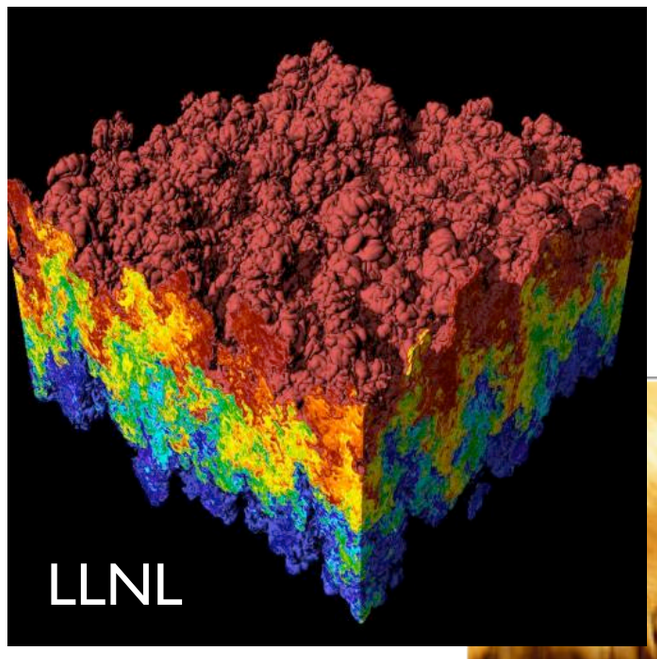
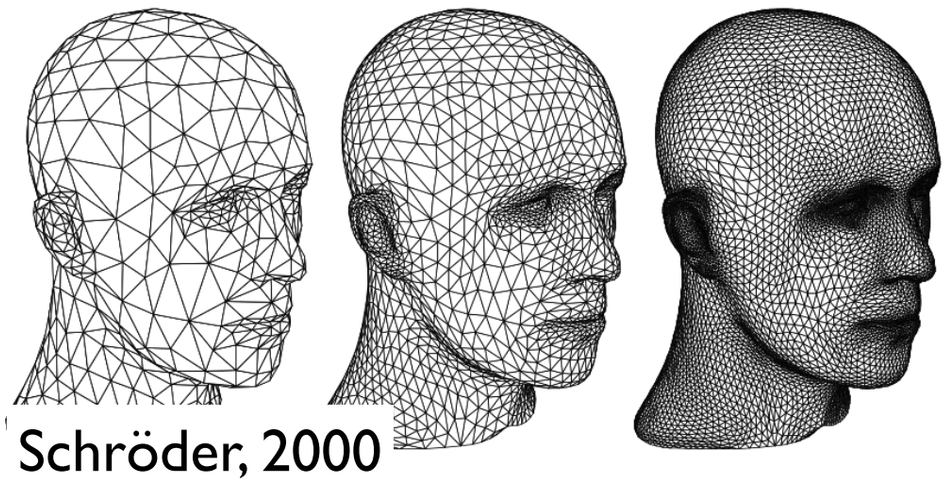
CS130 : Computer Graphics
Winter 2013

Tamar Shinar
Computer Science & Engineering
UC Riverside

Welcome to CS130!


Talton et al., 2011

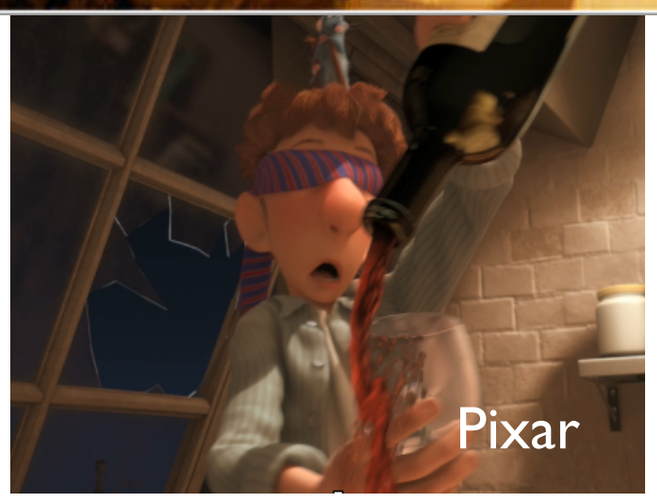

LLNL


Schröder, 2000


ILM


Henrik Wann Jensen


Hong et al. 2007


Pixar

Examples of different works in graphics. Clockwise: procedural modeling, scientific visualization, geometric modeling, live action special effects, animated special effects, physics-based special effects research, rendering

Today's agenda

- Course logistics
- Introduction: graphics areas and applications
- Introduction to OpenGL
- Math review

Course Overview

- Learn fundamental 3D graphics concepts
- Implement graphics algorithms
  - make the concepts concrete
  - expand your abilities and confidence for future work

Course Logistics

- Instructor: Tamar Shinar
- TA: Steve Cook
- Website: http://www.cs.ucr.edu/~scook005/cs130
- Piazza: https://piazza.com/ucr/winter2013/cs130/home
- Lectures: TuTh 9:40-11am
- Lab: M 2:10-5:00pm
- announcements (assignments, etc.) made in class and on course website

Course Logistics

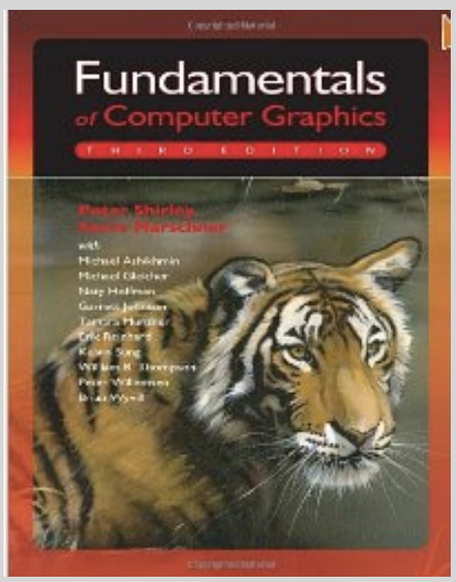
- Grading
  - 10% labs
  - 10% homework
  - 30% assignments (2 assignments, 15% each)
  - 50% tests (2 midterms, 1 final)
- Detailed schedule on class website

Course schedule

tentative; see course website for up-to-date schedule

Lecture	Date	Topic	Reading	Assigned	Due
1	4/2	Introduction	Chapters 1	Homework 1	
2	4/4	Graphics Pipeline	Chapter 3, and Section 8.0		
3	4/6	Math Review	Sections 2.3, 2.4		
Lab 1	4/2	Introduction to OpenGL			
4	4/9	2D Line Rasterization	Section 8.1.1 and Subsection "Implicit 2D Lines" (of Section 2.5)	Homework 2	Homework 1 due
5	4/11	Polygons	Sections 2.7, 8.1.2		
6	4/13	Polygons (continued)	Sections 8.1.3, 8.1.6, 8.2.0-8.2.3 (except "Precision Issues")		
Lab 2	4/9	Line Rasterization			
7	4/16	Transformation Matrices	Sections 6.1.0-6.1.5, 6.3	Homework 3	Homework 2 due
8	4/18	Transformation (cont.)		Assignment 1	
9	4/20	Transformations (cont.)			
Lab 3	4/16	Transformations			
10	4/23	Projection	Chapter 7	Homework 4	
11	4/25	Projection / Review	Homework 3 Solutions(updated)		
-	4/27	Test 1			
Lab 4	4/23	3D Modeling			
12	4/30	Shading	Chapter 10	Homework 5	
13	5/2	Shading (cont.)			
14	5/4	Shading (cont.)	Chapter 11		
Lab 5	4/30	Programmable Shading			
15	5/7	Texture mapping			
16	5/9	Texture mapping (continued)		Homework 6	
17	5/11	Texture mapping (continued)			Assignment 1 due **(due on Fr**
Lab 6	5/7	Texture Mapping			
18	5/14	Rotations	Chapter 17.2.2	Homework 7	Homework 6 due
19	5/16	Animation and Review	Chapter 17		
-	5/18	Test 2			
Lab 7	5/14	SLERP			
20	5/21	Ray Tracing	Chapter 4	Assignment 2	Homework 7 due

