


CS380: Introduction to Computer Graphics  
Introduction to OpenGLSL

Min H. Kim  
KAIST School of Computing


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## Welcome

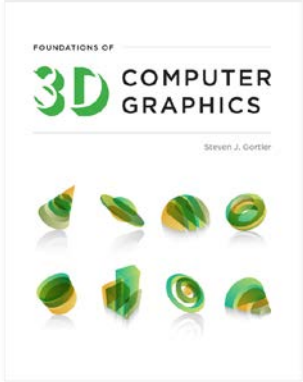
- [CS380] Introduction to Computer Graphics
- Professor: Min H. Kim (김민혁)  
(minhkim@vclab.kaist.ac.kr)
- (Lecture) Wednesday and Friday, 10:30—  
11:45AM, Rm. 114, N-1
- (Lab) Wednesday 19:00–22:00, Rm. 201, N-1
- Course website: <http://vclab.kaist.ac.kr/cs380/>

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## Textbook

- Textbook: Steven J. Gortler (2012)  
Foundations of 3D  
Computer  
Graphics, MIT Press  
(available from the  
KAIST library)
- Harvard CS  
textbook for  
Graphics



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## Tentative Timetable

Week	Date	Lecture	Reading
1	3/4, 3/6	Course Information and Hello World	Appendix A
2	3/11, 3/13	Linear and Affine Transformations	Chapter 2, 3
3	3/18, 3/20	Frames and Respect	Chapter 4, 5
4	3/25, 3/27	HelloWorld 3D and Quaternions	Chapter 6, 7
5	4/1, 4/3	Arcball and Hierarchical Transformations	Chapter 8, 5
6	4/8, 4/10	Skinning and Color	Chapter 19
7	4/15, 4/17	Spline, Interpolation and Animation	Chapter 9, 23
8	4/22	Midterm exam week	-
9	4/29, 5/1	Animation and Geometric Modeling	Chapter 23, 22
10	5/6, 5/8	Subdivision Surface and Projection	Chapter 22, 10
11	5/13, 5/15	Projection and Depth	Chapter 10, 11, 12
12	5/20, 5/22	From vertex to pixels, varying variables	Chapter 12, 13
13	5/27, 5/29	Reconstruction and sampling	Chapter 17, 18
14	6/3, 6/5	Shading and Ray Tracing	Chapter 14, 15
15	6/10, 6/12	Sampling	Chapter 18
16	6/17	Final exam week	-

## Grading



- Class participation: 10%
- Midterm/final exam: 50% (25% each)
- Programming assignments (about 9 HWs): 30%
- Class quizzes: 10%
  
- Unless a President's excuse is received, no assignment will be accepted for credit after its original due date. Plagiarism will not be tolerated by University rules (plagiarism detection software will be used.)

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## Prerequisites



- There are no official course prerequisites.
- **However**, we assume
  - programming experience in C (or C++)
  - a good knowledge of linear algebra
  - an exposure to calculus and image processing

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## Teaching Assistants



- Seung-Hwan Baek
  - PhD Student at VCLAB, ex. 7864
  - [shwbaek@vclab.kaist.ac.kr](mailto:shwbaek@vclab.kaist.ac.kr)
  
- Yeong Beum Lee
  - PhD Student at VCLAB, ex. 7864
  - [yblee@vclab.kaist.ac.kr](mailto:yblee@vclab.kaist.ac.kr)
  
- Joo Ho Lee
  - PhD Student at VCLAB, ex. 7864
  - [jhlee@vclab.kaist.ac.kr](mailto:jhlee@vclab.kaist.ac.kr)



