

Introduction to OpenGL

OpenGL API
Core and Compatibility Profiles
Colors
[Angel Ch. 2]

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What is OpenGL

- A low-level graphics library (API) for 2D and 3D interactive graphics.
- Descendent of GL (from SGI)
- First version in 1992; now: 4.5 (August 2014)
- Managed by Khronos Group (non-profit consortium)
- API is governed by Architecture Review Board (part of Khronos)



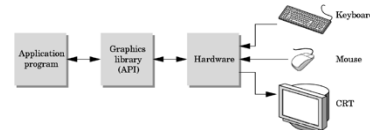
Where is OpenGL used

- CAD
- Virtual reality
- Scientific visualization
- Flight simulation
- Video games



Graphics library (API)

- Intermediary between applications and graphics hardware



- Other popular APIs:
Direct3D (Microsoft)
OpenGL ES (embedded devices)
X3D (successor of VRML)

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OpenGL is cross-platform

- Same code works with little/no modifications
- Windows: default implementation ships with OS
Improved OpenGL: Nvidia or AMD drivers
- Linux: Mesa, a freeware implementation
Improved OpenGL: Nvidia or AMD drivers
- Mac: ships with the OS

Choice of Programming Language

- OpenGL lives close to the hardware
- OpenGL is not object-oriented
- OpenGL is not a functional language (as in, ML)
- Use C to expose and exploit low-level details
- Use C++, Java, ... for toolkits
- Support for C in assignments

OpenGL is cross-platform

Include file (OpenGL Compatibility Profile) :

```
#if defined(WIN32) || defined(linux)
#include <GL/gl.h>
#include <GL/glu.h>
#include <GL/glut.h>
#elif defined(__APPLE__)
#include <OpenGL/gl.h>
#include <OpenGL/glu.h>
#include <GLUT/glut.h>
#endif
```

OpenGL is cross-platform

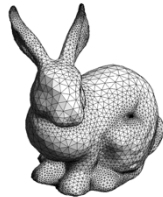
Include file (OpenGL Core Profile) :

```
#if defined(WIN32) || defined(linux)
#include <GL/glew.h>
#include <GL/glut.h>
#elif defined(__APPLE__)
#include <OpenGL/gl3.h>
#include <OpenGL/gl3ext.h>
#include <GLUT/glut.h>
#endif
```

How does OpenGL work

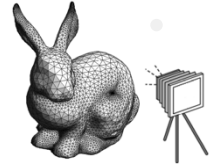
From the programmer's point of view:

1. Specify geometric objects
2. Describe object properties
 - Color
 - How objects reflect light

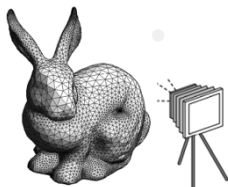


How does OpenGL work (continued)

3. Define how objects should be viewed
 - where is the camera
 - what type of camera
4. Specify light sources
 - where, what kind
5. Move camera or objects around for animation



The result



the result

OpenGL is a state machine

State variables: vertex buffers, camera settings, textures, background color, hidden surface removal settings, the current shader program...

These variables (the *state*) then apply to every subsequent drawing command.

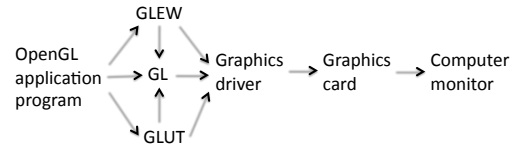
They persist until set to new values by the programmer.

Attributes:
color, shading and reflection properties

- Set before primitives are drawn
- Remain in effect until changed !

OpenGL Library Organization

- **GL** (Graphics Library): core graphics capabilities
- **GLUT** (OpenGL Utility Toolkit): input and windowing
- **GLEW** (Extension Wrangler): removes OS dependencies
- **GLU** (OpenGL Utility Library; compatibility profile only): utilities on top of GL



Core vs Compatibility Profile

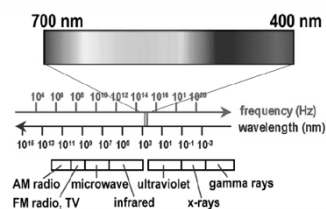
- Core Profile:
 - "Modern" OpenGL
 - Introduced in OpenGL 3.2 (August 2009)
 - Optimized in modern graphics drivers
 - Shader-based
 - Used in our homeworks
- Compatibility Profile:
 - "Classic" OpenGL
 - Supports the "old" (pre-3.2) OpenGL API
 - Fixed-function (non-shader) pipeline
 - Not as optimized as Core Profile

Mixing core and compatibility profiles

- Windows, Linux:
 - Can mix core and compatibility profile OpenGL commands
 - can lead to confusion (is the specific OpenGL command optimized?)
 - advantage: more flexible (can re-use old code)
- Mac:
 - Can only choose one profile (in each application)

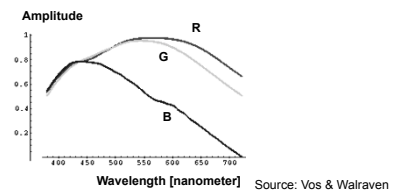
Physics of Color

- Electromagnetic radiation
- Can see only a tiny piece of the spectrum



Color Filters

- Eye can perceive only 3 basic colors
- Computer screens designed accordingly

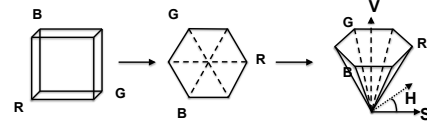
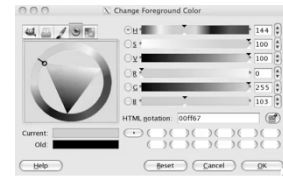


Color Spaces

- RGB (Red, Green, Blue)
 - Convenient for display
 - Can be unintuitive (3 floats in OpenGL)
- HSV (Hue, Saturation, Value)
 - Hue: what color
 - Saturation: how far away from gray
 - Value: how bright
- Other formats for movies and printing

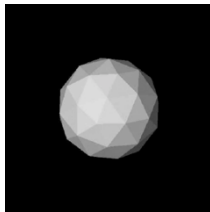
RGB vs HSV

Gimp Color Picker

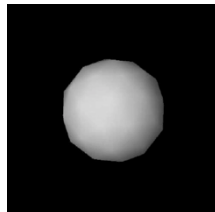


Flat vs Smooth Shading

Flat Shading



Smooth Shading



Flat vs Smooth Shading

color of last vertex



Compatibility profile:
glShadeModel(GL_FLAT)

each vertex separate color
smoothly interpolated

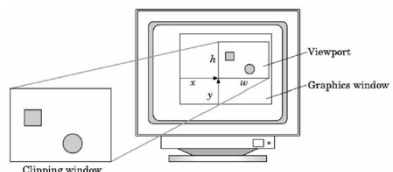


Compatibility profile:
glShadeModel(GL_SMOOTH)

Core profile: use interpolation qualifiers in the fragment shader

Viewport

- Determines clipping in window coordinates
- glViewport(x, y, w, h) (usually in reshape function)



Summary

1. OpenGL API
2. Core and compatibility profiles
3. Colors
4. Flat and smooth shading