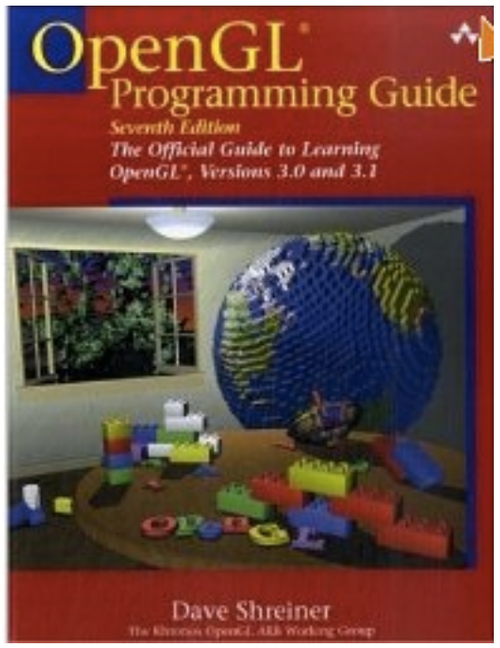
Textbook

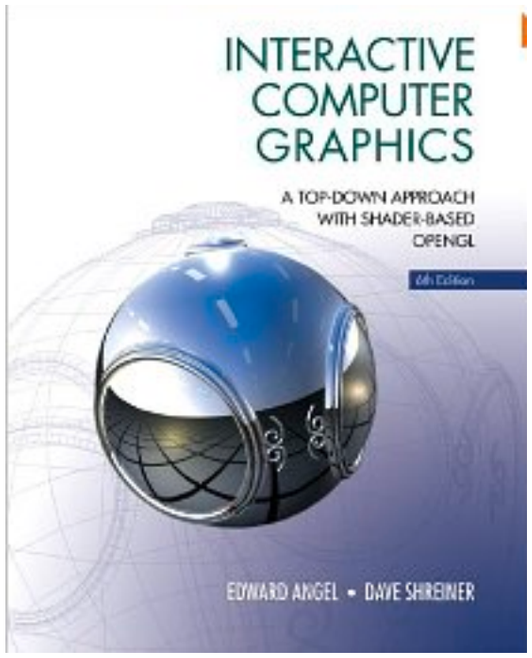


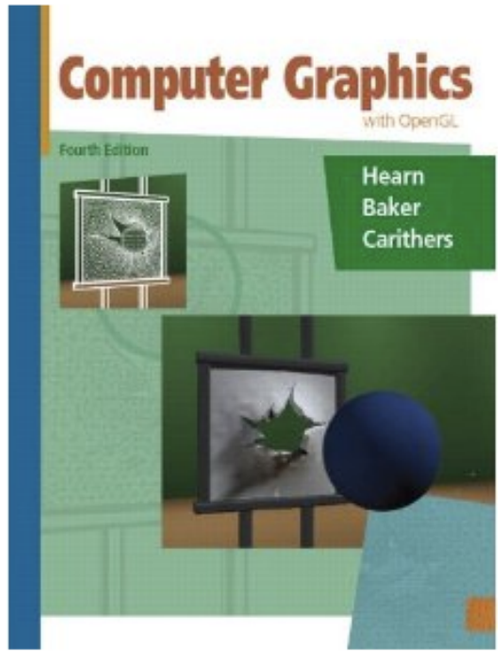
Fundamentals of Computer Graphics

Shirley and Marschner

Additional books







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About your instructors

- B.S., University of Illinois in Urbana-Champaign, Mathematics, Computer Science, Art
- Ph.D., 2008, Stanford University on simulation methods for computer graphics
- Started at UCR in the fall of 2011
- Work in graphics simulation and biological simulation

http://www.cs.ucr.edu/~shinar

http://www.cs.ucr.edu/~scook005

Introduction

Graphics applications

- 2D drawing
- Drafting, CAD
- Geometric modeling
- Special effects
- Animation
- Virtual Reality
- Games
- Educational tools
- Surgical simulation
- Scientific and information visualization
- Fine art

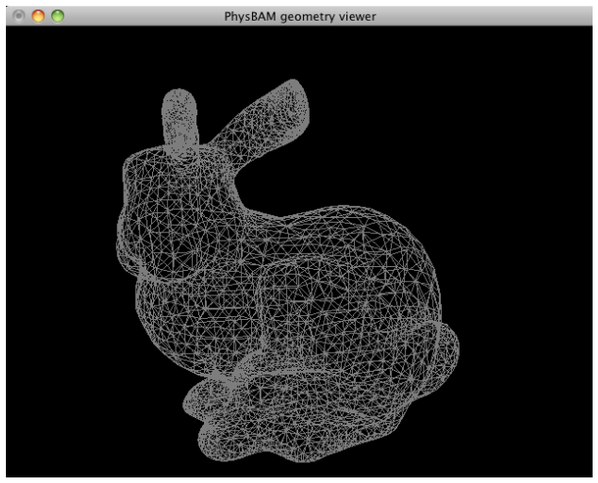
Graphics areas

- **Modeling -** mathematical *representations* of physical objects and phenomena
- **Rendering -** creating a *shaded image* from 3D models
- **Animation -** creating motion through a sequence of images
- **Simulation -** physics-based models for modeling dynamic environments

Modeling and **rendering** are separate stage
- first design and position objects -- **modeling**
- then add lights, materials properties, effects -- **rendering**

Modeling

Talton et al., 2011



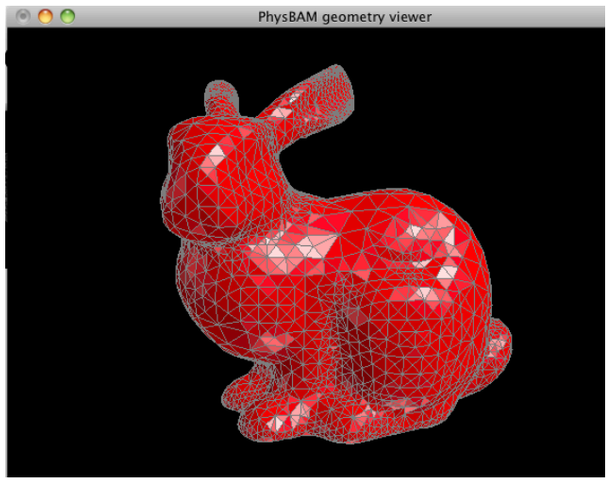
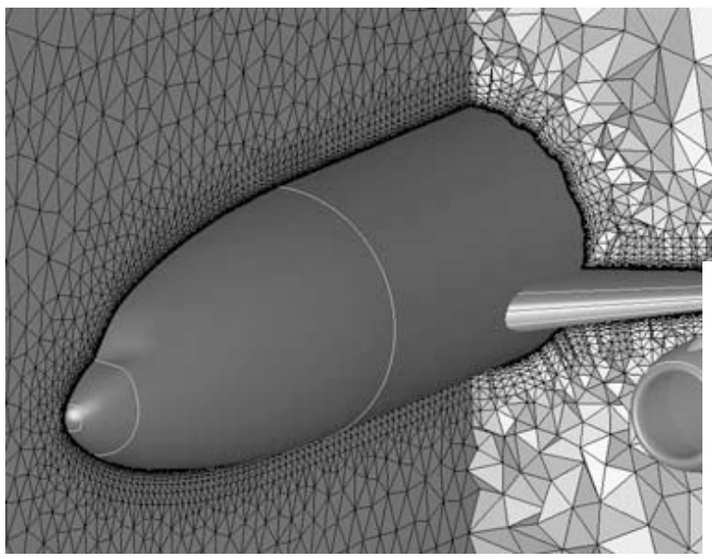


