Introduction to OpenGL

CSCI 4229/5229
Computer Graphics
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OpenGL by Example

- Learn OpenGL by reading
- nehe.gamedev.net
  - Excellent free tutorial
  - Code available for many platforms and languages
- OpenGL: A Primer (3ed) by Edward Angel
  - Short and sweet
- OpenGL Programming Guide (Vermillion Book)
  - Free older editions as PDF
- OpenGL Superbible
  - Theory and Applications

What is OpenGL?

- Sometimes called a language, actually an Application Programming Interface (API)
- Specification is controlled by OpenGL Architecture Review Board (ARB)/Kronos
- Multiple implementations by different vendors
  - Mesa3D free implementation
- OpenGL just does real time graphics
  - Need GLX/WGL/AGL for windowing and input
  - Limited font support (in GLUT)
  - No sound, printing, etc. support

OpenGL Versions

1.0 Initial release (1992)

1.1 Major upgrade (1997)

- Lastest version on some Windows system

1.2 Improves textures (1998)

1.3-1.5 Incremental improvements (2001-2003)

2.0 Relaxes restrictions, adds shader (2004)

2.1-2.3 Incremental improvement (2006-7)

3.0 Support advanced hardware features (2008)

3.1-3.3 Improved shaders (2009)

4.0 Merge desktop and devices (2010)

4.1-4.7 Additional shaders

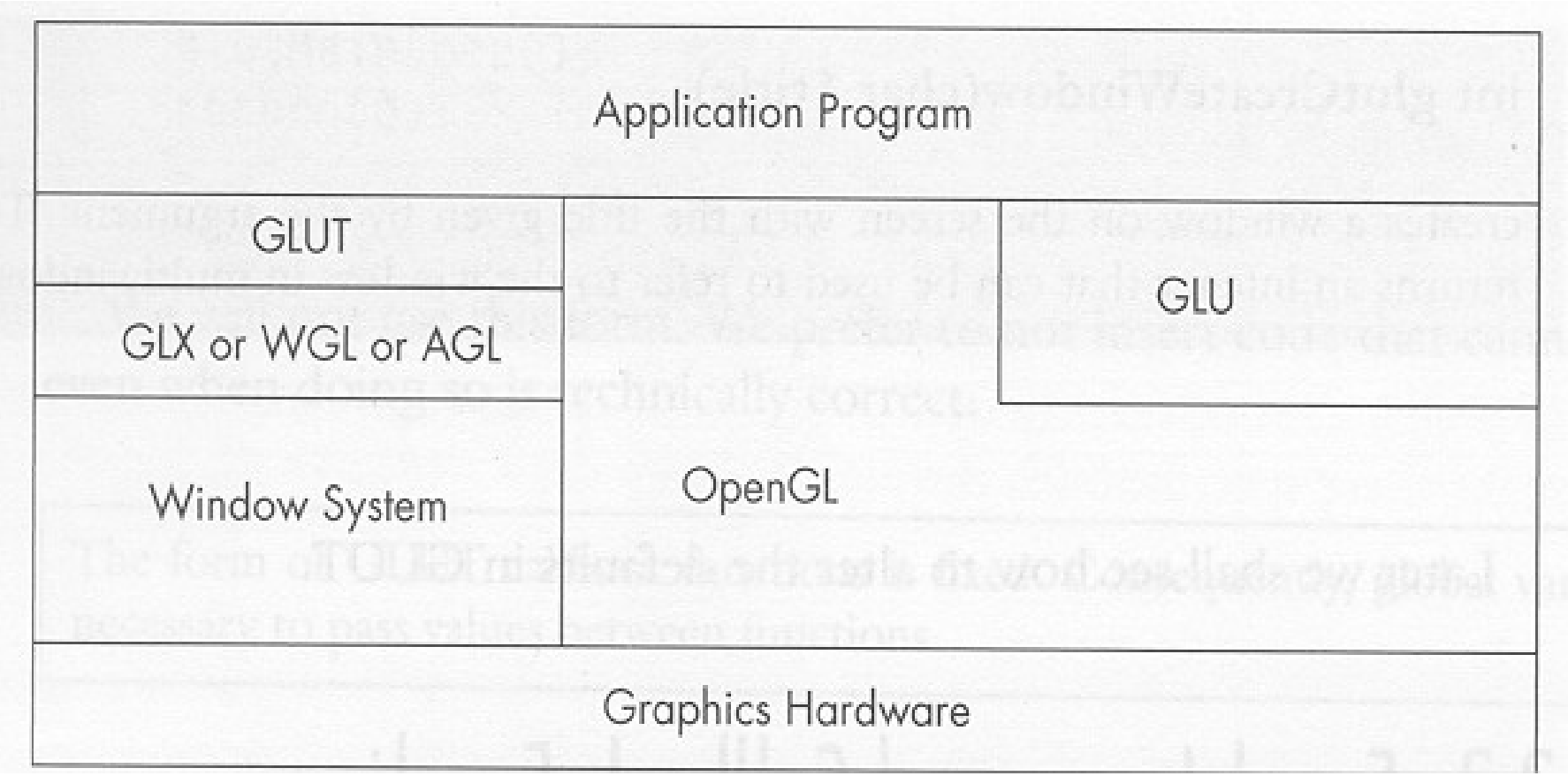
OpenGL Deprecation

- I will mostly use OpenGL 2.0
  - Feature rich
  - Flat learning curve
- OpenGL Core Profile concentrates on rendering
  - Improved execution time performance
- User must provide deprecated functionality
  - Steepens the learning curve
  - Deprecated features in Compatibility Profile
  - Increases reliance on third party libraries
  - Adds development time until tools mature

OpenGL APIs

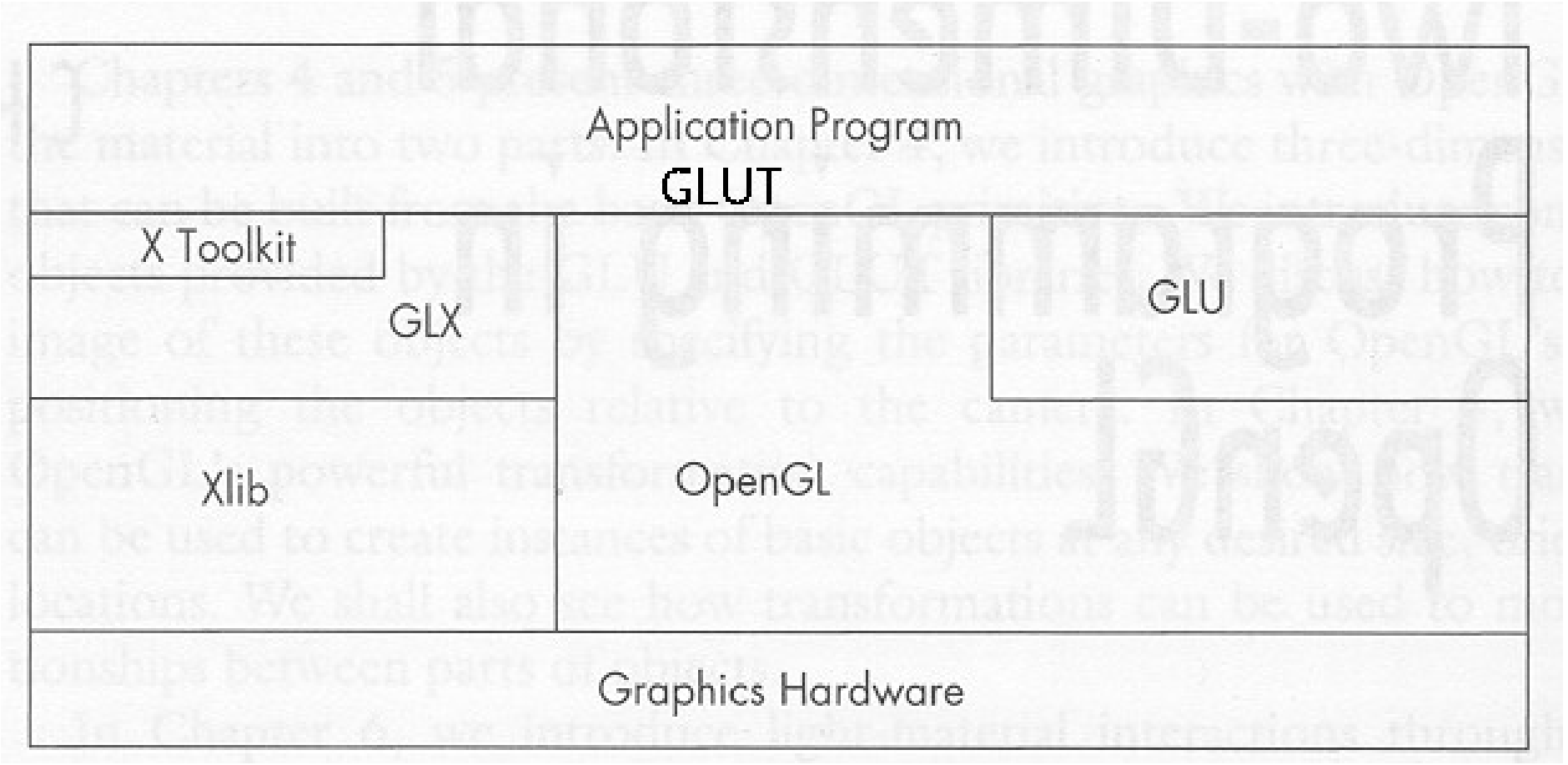
- Languages
  - C, C++, C#
  - FORTRAN
  - Java
  - Perl
  - Python
  - Ada
- Wrapper packages
  - Qt (QGLWidget or QOpenGLWidget)
  - GLFW, SDL
  - Many others

