Introduction to OpenGL

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

Jernej Barbic
University of Southern California
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: 4.6 (July 2017)
- 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)
  Vulkan (more low-level than OpenGL)
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. Apple announced deprecation in 2018, but OpenGL continues to work.
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):

```c
#if defined(WIN32) || defined(linux)
    #include <GL/gl.h>
    #include <GL/glu.h>
    #include <GL/glut.h>
#else if defined(__APPLE__)
    #include <OpenGL/gl.h>
    #include <OpenGL/glu.h>
    #include <GLUT/glut.h>
#endif
```
OpenGL is cross-platform

Include file (OpenGL Core Profile):

```c
#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
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
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

Diagram:

- OpenGL application program
- Graphics driver
- Graphics card
- Computer monitor
- GLEW
- GL
- GLUT
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

Source: Vos & Walraven
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
- Each vertex separate color smoothly interpolated

Compatibility profile:
- `glShadeModel(GL_FLAT)`
- `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