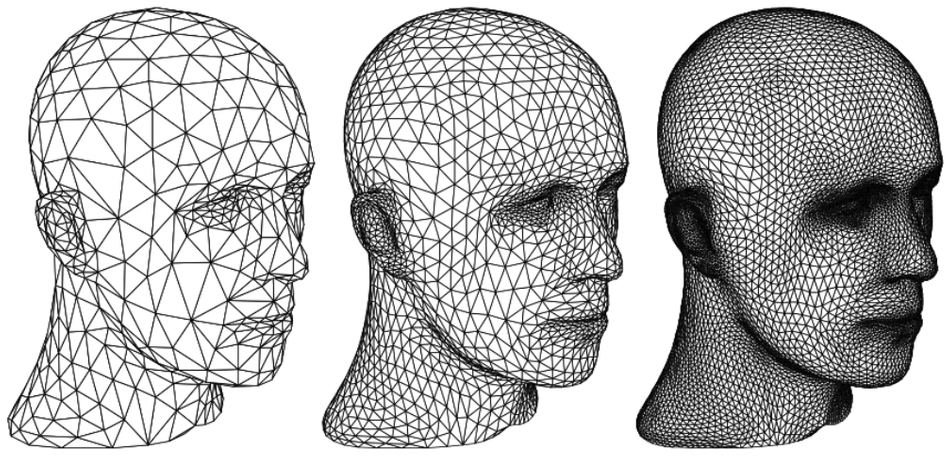
Figure1: Teddy in use on a display-integrated tablet.

Igarashi et al., 2007



CFD Technologies

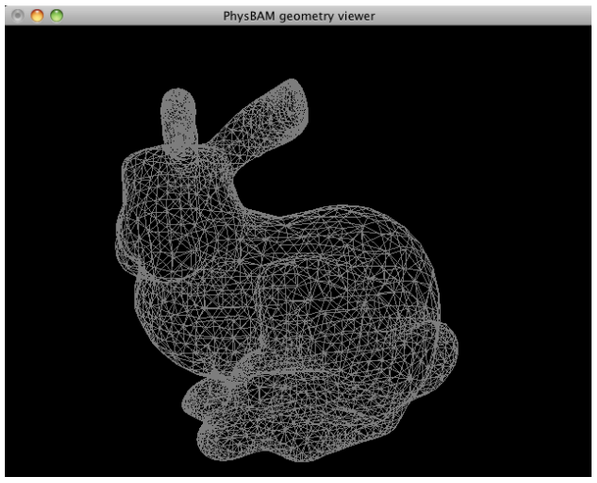
Bronstein et al., 2011

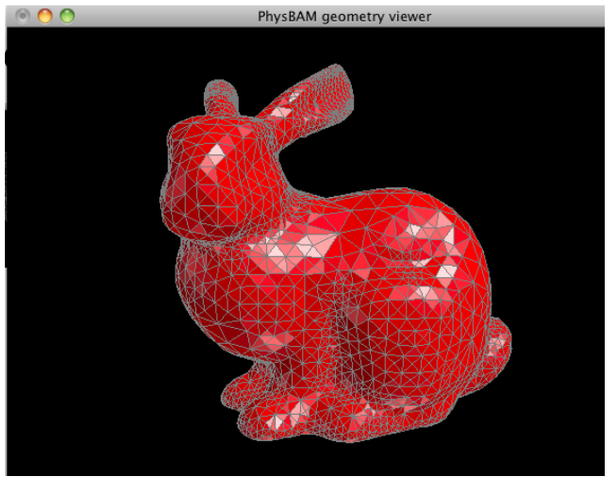


Schröder, 2000

- subdivision surface – Siggraph course notes 2000
- Teddy : sketch based interface for 3D modeling
- Talton et al. -- procedural modeling – for games, virtual worlds, design, etc.
  - combine machine learning and graphics
- Bronstein – reasoning about geometric models for search

Rendering





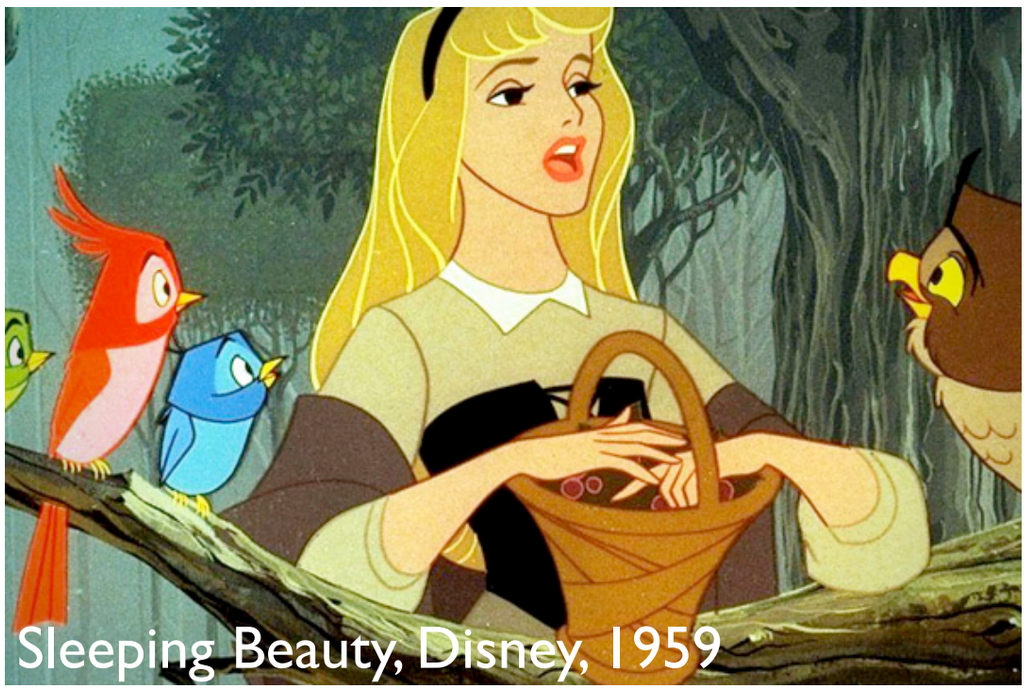
Henrik Wann Jensen

- opengl – 3D graphics (z-buffer) rendering
- **teapot – image-based lighting –** illuminated by a high dynamic range environment – metal, glass, diffuse, and glossy
- **subsurface scattering** – to capture translucent materials such as skin and marble
- rendering a emissive material such as fire – **participating medium** – scattering, absorption
- **local** vs **global** illumination