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## Resources



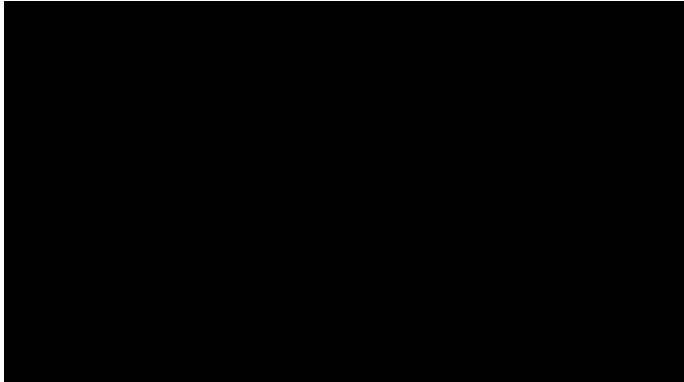
Useful website	Address
Textbook website	<a href="http://www.3dgraphicsfoundations.com/">http://www.3dgraphicsfoundations.com/</a>
LightHouse3D.com	<a href="http://www.lighthouse3d.com/">http://www.lighthouse3d.com/</a>
MIT Press	<a href="http://mitpress.mit.edu/books/foundations-3d-computer-graphics-0">http://mitpress.mit.edu/books/foundations-3d-computer-graphics-0</a>
OpenGL GLEW	<a href="http://glew.sourceforge.net/">http://glew.sourceforge.net/</a>
OpenGL Shade Language	<a href="http://www.opengl.org/documentation/glsl/">http://www.opengl.org/documentation/glsl/</a>

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## What is Computer Graphics?



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## What is Computer Graphics?

- *The Study of Algorithms and Systems for **Generating Images** with Computers*
- Includes the study of:
  - Representation 
  - Interaction 
  - Manipulation 
  - Applications 

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## What is Computer Graphics?

- What computers do ...
  - process, transform, and communicate information
- Aspects of communication
  - Origin (where does the information come from?)
  - Throughput (how frequent?)
  - Latency (how long do I have to wait?)
  - Presentation (what does it look like?)
- Computer Graphics is ...
  - the technology for visually presenting information

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## What is Computer Graphics?

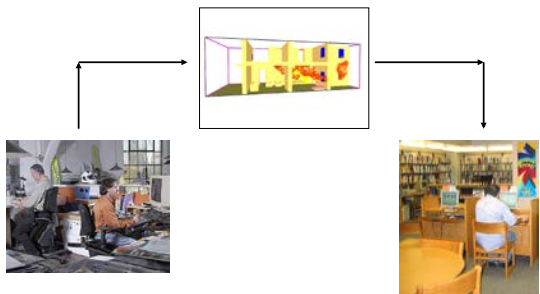
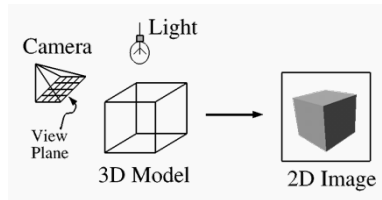


Image Creator: What controls are available?      Image User: How will the image be perceived?

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## What is Computer Graphics?

- **Imaging** = representing 2D images
- **Modeling** = representing 3D objects
- **Rendering** = constructing 2D images from 3D models
- **Animation** = simulating changes over time



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## Research in Computer Graphics

- 2D imaging
  - Digital imaging/filtering
  - Color transformations
  - Display technology
  - Compositing and layering
- 2D drawing
  - Sketching, illustration
  - User interface

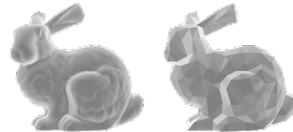
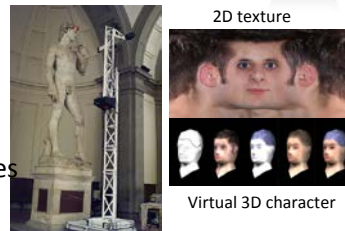


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## Research in Computer Graphics

- 3D modeling
  - Scanning 3D shapes
  - 2D texture mapping
  - Polygons, curved surfaces
  - Procedural modeling



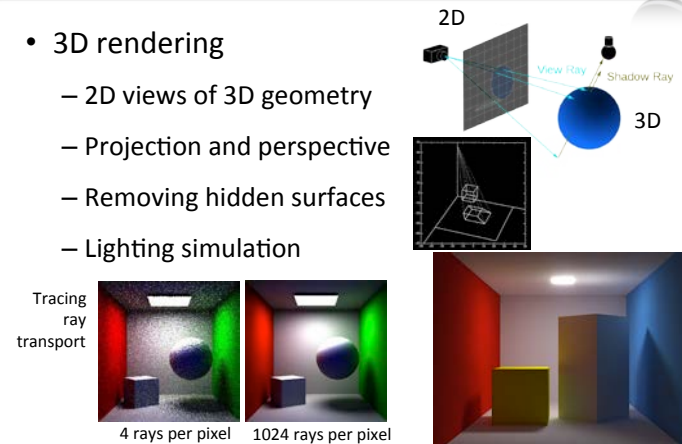
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## Research in Computer Graphics

