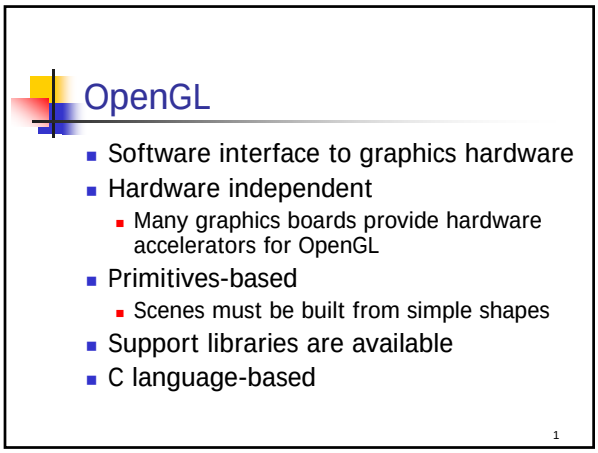
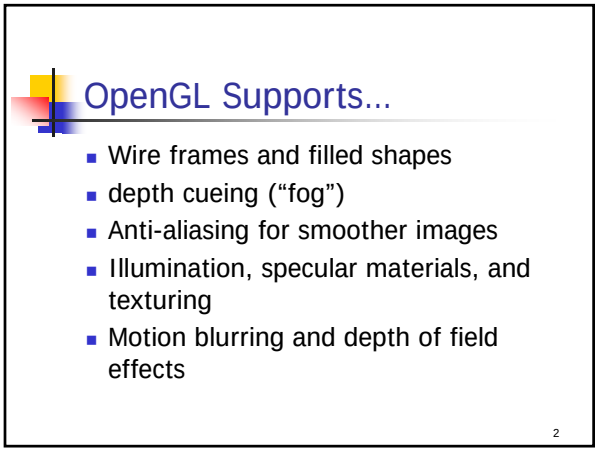
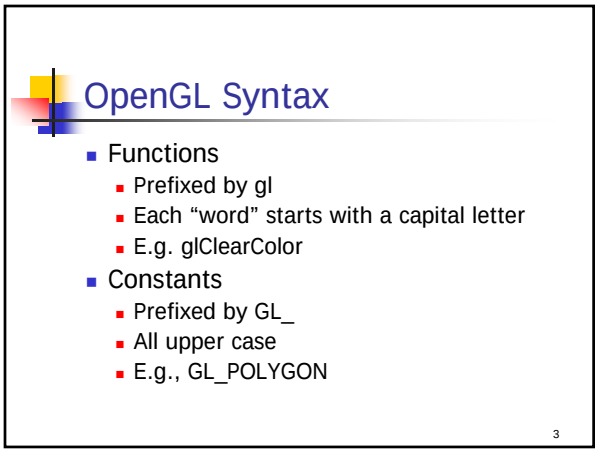

OpenGL
Software interface to graphics hardware
Hardware independent
Many graphics boards provide hardware accelerators for OpenGL
Primitives-based
Scenes must be built from simple shapes
Support libraries are available
C language-based
1


OpenGL Supports...
Wire frames and filled shapes
depth cueing (“fog”)
Anti-aliasing for smoother images
Illumination, specular materials, and texturing
Motion blurring and depth of field effects
2


OpenGL Syntax
Functions
Prefixed by gl
Each “word” starts with a capital letter
E.g. glClearColor
Constants
Prefixed by GL_
All upper case
E.g., GL_POLYGON
3

OpenGL Flexibility

- Language “independent”
- Most routines support multiple variations
  - Similar to C++ overloading
  - Function names are suffixed with parameter type information
  - Provide “safe” type names
- Qt wrapper (QGLWidget)
  - http://doc.trolltech.com/opengl.html
  - Only in Qt Enterprise and Qt Free Editions

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OpenGL Type Suffixes

Suffix	Type	C Type	OpenGL Type
b	8-bit integer	signed char	GLbyte
s	16-bit integer	short	GLshort
i	32-bit integer	int or long	GLint, GLsizei
f	32-bit float	float	GLfloat, GLclampf
d	64-bit float	double	GLdouble, GLclampd
ub	8-bit unsigned int	unsigned char	GLubyte, GLboolean
us	16-bit unsigned int	unsigned short	GLushort
ui	32-bit unsigned int	unsigned int, unsigned long	GLuint, GLenum, GLbitfield