- direct vs. global illumination

- direct vs. global illumination

Animation



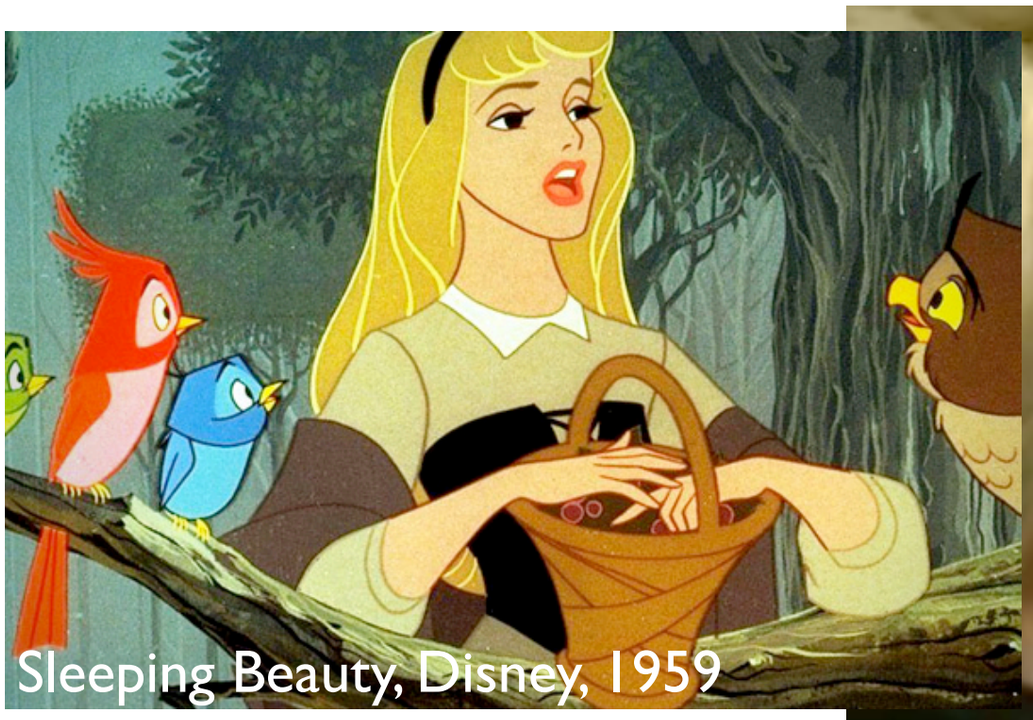
Sleeping Beauty, Disney, 1959

Monsters Inc, Pixar, 2001

Adventures of Tintin, Weta 2011

Life of Pi, 2012

Animation



Sleeping Beauty, Disney, 1959

Adventures of Tintin, Weta 2011

Monsters Inc, Pixar, 2001

Life of Pi, 2012

Simulation

The Perfect Storm, ILM
Firestorm, Harry Potter and the Half-Blood Prince
Lord of the Rings, FOTR River Scene

Firestorm
Harry Potter and the Half Blood Prince
Industrial Light + Magic

Firestorm
Harry Potter and the Half Blood Prince
Industrial Light + Magic

fluid simulation in Pixar's *Ratatouille*

fluid simulation in Pixar's *Ratatouille*

Introduction to OpenGL

Introduction to OpenGL

- **Open G**raphics **L**ibrary, managed by Khronos Group
- A software interface to graphics hardware (GPU)
- Standard API with support for multiple languages and platforms, open source
- ~250 distinct commands
- Main competitor: Microsoft's Direct3D
- **http://www.opengl.org/wiki/Main_Page**

- used to produce interactive 3D graphics
- sits between programmer and 3D accelerators in hardware
- **standard** requires support for feature set for all implementations
- Both OpenGL and Direct3D support feature sets -- they take advantage of hardware acceleration or use software emulation when a feature is unavailable in hardware
- Direct3D is proprietary
- OpenGl and Direct3D both implemented in the display driver

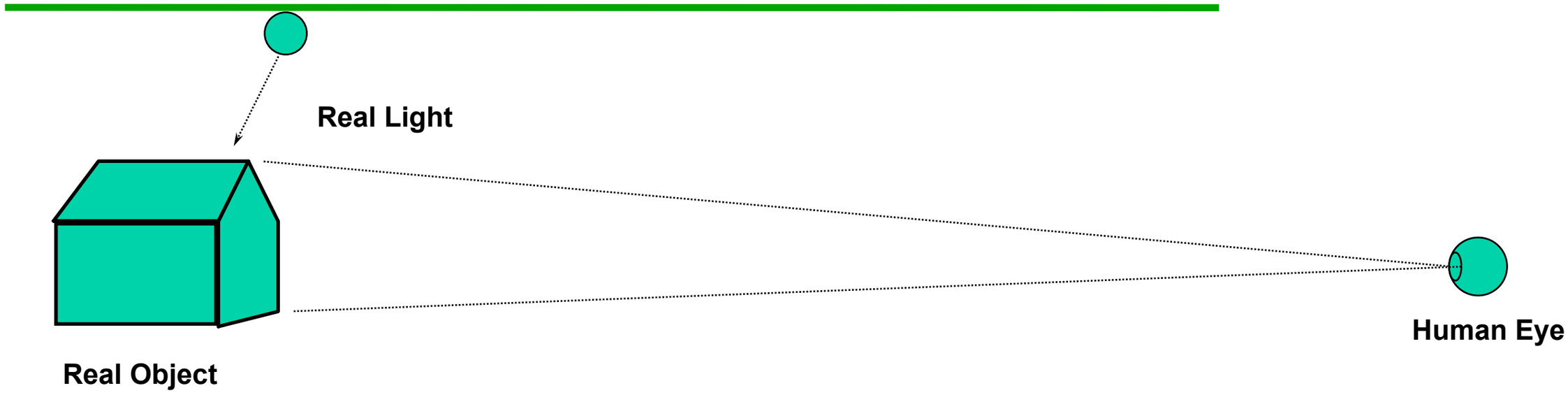
OpenGL - Software to Hardware

- Silicon Graphics (SGI) revolutionized the graphics workstation by putting graphics pipeline in hardware (1982)
- To use the system, application programmers used a library called GL
- With GL, it was relatively simple to program three dimensional interactive applications