OpenGL and Friends



From *OpenGL: A Primer*

OpenGL on X11



From *OpenGL: A Primer*

GLU: OpenGL Utility

- Higher Level and Convenience Functions
  - Projections
  - Creating texture maps
  - NURBS, quadrics, tessalation
  - Predefined objects (sphere, cylinder, teapot)
- Collections of calls for convenience
- Standard with all OpenGL implementations

GLUT: GL Utility Toolkit

- Provides access to OS and Window System
  - Open windows and setting size and capabilities
  - Register and triggers callbacks
  - Keyboard and mouse interaction
  - Elementary fonts
- Not part of OpenGL, but provides a portable abstraction of the OS
  - FreeGLUT
  - OpenGLUT
- Alternatives: SDL, glfw, Qt, ...

Header Files and Libraries

- Usually you only need
  - #define GL_GLEXT_PROTOTYPES
  - #include <GL/glut.h>
- Header file locations
  - /usr/include/GL on most systems
- Linking may only need
  - -l glut -l GLU -l GL
- Special cases
  - OS/X separates GL and GLUT
  - Windows differs depending on the compiler

OpenGL Naming Convention

- glDoSomethingXy()
  - *DoSomething* is the name of the function
  - X is 2 or 3 or 4 for the dimension
  - y is for the the variable type

• b	GLbyte	(signed char)	8 bit
• s	GLshort	(signed short)	16 bit
• i	GLint	(signed int)	32 bit
• ub	GLubyte	(unsigned char)	8 bit
• us	GLushort	(unsigned short)	16 bit
• ui	GLuint	(unsigned int)	32 bit
• f	GLfloat	(float)	32 bit
• d	GLdouble	(double)	64 bit

OpenGL Naming Example

- Vertex
  - glVertex3i(0 , 0 , 1)
  - glVertex2d(27.34 , 88.12)
  - glVertex3dv(array)
- Few functions return a value
- Most functions created by name mangling
- Constants are GL_SOMETHING
- Variable types are GLsomething

GLUT and GLU Naming

- Functions
  - glutDoSomething
  - gluDoSomething
- Constants
  - GLUT_SOMETHING
  - GLU_SOMETHING
- You can always tell by the name which API supplies a function or constant
- Avoid things starting with glx, wgl & agl

