm::"** syntax and not use **"using namespace"** syntax because they have not made any effort to create unique function names

// multiplications – the * operator has been overloaded:

```
glm::mat4  *  glm::mat4
glm::mat4  *  glm::vec4
glm::mat4  *  glm::vec4( glm::vec3, 1. )        // promote vec3 to a vec4 via a constructor
```

// emulating OpenGL transformations *with concatenation*:

glm::mat4 **glm::rotate**(glm::mat4 const & m, float angle, glm::vec3 const & axis);

glm::mat4 **glm::scale**(glm::mat4 const & m, glm::vec3 const & factors);

glm::mat4 **glm::translate**(glm::mat4 const & m, glm::vec3 const & translation);

The Most Useful GLM Variables, Operations, and Functions

// viewing volume (assign, not concatenate):

glm::mat4 **glm::ortho**(float left, float right, float bottom, float top, float near, float far);
glm::mat4 **glm::ortho**(float left, float right, float bottom, float top);

glm::mat4 **glm::frustum**(float left, float right, float bottom, float top, float near, float far);
glm::mat4 **glm::perspective**(float fovy, float aspect, float near, float far);

// viewing (assign, not concatenate):

glm::mat4 **glm::lookAt**(glm::vec3 const & eye, glm::vec3 const & look, glm::vec3 const & up);

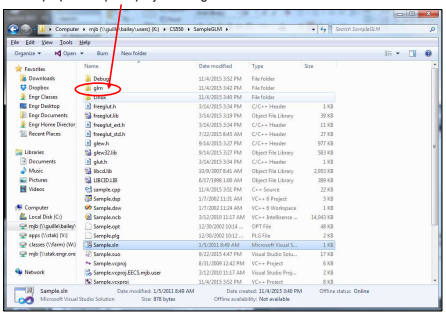
// loading matrices into opengl:

glLoadMatrix(**glm::value_ptr**(glm::mat4));

glUniformMatrix4fv(Location, 1, GL_FALSE, **glm::value_ptr**(glm::mat4));

Installing GLM into your own space

I like to just put the whole thing under my Visual Studio project folder so I can zip up a complete project and give it to someone else.



Here's what that GLM folder looks like

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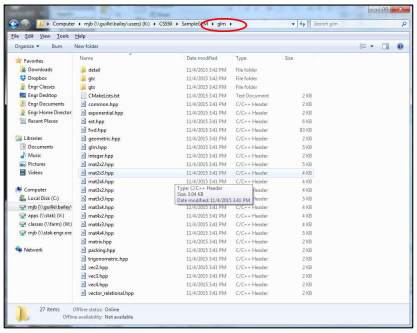

Telling Linux about where the GLM folder is

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g++ … **-I.** …

"minus-capital-eye-period" means "also look for the < > includes in this folder"

Instead of the period, you can list a full or relative pathname.

Telling Visual Studio about where the GLM folder is

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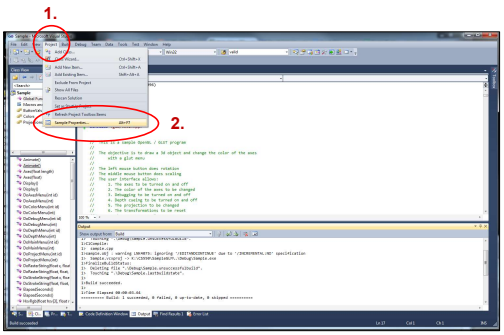

Telling Visual Studio about where the GLM folder is

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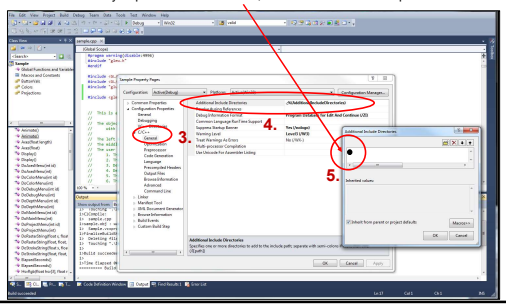
A ***period***, indicating that the **project folder** should also be searched when a **#include <xxx>** is encountered. If you put it somewhere else, enter that full or relative path instead.



Using Transformations, OpenGL-style, like in the sample.cpp Program

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```
glMatrixMode( GL_PROJECTION );
glLoadIdentity( );
if( WhichProjection == ORTHO )
        glOrtho( -3., 3.,     -3., 3.,     0.1, 1000. );
else
        gluPerspective( 90., 1.,       0.1, 1000. );

// place the objects into the scene:
glMatrixMode( GL_MODELVIEW );
glLoadIdentity( );

// set the eye position, look-at position, and up-vector:
gluLookAt( 0., 0., 3.,     0., 0., 0.,     0., 1., 0. );

// rotate the scene:
glRotatef( (GLfloat)Yrot, 0., 1., 0. );
glRotatef( (GLfloat)Xrot, 1., 0., 0. );

// uniformly scale the scene:
if( Scale < MINSCALE )
        Scale = MINSCALE;
glScalef( (GLfloat)Scale, (GLfloat)Scale, (GLfloat)Scale );
```


Using Transformations, GLM-style, I

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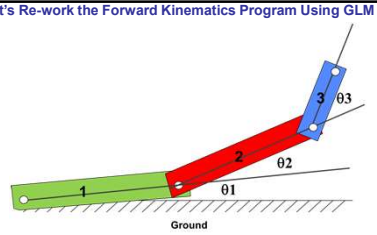
```
#include <glm/vec3.hpp>
#include <glm/mat4x4.hpp>
#include <glm/gtc/matrix_transform.hpp>
#include <glm/gtc/type_ptr.hpp>

        . . .