- 3D rendering
  - 2D views of 3D geometry
  - Projection and perspective
  - Removing hidden surfaces
  - Lighting simulation



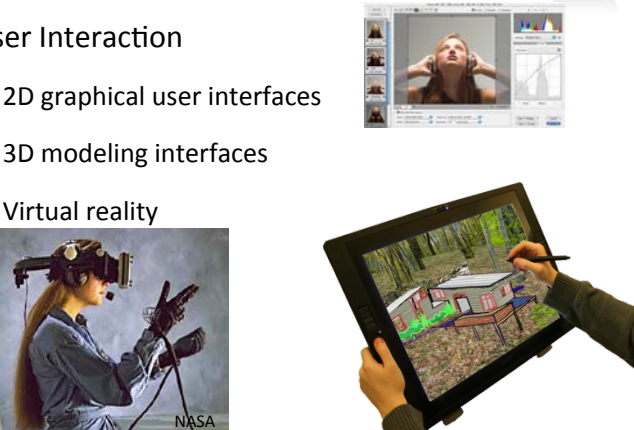
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## Research in Computer Graphics

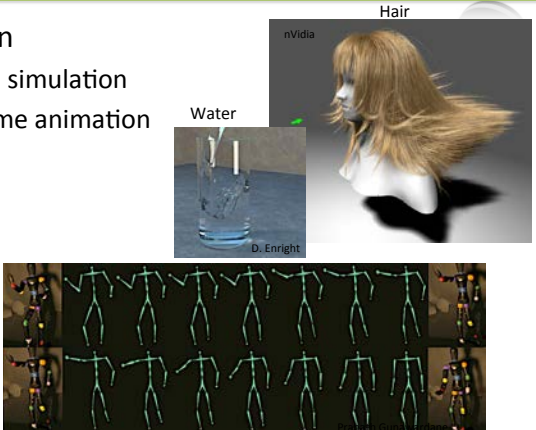
- User Interaction
  - 2D graphical user interfaces
  - 3D modeling interfaces
  - Virtual reality



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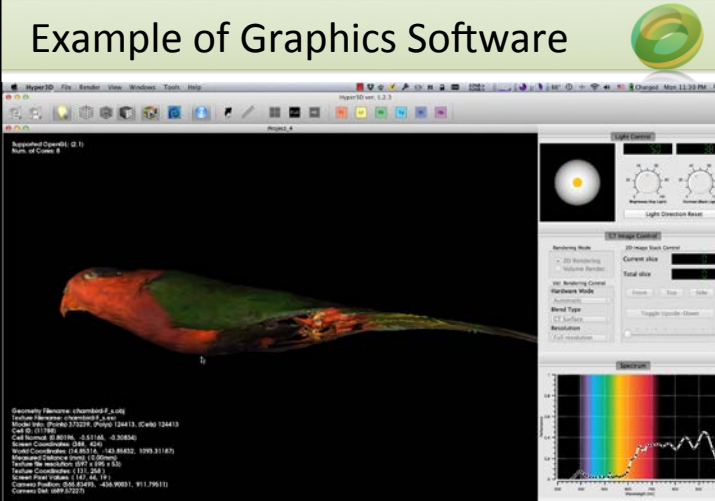
## Research in Computer Graphics

- Animation
  - Physical simulation
  - Key-frame animation



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## Example of Graphics Software