GLUT: GL Utility Toolkit

- Supplies interface to OS
  - Windowing
  - Interaction
- Hello World in GLUT (well sorta)

```
int main(int argc,char* argv[ ])
{
  glutInit(&argc,argv);
  glutCreateWindow("Hello World");
  glutDisplayFunc(display);
  glutMainLoop();
}
```

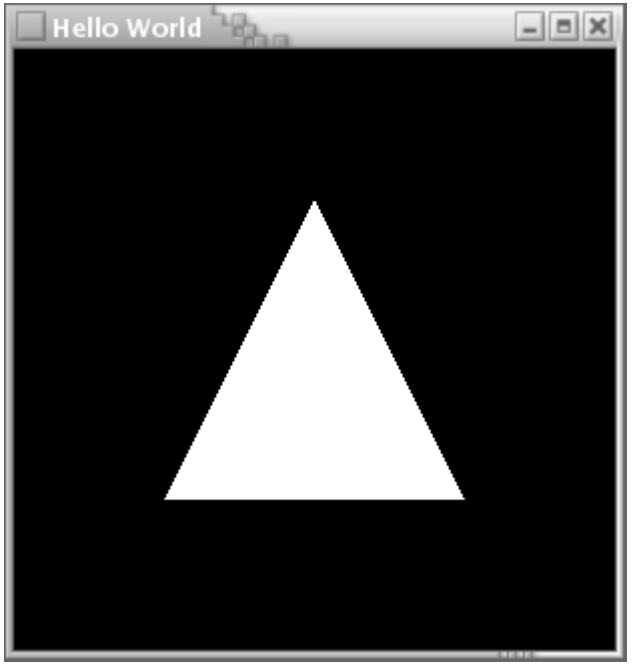
Completing Hello World

- Draw a triangle

```
#include <GL/glut.h>
void display()
{
  glClear(GL_COLOR_BUFFER_BIT);
  glBegin(GL_POLYGON);
  glVertex2f(0.0,0.5);
  glVertex2f(0.5,-0.5);
  glVertex2f(-0.5,-0.5);
  glEnd();
  glFlush();
}
```

Compile, link and run

- cc -o helloworld helloworld.c -lglut
- Heavily relies on defaults
  - Window
  - Viewport
  - Projection
  - Color



Event Driven Programming

- Don't call us, we'll call you
  - register callbacks corresponding to events
  - similar to interrupt driven programs
- DO NOT explicitly call display()
  - request redisplay using glutPostRedisplay()
- NEVER call sleep()
  - use global/static variables and wall time for timing
  - use glutTimerFunc() for regular events
- Return control as soon as possible

Types of Objects

- glBegin(type)
  - GL_POINTS points
  - GL_LINES lines between pairs of points
  - GL_LINE_STRIP series of line segments
  - GL_LINE_LOOP closed GL_LINE_STRIP
  - GL_POLYGON simple polygon
  - GL_TRIANGLES triangles between triples of points
  - GL_TRIANGLE_STRIP series of triangles
  - GL_TRIANGLE_FAN fan of triangles
- Set coordinates with glVertex
- glEnd()

Qualifiers

- glPointSize(float size)
  - POINT size in pixels (default 1)
- glLineWidth(float width)
  - LINE width in pixels (default 1)
- glLineStipple(int factor,unsigned short pattern)
  - LINE type
  - Requires glEnable(GL_LINE_STIPPLE)

Color

- Default is RGB color
  - X11 TrueColor
  - R,G,B 0-1 or integer range
    - glColor3f(1.0 , 0.0 .0.0)
    - glColor3b(127 , 0 , 0);
    - glColor3ub(255 , 0 , 0);
    - glColor3fv(rgbarray);
- Color can also contain transparency (alpha)
  - glColor4f(1.0 , 0.0 . 0.0 , 0.5);
  - Default alpha=1 (opaque)
- Stays in effect until you change color

Indexed Color

- X11 Direct Color
  - Based on a colormap
- Set color using glIndexi(27)
- Need to load colors into color map using glutSetColor()
- Use RGB color unless hardware constraine
- Deprecated in OpenGL 3 since it really is obsolete

