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)

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):

```c
#if defined(WIN32) || defined(linux)
#include <GL/gl.h>
#include <GL/glu.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):

```c
#if defined(WIN32) || defined(linux)
#include <GL/glew.h>
#include <GL/glut.h>
#elif defined(__APPLE__)
#include <OpenGL/glu3.h>
#include <OpenGL/glu3ext.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

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

<table>
<thead>
<tr>
<th>Flat Shading</th>
<th>Smooth Shading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color of last vertex</td>
<td>Each vertex separate color</td>
</tr>
<tr>
<td>Compatibility profile: glShadeModel(GL_FLAT)</td>
<td>Compatibility profile: glShadeModel(GL_SMOOTH)</td>
</tr>
<tr>
<td>Core profile: use interpolation qualifiers in the fragment shader</td>
<td></td>
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</tbody>
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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