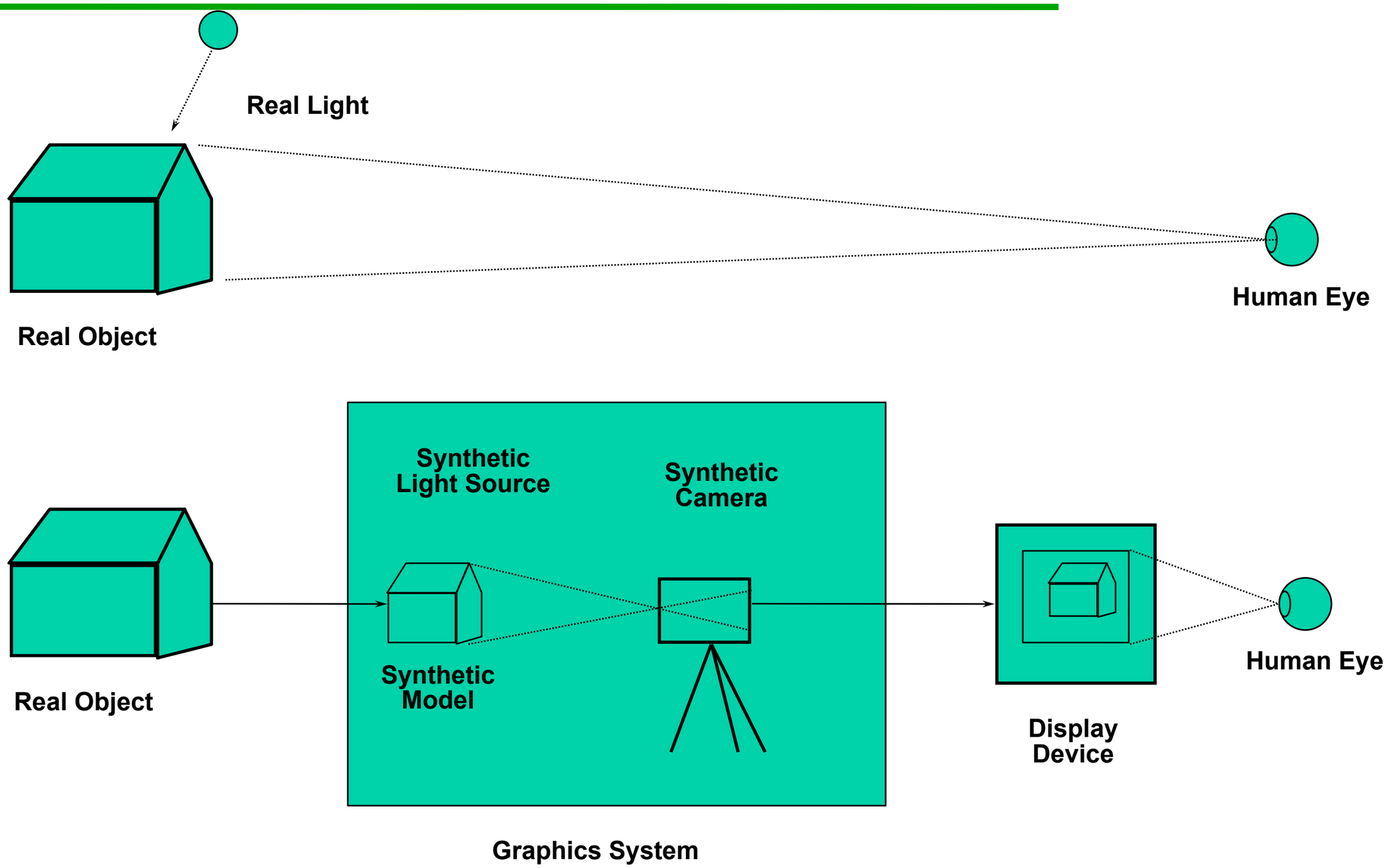
OpenGL

- The success of GL lead to OpenGL (1992), a platform-independent API that was
  - Easy to use
  - Close to the hardware - excellent performance
  - Focus on rendering
  - Omitted windowing and input to avoid window system dependencies

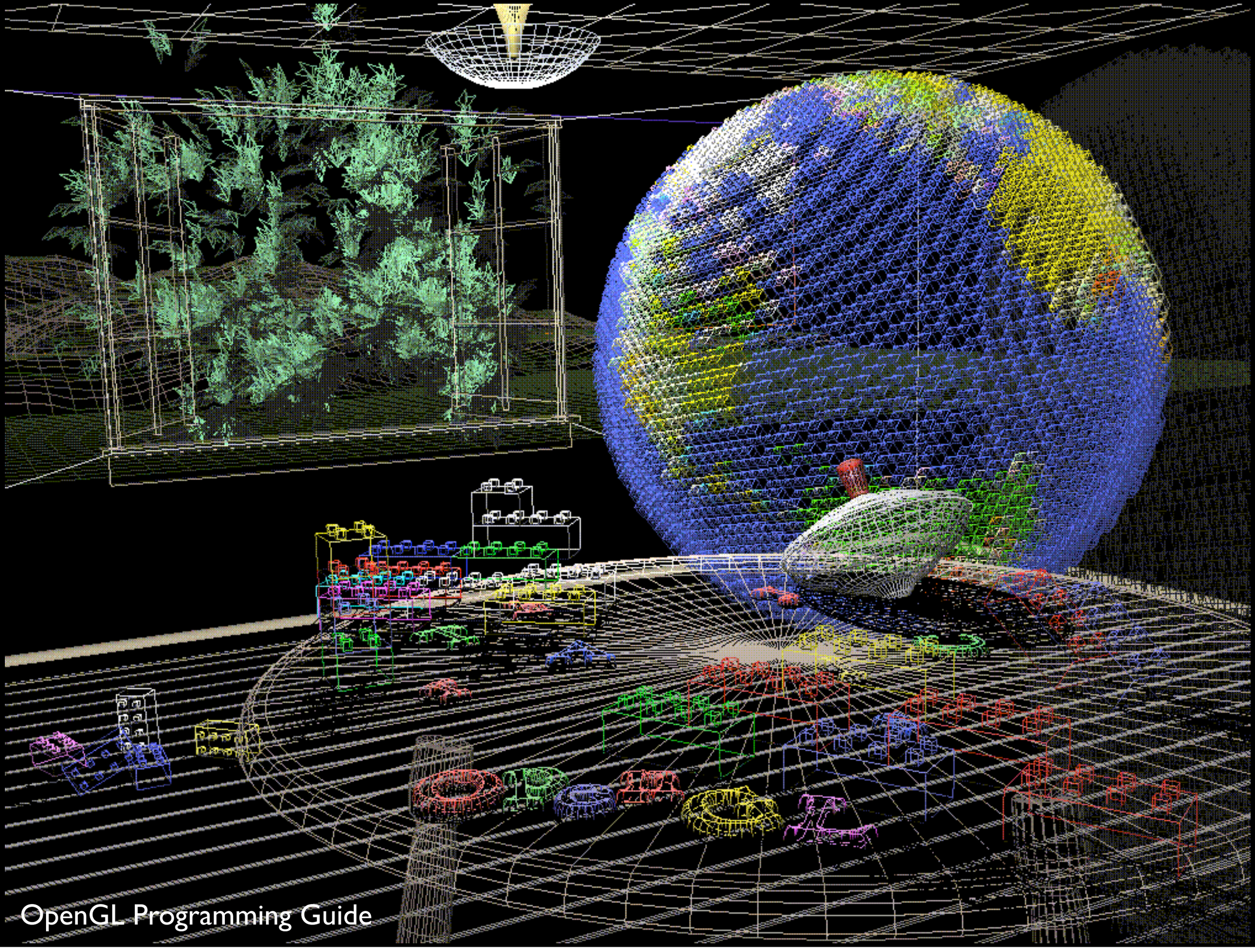
OpenGL: Conceptual Model



OpenGL: Conceptual Model



What can OpenGL do?
Examples from the
OpenGL Programming Guide ("red book")



- **Wireframe** models
  - shows each object made up of polygons
- the **lines are are the edges** and the **faces of the polygons make up the object surface**