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OpenGL Type Suffix Examples

- Set Color to “Red” via RGB values
  - glColor3ub(255,0,0); // (1<<8)-1
  - glColor3us(65535,0,0); // (1<<16)-1
  - glColor3ui(4294967295,0,0); // (1<<32)-1 (?)
  - glColor3f(1.0f,0.0f,0.0f);
  - glColor3d(1.0,0.0,0.0);

Range: 0..1

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OpenGL is State-based

- Many attributes are state-based
  - They remain in effect until changed
  - Similar to having a single QPainter in Qt
    - With a current QPen, QBrush, etc.
- State attributes can be queried
  - glGet**TYPE**v(GLenum *pname*, GL**type*** params);
    - GLint currentColor[4]; // RGBA
    - glGetIntegerv(GL_CURRENT_COLOR, currentColor);
- State attributes can be saved for later use
  - glPush...
  - glPop...

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OpenGL State Items

- Color
- Viewing
  - Depth, etc.
- Transformations
  - Model
  - Projection
- Line patterns
- Polygon modes
- Light source characteristics
- Material/surface properties
- Texturing
- Anti-aliasing
- Dithering
- Pixel storage options

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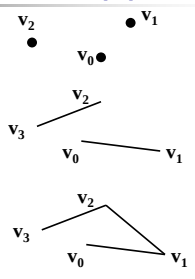
OpenGL Primitives (1)

- GL_POINTS
- GL_LINES
- GL_LINE_STRIP



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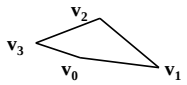
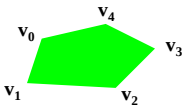
OpenGL Primitives (2)

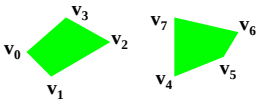
- GL_LINE_LOOP



- GL_POLYGON



- GL_QUADS



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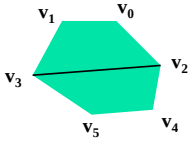
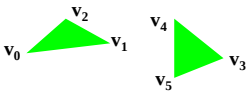
OpenGL Primitives (3)

- GL_QUAD_STRIP



- GL_TRIANGLES



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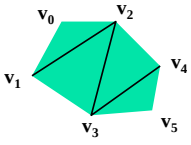
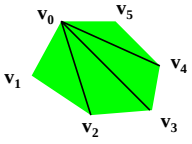
OpenGL Primitives (4)

- GL_TRIANGLE_STRIP



- GL_TRIANGLE_FAN



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Using OpenGL Primitives

- Built-up using a “Code Block”
- Example

```
glBegin(GL_LINE_LOOP);
  glVertex3d(5.0, -3.5, 0.0);
  glVertex3d(6.9, 2.5, 9.1);
  glVertex3d(-2.2, -5.1, -4.0);
glEnd();
```

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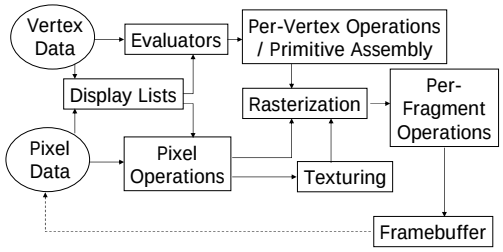
OpenGL Rendering Pipeline



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OpenGL Pipeline Steps

- Evaluators – Convert curve control vertices to facet vertices
- Per-Vertex – Transform/project, clip, generate texture coordinates, etc.
- Pixel – Packing, bias/scale/map, etc.
- Texture – Adding texture to surfaces
- Fragments – Potentially drawn pixels (color & depth)
- Rasterization – Determining fragment info
- Per-Fragment – texture, tests to discard, blending, logical operations

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OpenGL Utility Library (GLU)

- Utility routines for complex shapes
  - Tessellation (division into convex polygons), Curves, etc.
- Include files
  - `#include <GL/gl.h>`
  - `#include <GL/glu.h>`
- Link Libraries
  - opengl32.{lib,dll} libGL.{a,so}
  - glu32.{lib,dll} libGLU.{a,so}

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OpenGL Utility Toolkit (GLUT)

- Complex 3D primitives
  - Sphere, icosahedron, torus, teapot
- Windowing functions
  - Size, position, exposure control, etc.
- Include files
  - `#include <GL/glut.h>`

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Qt OpenGL Widget (QGLWidget)

- OpenGL rendering within a Qt application
  - Lets Qt handle UI and OpenGL handle 3-D rendering
- Modeled after GLUT
  - Callbacks replaced with overridable, virtual functions: {initialize,resize,paint}GL
- Include file
  - `#include <qgl.h>`

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