Displaying a scene

- Register using glutDisplayFunc()
- glClear()
- *Draw Something*
- glFlush()
- glutSwapBuffers()
- Schedule using glutPostRedisplay()

Transformations

- Transformation apply to everything that follows
- Transformations are cumulative
  - Call glLoadIdentity() in display()
- Primitive operations
  - glLoadIdentity();
  - glTranslate[fd](dx , dy , dz)
  - glScale[fd](Sx , Sy , Sz)
  - glRotate[fd](angle , Ux , Uy , Uz)
- Compatibility profile in OpenGL4 still useful

glTranslate[fd](dx , dy , dz);

- Move an object in three dimensions
- Allows you to easily produce multiple copies of an object
- Always takes 3D coordinates (float or double)

glScale[fd](Sx , Sy , Sz)

- Change the scale along the axes
- Multiplicative factors
  - |S|<1 shrink
  - |S|>1 expand
  - Negative values creates mirror image
- Allows you to easily create multiple copies of the same type at different sizes

glRotate[fd](angle , Ux , Uy , Uz)

- Rotates around the origin and axis (Ux,Uy,Uz)
- Angle is measured in degrees
- The axis can be a primary axis (X,Y,Z) but may be axis
- Allows you to create multiple copies of the same object viewed from different sides, or to view the scene from different positions

Temporary Transformations

- glPushMatrix()
  - Saves the current transformation
- glPopMatrix()
  - Resets the transformation to what it was when you did the push
- Allows you to build complex transformations and then get them back

Compound Transformations

- Rotate angle around the point (X,Y,Z) and axis (Ux,Uy,Uz)
  - glTranslated(-X,-Y,-Z)
  - glRotated(angle,Ux,Uy,Uz)
  - glTranslated(X,Y,Z)
- OpenGL does this intelligently

Projections

- Orthographic
  - glOrtho(left,right,bottom,top,near,far)
  - Same size regardless of distance
  - Easiest to use
- Perspective
  - glFrustrum(left,right,bottom,top,near,far)
  - Closer objects are bigger
  - GLU convenience functions
    - gluPerspective(fov,aspect,Znear,Zfar)
    - gluLookAt(Ex,Ey,Ez , Cx,Cy,Cz , Ux,Uy,Uz)

Text

- OpenGL provides only hooks for fonts
- Stroked fonts
  - Lines and fills write the characters
- Bitmap (raster) fonts
  - Characters are raster images
- Orientation, size, etc. treated just like any other drawing elements

Text using GLUT

- glutBitmapCharacter(GLUT_FONTTYPE,ch)
  - Single charcter
  - Limited font selection
- glRasterPos3d(x,y,z)
  - Sets position to write text in (x,y,z) coordinates
- glWindowPos2i(x,y)
  - Sets position to write text in pixels coordinates

Registering Callbacks

- Display
  - glutDisplayFunc() Draw the scene
  - glutReshapeFunc() Window resized
  - glutIdleFunc() Nothing more scheduled
- User input
  - glutKeyboardFunc() Key pressed
  - glutSpecialFunc() Special key pressed
  - glutMouseFunc() Mouse button
  - glutMotionFunc() Mouse motion
- Many more

Keyboard Input

- special(int key,int x,int y)
  - Cursor keys GLUT_KEY_LEFT, GLUT_KEY_UP,...
  - Function keys GLUT_KEY_Fx
  - Basically anything not an ASCII key
- keyboard(char ch,int x,int y)
  - Regular keystrokes
- (x,y) is the mouse position in pixels

Setting Modes

- glutInitDisplayMode
  - Interfaces with the window manager to get the right kind of window (BE CAREFUL ABOUT DEFAULTS)
- glEnable() & glDisable()
  - Switches OpenGL into various modes
    - GL_DEPTH_TEST
    - GL_ALPHA_TEST
    - GL_CULL_FACE
    - GL_LIGHTING
  - Different modes for different objects

Checking for Errors

- OpenGL fails silently
- Functions do not return an error code
- glGetError() must be called explicitly to check for errors
- A black screen is a sure signal of an error
- **Always use my ErrCheck function**