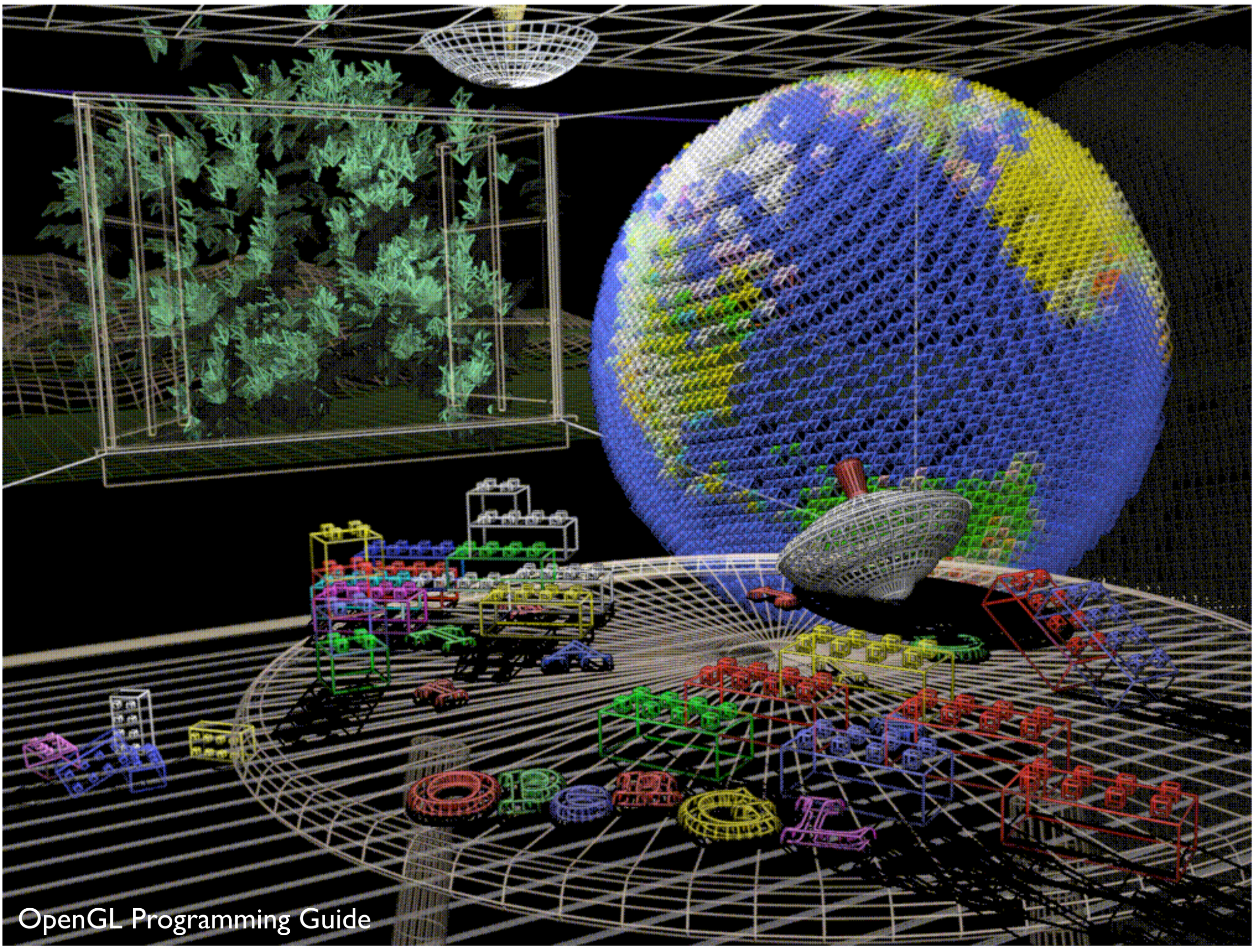


Plate 3. The same scene with **antialiased lines** that **smooth the jagged edge**s. See Chapter 7 .

when you approximate smooth edges using pixels, this leads to jagged lines
especially with near vertical and near horizontal lines

OpenGL Programming Guide

Plate 4. The scene drawn with **flat-shaded polygons** (a **single color for each filled polygon**). See Chapter 5 .

“unlit scene”

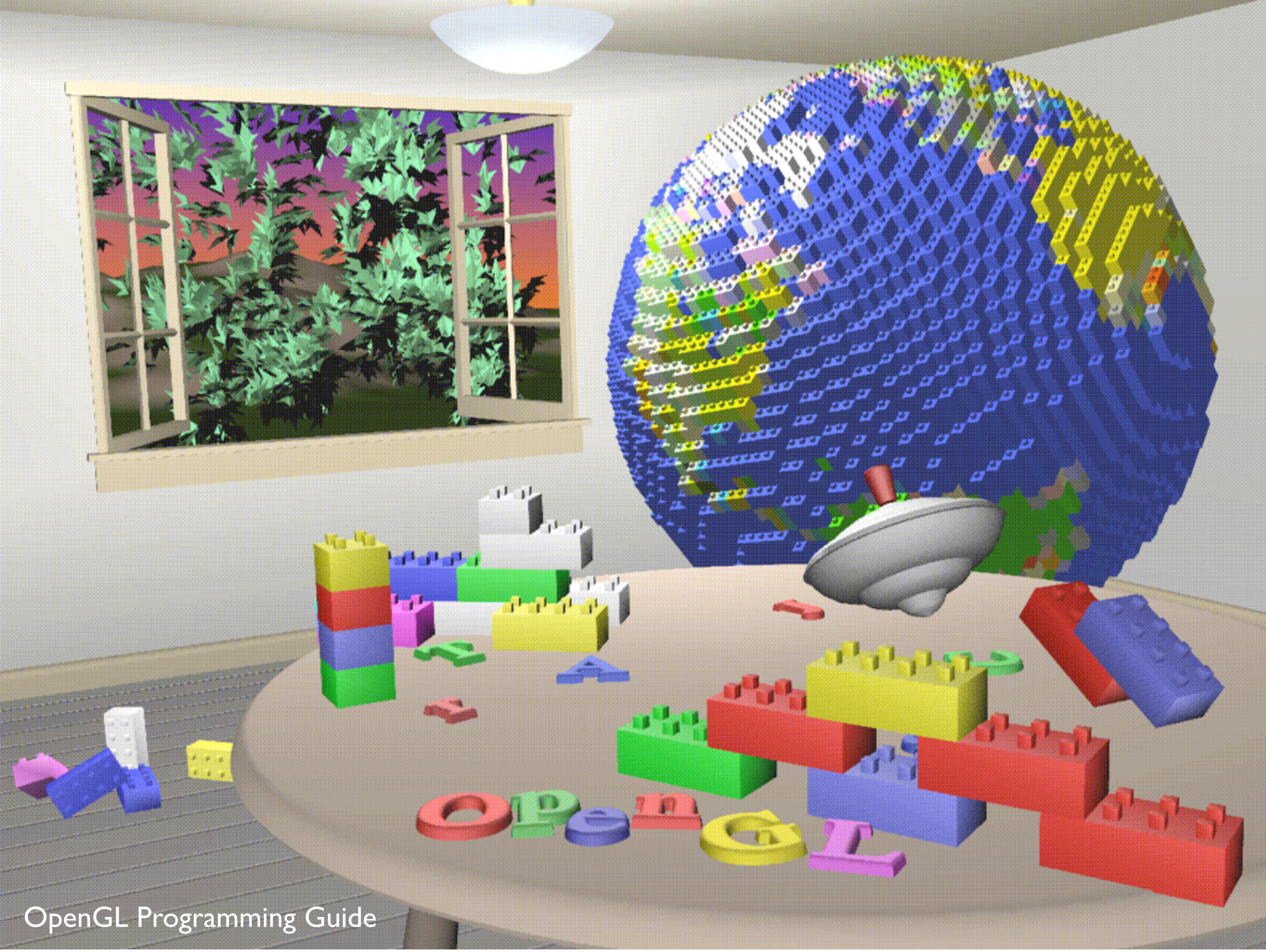


Plate 5. The scene rendered with **lighting** and **smooth-shaded polygons.** See Chapter 5 and Chapter 6 .

Plate 6. The scene with **texture maps and shadows added.** See Chapter 9 and Chapter 13 .

Plate 7. The scene drawn with one of the objects **motion-blurred**. The **accumulation buffer** is used **to compose the sequence of images** needed to blur the moving object. See Chapter 10 .