// convert degrees to radians:
const float D2R = M_PI/180.f;                   // 0.01745…

        . . .

glMatrixMode( GL_PROJECTION );
glLoadIdentity( );
glm::mat4  projection;

if( WhichProjection == ORTHO )
        projection = glm::ortho( -3., 3.,     -3., 3.,     0.1, 1000. );
else
        projection = glm::perspective( D2R*90., 1., 0.1, 1000. );

// apply the projection matrix:
glMultMatrixf(  glm::value_ptr( projection )  );
```

Using Transformations, GLM-style, II


```
// place the objects into the scene:
glMatrixMode( GL_MODELVIEW );
glLoadIdentity( );

// set the eye position, look-at position, and up-vector:
glm::vec3  eye(0.,0.,3.);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);
glm::mat4  modelview = glm::lookAt( eye, look, up );

// rotate the scene (warning -- unlike OpenGL's glRotatef,
//        GLM's rotate method takes angles in *radians*):
modelview = glm::rotate( modelview, D2R*Yrot,  glm::vec3(0.,1.,0.) );
modelview = glm::rotate( modelview, D2R*Xrot,  glm::vec3(1.,0.,0.) );

// uniformly scale the scene:
if( Scale < MINSCALE )
        Scale = MINSCALE;
modelview = glm::scale( modelview,  glm::vec3(Scale,Scale,Scale) );

// apply the modelview matrix:
glMultMatrixf(  glm::value_ptr( modelview )  );
```


Let's Re-work the Forward Kinematics Program Using GLM



$$[M_{3/G}] = [T_{1/G}] * [R_{\theta 1}] * [T_{2/1}] * [R_{\theta 2}] * [T_{3/2}] * [R_{\theta 3}]$$

$$[M_{3/G}] = [M_{1/G}] * [M_{2/1}] * [M_{3/2}]$$

Let's Re-work the Forward Kinematics Program Using GLM

Standard OpenGL

```
void DrawMechanism( float θ1, float θ2, float θ3 )
{
    glPushMatrix( );
        glRotatef( θ1,  0.,  0.,  1. );
        DrawLinkOne( );

        glTranslatef( LENGTH_1, 0., 0. );
        glRotatef( θ2,  0.,  0.,  1. );
        DrawLinkTwo( );

        glTranslatef( LENGTH_2, 0., 0. );
        glRotatef( θ3,  0.,  0.,  1. );
        DrawLinkThree( );
        glPopMatrix( );
}
```

Using GLM

```
void DrawMechanism( float θ1, float θ2, float θ3 )
{
    glm::mat4  identity = glm::mat4( 1. );
    glm::vec3  zaxis    = glm::vec3(0.,0.,1.);
    glPushMatrix( );
        glm::mat4 m1g = glm::rotate( identity, θ1,  zaxis );
        glMultMatrixf(  glm::value_ptr( m1g )  );
        DrawLinkOne( );

        glm::mat4  m21 = glm::translate( m1g, glm::vec3( LENGTH_1, 0., 0. ) );
        m21 = glm::rotate( m21, θ2,  zaxis );
        glMultMatrixf(  glm::value_ptr( m21 )  );
        DrawLinkTwo( );

        glm::mat4  m32 = glm::translate( m21, glm::vec3( LENGTH_2, 0., 0. ) );
        m32 = glm::rotate( m32, θ3,  zaxis );
        glMultMatrixf(  glm::value_ptr( m32 )  );
        DrawLinkThree( );
    glPopMatrix( );
}
```

$$[M_{3/G}] = [M_{1/G}] * [M_{2/1}] * [M_{3/2}]$$

Passing GLM Matrices into a Vertex Shader

In the shader:

```
uniform mat4      projectionMatrix;
uniform mat4      viewMatrix;
uniform mat4      modelMatrix;

mat4 PVM = projectionMatrix * viewMatrix * modelMatrix;
gl_Position = PVM * gl_Vertex;
```

In the C/C++ program:

```
glm::mat4  projection = glm::perspective( D2R*90., 1., 0.1, 1000. );

glm::vec3  eye(0.,0.,3.);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);
glm::mat4  view  =  glm::lookAt( eye, look, up );

glm::mat4  model( 1. );      // identity
model = glm::rotate( model, D2R*Yrot,  glm::vec3(0.,1.,0.) );
model = glm::rotate( model, D2R*Xrot,  glm::vec3(1.,0.,0.) );

Pattern.Use( );
Pattern.SetUniformVariable( "projectionMatrix", projection );
Pattern.SetUniformVariable( "viewMatrix", view );
Pattern.SetUniformVariable( "modelMatrix", model );
```


GLM for Vulkan


```
glm::mat4  projection = glm::perspective( D2R*90., 1., 0.1, 1000. );
projection[1][1]  *=  -1.;          // Vulkan's projected Y is inverted from OpenGL's

glm::vec3  eye(0.,0.,3.);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);
glm::mat4  view  =  glm::lookAt( eye, look, up );

glm::mat4  model( 1. );  // identity
model = glm::rotate( model, D2R*Yrot,  glm::vec3(0.,1.,0.) );
model = glm::rotate( model, D2R*Xrot,  glm::vec3(1.,0.,0.) );
```