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## Historical Perspective

- A short history of graphics:
  - 1950: MIT Whirlwind (CRT)
  - 1955: Sage, Radar with CRT and light pen
  - 1958: Willy Higinbotham "Tennis for Two"
  - 1960: MIT "Spacewar" on DEC PDP-1
  - 1963: Ivan Sutherland's "Sketchpad" (CAD)
  - 1969: ACM SIGGRAPH founded
  - 1968: Tektronix storage tube (\$5-10,000)
  - 1968: Evans & Sutherland (flight simulators) founded
  - 1968: Douglas Engelbart: computer mouse
  - 1970: Xerox: GUI
  - 1971: Gourand shading
  - 1974: Z-buffer
  - 1975: Phong shading model
  - 1976: First animations rendered
  - 1979: Eurographics founded
  - 1980: Whitted: Ray tracing

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## Historical Perspective

- **A short history of graphics (Cont.):**
  - 1981: Apollo Workstation, IBM PC
  - 1982: Silicon Graphics (SGI) founded
  - 1984: X Window System
  - 1984: First Silicon Graphics Workstations (IRIS GL)
  - Until mid/end of 1990s: Dominance of SGI in the high end
    - HW: Reality Engine, InfiniteReality, RealityMonster, ...
    - SW: OpenGL, OpenInventor, Performer, DigitalMediaLibs, ...
  - End of 1990s: Low- to mid range taken over by “PCs” (Nvidia, ATI, ...)
    - HW: Fast development cycles, Graphics-on-a-chip, ...
    - SW: Direct3D & OpenGL, computergames
  - 1995: First feature film “Toy Story”
  - Today
    - Programmable graphics hardware, Cg, Cuda
    - Realtime Ray Tracing

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## Applications in Computer Graphics

Movies

Games

Computer-Aided Design

Computer-Aided Analysis

Information Visualization

Cultural Heritage

User Interface

Medical Imaging

Simulation Training

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## Applications in Computer Graphics



SEGA - Iron Man 2, 2010

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## Applications in Computer Graphics



Microsoft Studio - Halo 4, 2012

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# Applications in Computer Graphics



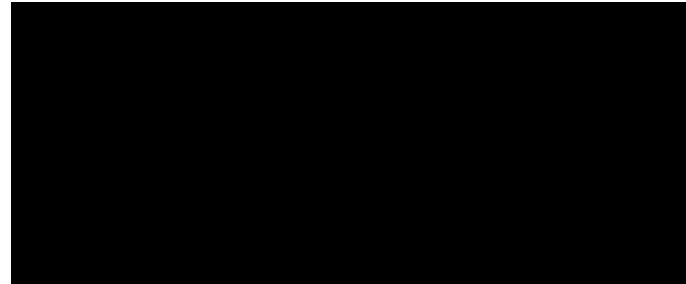
Video courtesy of © 2015 Disney "Big Hero 6"

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# Applications in Computer Graphics



Frozen (2013) © Walt Disney Animation Studios

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# What We Are Doing Underneath

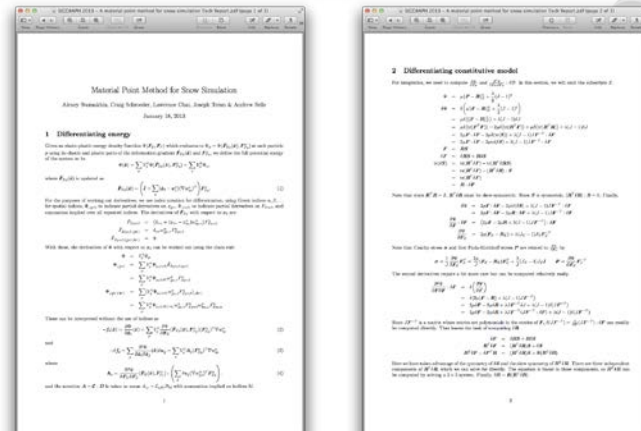


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# What We Are Doing Underneath



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## INTRODUCTION TO OPENGL


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## What is OpenGL?

- OpenGL = Open Graphics Library
- An open industry-standard API for hardware accelerated graphics drawing
- Implemented by graphics-card vendors
- Maintained by the Khronos-Group


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## What is OpenGL?

- Pros & Cons:
  - + Full specification freely available
  - + Everyone can use it
  - + Can use it anywhere (Windows, Linux, Mac, BSD, Mobile phones, Web-pages (soon), ...)
  - + Long-term maintenance for older applications
  - + New functionality usually earlier available through Extensions
  - - Inclusion of Extensions to core may take longer
  - ? Game-Industry

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## Setup OpenGL Project

- Include OpenGL-header:
 

```
#include <GL/gl.h> // basic OpenGL
```
- Link OpenGL-library “opengl32.lib”
- If needed, also link other libraries (esp. GLEW, see later!).