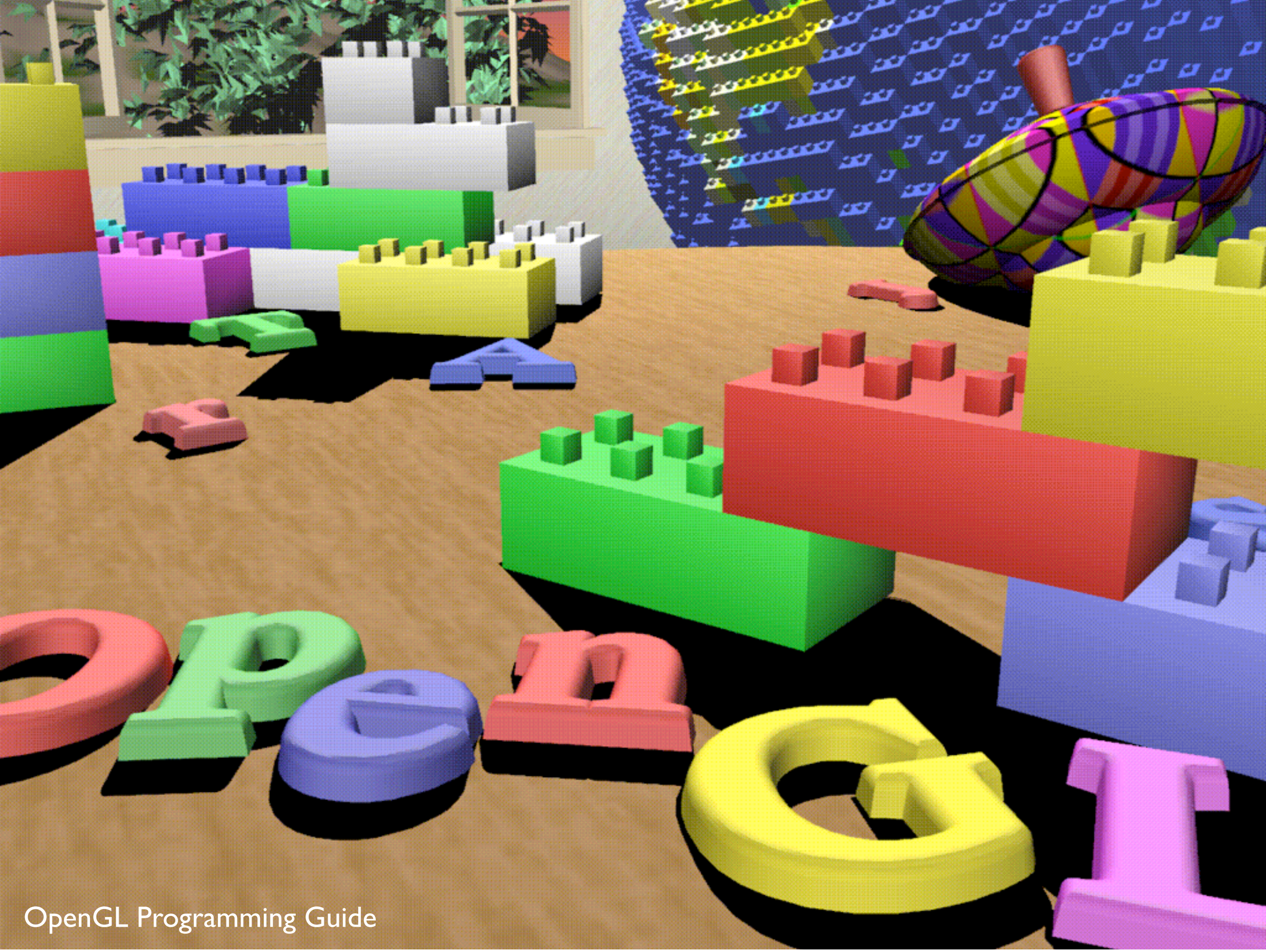


Plate 8. A close-up shot - the scene is **rendered from a new viewpoint.** See Chapter 3 .

OpenGL state machine

- put OpenGL into various states
  - e.g., current color, current viewing transformation
  - these remain in effect until changed
  - glEnable(), glDisable(), glGet(), glIsEnabled()
  - glPushAttrib(), glPopAttrib() to temporarily modify some state

OpenGL command syntax

- commands: **gl**ClearColor();
  - glVertex**3f**()
- constants: **GL**_COLOR_BUFFER_BIT
- types: GLfloat, GLdouble, GLshort, GLint,

Simple OpenGL program

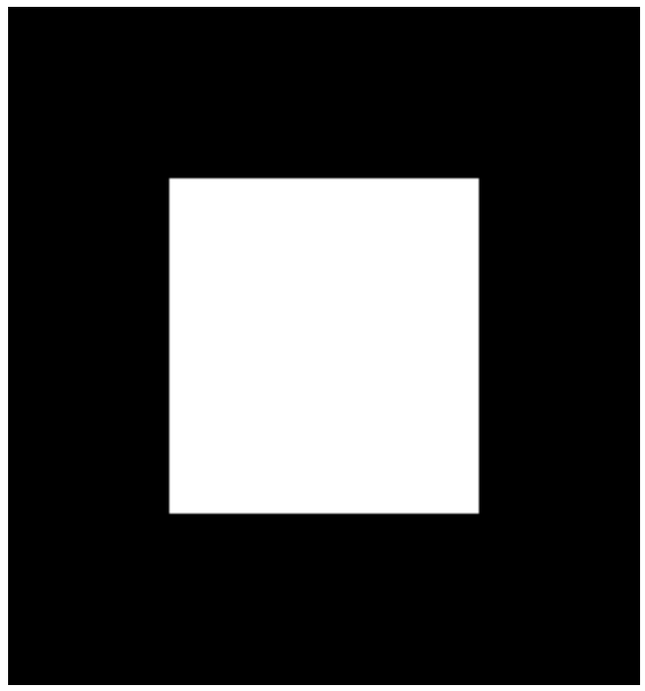
```
#include <whateverYouNeed.h>

main() {

   InitializeAWindowPlease();

   glClearColor(0.0, 0.0, 0.0, 0.0);
   glClear(GL_COLOR_BUFFER_BIT);
   glColor3f(1.0, 1.0, 1.0);
   glOrtho(0.0, 1.0, 0.0, 1.0, -1.0, 1.0);
   glBegin(GL_POLYGON);
      glVertex3f(0.25, 0.25, 0.0);
      glVertex3f(0.75, 0.25, 0.0);
      glVertex3f(0.75, 0.75, 0.0);
      glVertex3f(0.25, 0.75, 0.0);
   glEnd();
   glFlush();

   UpdateTheWindowAndCheckForEvents();
}
```



OpenGL Programming Guide, 7th Ed.