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## OpenGL in more detail

- OpenGL-functions prefixed with “gl”:  
`glFunction{1234}{bsifd...}{v}(T arg1, T arg2, ...);`  
 Example: `glDrawArrays(GL_TRIANGLES, 0, vertexCount);`
- OpenGL-constants prefixed with “GL\_”:  
`GL_SOME_CONSTANT`  
 Example: `GL_TRIANGLES`
- OpenGL-types prefixed with “GL”:  
`GLtype`  
 Example: `GLfloat`

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## OpenGL in more detail

- OpenGL is a **state-machine**
- Remember state-machines:
  - Once a **state** is set, it remains **active** until the state is changed to something else via a **transition**.
  - A **transition** in OpenGL equals a **function-call**.
  - A state in OpenGL is defined by the OpenGL-objects which are current.



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## OpenGL in more detail

- Set OpenGL-states:  
`glEnable(...);`  
`glDisable(...);`  
`gl*(...); // several call depending on purpose`
- Query OpenGL-states with Get-Methods:  
`glGet*(...); // several calls available, depending on what to query`

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## OpenGL 2.1

- Released in August 2006
- Fully supported “fixed function” (FF)
- GLSL-Shaders supported as well
- Mix of FF and shaders was possible, which could get confusing or clumsy quickly in bigger applications
- Supported by all graphics-drivers

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## No-FF in OpenGL 2.1



- If OpenGL 3.x context can not be created on your hardware, one can use 2.1 without the “fixed function”-pipeline:
  - Be sure to use the latest drivers, libs et al. and test if our OpenGL 3.x demo is running!
  - If it doesn’t work out, you can use OpenGL 2.1 w/o FF.
  - This means...

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## No-FF in OpenGL 2.1



- Do NOT use the following in OpenGL 2.1:
  - Built-In matrix-functions/stacks:
    - `glMatrixMode`, `glMult/LoadMatrix`,
    - `glRotate/Translate/Scale`, `glPush/PopMatrix...`
  - Immediate Mode:
    - `glBegin/End`, `glVertex`, `glTexCoords...`
  - Material and Lighting:
    - `glLight`, `glMaterial`, ...
  - Attribute-Stack:
    - `glPush/PopAttrib`, ...
  - some Primitive Modes:
    - `GL_QUAD*`, `GL_POLYGON`

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## No-FF in OpenGL 2.1



- Do NOT use the following in GLSL 1.1/1.2:
  - `ftransform()`
  - All built-in `gl_*`-variables, except:
    - `gl_Position` in vertex-shader
    - `gl_FragColor`, `gl_FragData[]` in fragment-shader
- The list may not be complete!

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## GLEW



- On Windows only OpenGL 1.1 supported natively.
- To use newer OpenGL versions, each additional function, i.e., all extensions (currently ~1900), must be loaded manually!
- → Lots of work! Therefore:
- Use GLEW = OpenGL Extension Wrangler

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## GLEW

- Include it in your program and initialize it:
 

```
#include <GL/glew.h> // include before other GL headers!
// #include <GL/gl.h> included with GLEW already

void initGLEW() {
    GLenum err = glewInit(); // initialize GLEW
    if (err != GLEW_OK) // check for error {
        cout << "GLEW Error: " << glewGetErrorString(err);
        exit(1);
    }
}
```

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## GLEW

- Check for supported OpenGL version:
 

```
if (glewIsSupported("GL_VERSION_3_2")) {
    // OpenGL 3.2 supported on this system
}
```
- To check for a specific extension:
 

```
if (GLEW_ARB_geometry_shader4) {
    // Geometry-Shader supported on this system
}
```

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## GLEW

- How to use:
  - Include GLEW-header:
 

```
#include <GL/glew.h> // GLEW
```
  - Link OpenGL-library “opengl32.lib” and “glew32.lib”
  - Copy “glew32.dll” to bin folder
  - You’re ready to go.

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