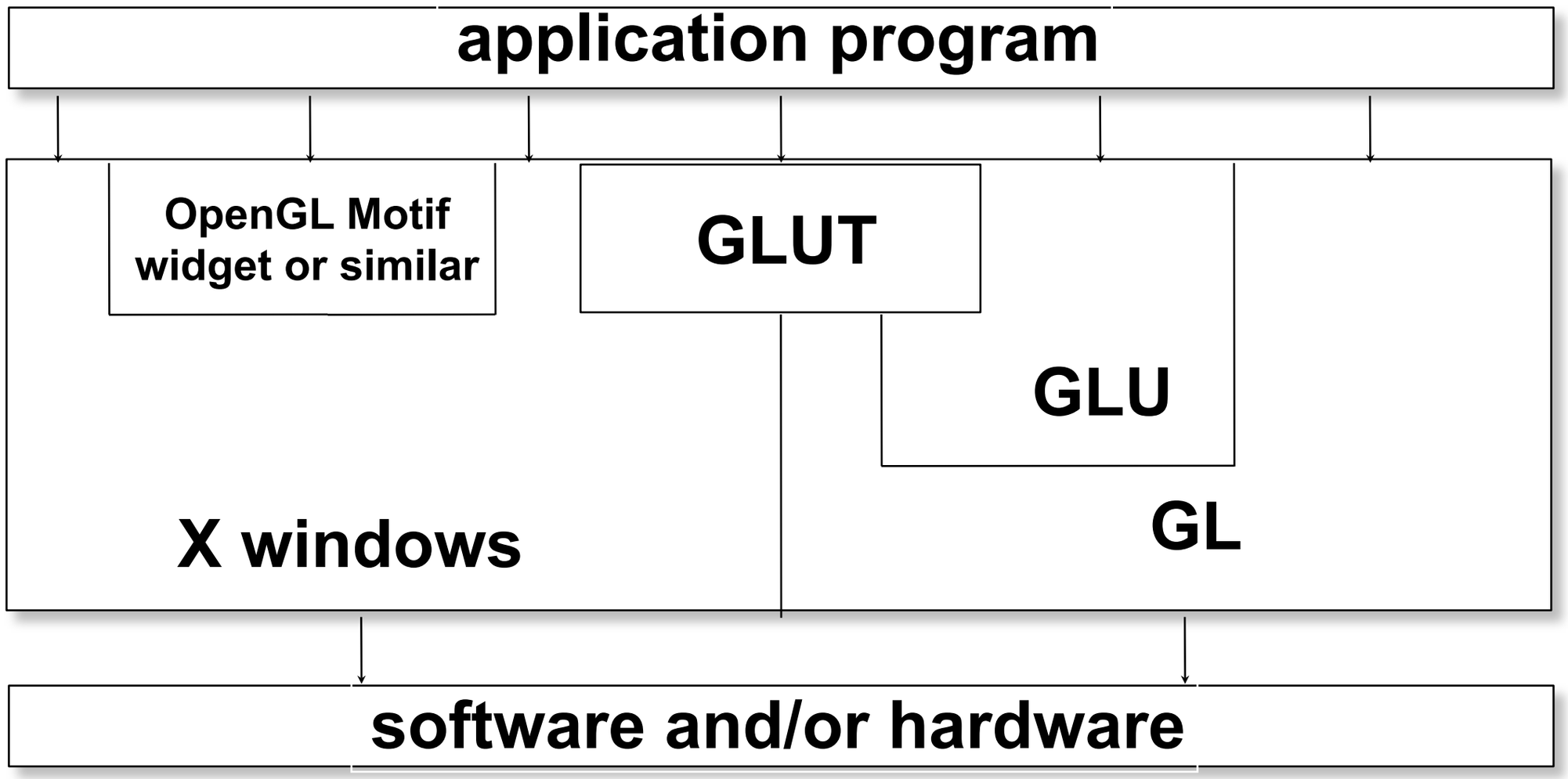
- blue are placeholders for windowing system commands
- clear color, actual clear
- Ortho – the coordinate system
- flush executes the commands

OpenGL Libraries

- OpenGL core library (gl.h)
  - OpenGL32 on Windows
  - GL on most unix/linux systems
- OpenGL Utility Library -GLU (glu.h)
  - avoids having to rewrite code
- OpenGL Utility Toolkit -GLUT (glut.h)
  - Provides functionality such as:
    - Open a window
    - Get input from mouse and keyboard
    - Menus

- GL
  - no windowing commands
  - no commands for higher-level geometry - you build these using primitives (points, lines, polygons)
- GLU - standard in every implementation
- OpenGL Utility library provides modeling support
  - quadratic surfaces, NURBS curves and surfaces

Software Organization



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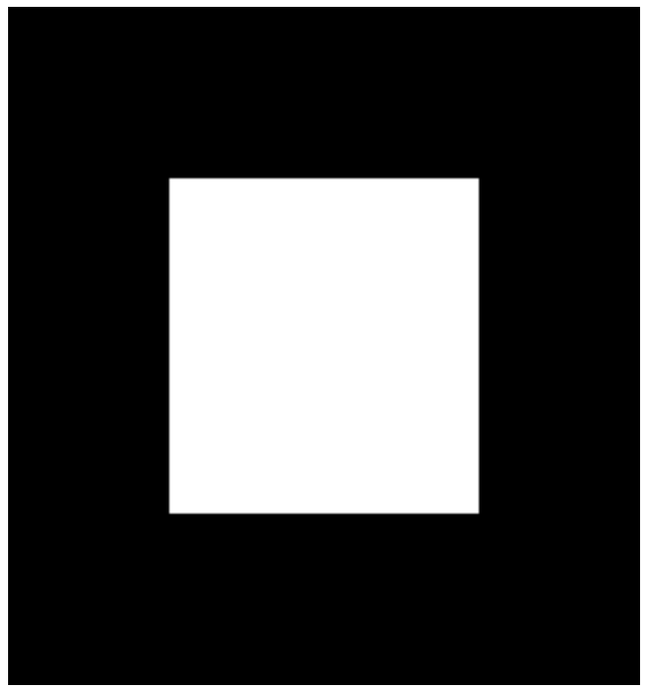
   glClear(GL_COLOR_BUFFER_BIT);
   glColor3f(1.0, 1.0, 1.0);
   glOrtho(0.0, 1.0, 0.0, 1.0, -1.0, 1.0);
   glBegin(GL_POLYGON);
      glVertex3f(0.25, 0.25, 0.0);
      glVertex3f(0.75, 0.25, 0.0);
      glVertex3f(0.75, 0.75, 0.0);
      glVertex3f(0.25, 0.75, 0.0);
   glEnd();
   glFlush();

   UpdateTheWindowAndCheckForEvents();
}
```



OpenGL Programming Guide, 7th Ed.

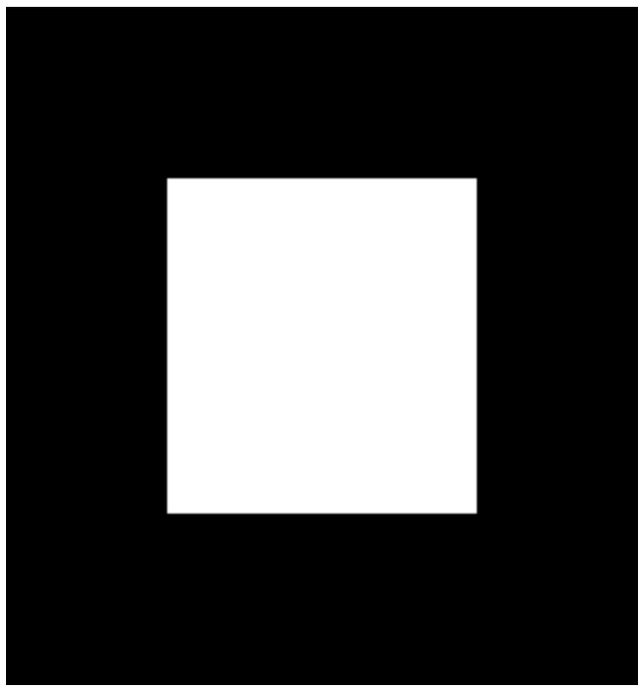
- blue are placeholders for windowing system commands
-can replace blue code with calls to **glut**

Simple OpenGL program

```
#include<GL/glut.h>

void init() {
   glClearColor(0.0, 0.0, 0.0, 0.0);
}

void display() {
   glClear(GL_COLOR_BUFFER_BIT);
   glColor3f(1.0, 1.0, 1.0);
   glOrtho(0.0, 1.0, 0.0, 1.0, -1.0, 1.0);
   glBegin(GL_POLYGON);
      glVertex3f(0.25, 0.25, 0.0);
      glVertex3f(0.75, 0.25, 0.0);
      glVertex3f(0.75, 0.75, 0.0);
      glVertex3f(0.25, 0.75, 0.0);
   glEnd();
   glFlush();
}
main() {
    glutInit(&argc, argv);
    glutInitDisplayMode (GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize (FB_WIDTH, FB_HEIGHT);
    glutCreateWindow ("Test OpenGL Program");
    init();
    glutDisplayFunc(display);
    glutMainLoop();
}
```



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Math Review
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