Computer Graphics

Anders Hast
Who am I?

- 5 years in Industry after graduation, 2 years as highschool teacher.
- 1996 Teacher, University of Gävle
- 2004 PhD, Computerized Image Processing
  - Computer Graphics
- 2007 Application Expert in Visualisation (UPPMAX)
- 2010 ”Docent”
- 2011 ERCIM Fellow, IIT, CNR, Pisa, Italy
- 2012 Associate Professor, Uppsala University
  - Department of Information Technology
  - MIC building 2, floor 1, room 2112
  - +46 18 - 471 2829
  - www.cb.uu.se/~aht
  - anders.hast@it.uu.se
The others in the Team

- Pontus Olsson
  - Teacher, assisting Johan
  - All laborations, assignments and project
  - Located at Centre for Image Analysis, building 2, Room 2111

- Johan Nysjö
  - Teacher, assisting Pontus
  - All laborations, assignments and project
  - Located at Centre for Image Analysis, building 2 Room 2103
Formalities

- Did you register?
  - www.antagning.se

- 4 Mandatory Assignments

- 1 Exam (3 hours)

- Course book
  - Angel: Interactive Computer Graphics: A top-down approach with OpenGL
What CG?

- It is "concerned with all aspects of producing pictures or images using a computer."
  - E. Angel

- "a branch of computer science", which "has attracted some of the most creative people in the world to its fold. They come from all disciplines- art, science, music, dance, film making and many others"
  - Foley et. al
What can it be used for?

- Display of information
  - Visualisations etc...
- Interfaces
  - Computers
  - Cell Phones
  - Hand held devices
- Entertainment
  - Games
  - Films
Graphics in Movies

- TRON
  - First 3D shaded graphics in a Hollywood film
Special Effects

- 1983 ILM computer graphics division develops "Genesis effect" for Star Trek II - The Wrath of Khan

[Video Link: http://www.youtube.com/watch?v=QXbWCrzWJo4]
Many Areas make use of it

- Visualisation
- Image Processing
- Computer Vision
- Scientific Visualisation
- Cartography
- GIS
- CAD
- Special Effects (Film)
Visualisation

- **2D**
  - Charts and Diagrams

- **3D**
  - Volumes
  - Polygon Models
Image Processing

- Extracts information from images or volumes
- Produces
  - 2D Images
  - 3D objects
- Haptics
Computer Vision

- Feature Matching
- Tracking
- 3D Reconstruction
Cartography

- 2D
- 3D
GIS

- Combining
  - Maps
  - Information
CAD

- Computer Aided Design
Special Effects

- Special effects often needs special tools
  - Because they are special effects!
  - Therefore it was necessary to create this tool from scratch
What we will Learn

- How lines are drawn, surfaces painted, etc
- How to use graphic function libraries (OpenGL)
- How to give 3D impression on a 2D display
- Create 3D model worlds and display them
- What colour, resolution etc means in an Image
- In what order things are done (graphics pipeline)
- How to program graphics hardware shaders

These things will be covered in 3 practicals (labbar) and one Project
What YOU are expected to know already:

- C or C++
- Data structures (arrays, linked lists)
- Geometry
- Linear algebra (matrices)

- You are responsible for your studies - lecture notes is only a part of the whole
Course Syllabus (outcomes)

- describe the data flow in a graphics rendering system;
- use matrix algebra in computer graphics applications;
- implement fundamental algorithms and transformations involved in viewing models, projection models, illumination models and the handling of hidden surfaces in polygon-based computer graphics;
- describe effects such as texture mapping, bump mapping and antialiasing;
- describe curves and surfaces that can be represented by splines;
- use the OpenGL API with C++ in 3D graphics programming;
- program GPU hardware, so called shader programming;
Contents (Syllabus)

Evaluation of last years course

- Students were very pleased with last years course :)  
  - Interesting & inspiring!
- However, they thought there was too little time to do the last lab
- However that lab is a project  
  - It’s a 10hp Course after all...
Images

- **Spatial Resolution**
  - A modern computer display (1980x1080) pixels
  - Pixel = Picture Element

- **Colour Depth**
  - The number of bits used to represent the colour of a single pixel
  - True Colour 24 bit (8 bit per colour channel)
  - 3 Colour Channels: R,G,B
Raster Graphics

- Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*
# History

**70’s**
- University of Utah
  - Sutherland, Blinn, Phong, Guoraud, Catmull, Newell (the teapot) and others.
- The fundamentals of CG

**80’s**
- Graphical User Interfaces
  - Macintosh, Amiga
- Graphics in Movies
History

- 90’s
  - Image Based Rendering
  - Toy Story
  - Special Effects

- 00’s
  - GPU’s

- 10’s
  - Fusion with Image Processing and Computer Vision

http://www.youtube.com/watch?v=RPV1Dqo_RWE
Some things you will learn

- Transformations
- Shading
- Illumination
- Mapping
- Graphics Pipeline
Transformations

- Affine

\[ T = \begin{bmatrix} 1 & 0 & 0 & \alpha_x \\ 0 & 1 & 0 & \alpha_y \\ 0 & 0 & 1 & \alpha_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \]

\[ R_z = R_z(\theta) = \begin{bmatrix} \cos \theta & -\sin \theta & 0 & 0 \\ \sin \theta & \cos \theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \]

\[ S = \begin{bmatrix} \beta_x & 0 & 0 & 0 \\ 0 & \beta_y & 0 & 0 \\ 0 & 0 & \beta_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \]
Shading

- Gouraud
- Phong
Illumination

- The Phong Illumination Equation

\[ I = \frac{1}{a + bd + cd^2} (K_a L_a + K_d L_d \max(N \cdot L, 0) + K_s L_s (R \cdot V)^\alpha) \]
Mapping Techniques

- Texture mapping
- Bump mapping
- Environment mapping
- Geometry mapping
- Normal mapping
Graphics Pipeline

- The input is the objects and its vertices
- The output are pixels on the screen
- Performs
  - Transformations
  - Clipping
  - Shading and illumination
  - Texturing, etc
Splines

- The Utah Teapot is made by Bezier Splines

![Diagram of Bezier Splines with points labeled P0, P1, P2, and P3. The curve is parameterized by P(t). A teapot image is also shown.]
OpenGL

- stands for Open Graphics Library.
- It is a specification of an API for rendering graphics, usually in 3D.
- OpenGL implementations are libraries that implement the API defined by the specification.
- Graphics cards usually have an OpenGL implementation.
- Because the OpenGL specification is not platform-specific, it is possible to write an application that will be possible to use against many different types of graphics cards.
- It also increases the chance that the application will continue to work when new hardware will become available.

http://www.opengl.org/wiki/FAQ
What is it?

- OpenGL is an open specification.
- Latest version 4.3 (2012)
- describes the interface the programmer uses and expected behavior.
- There is an implementation of GL that is Open Source and it is called Mesa3D [http://www.mesa3d.org](http://www.mesa3d.org)
- Its announcing itself as [OpenGL 2.1](http://www.opengl.org) compliant.
Coordinate System

- The negative Z-axis is in front of you
Code Example

- A Triangle
  - 3 coordinates (float)

```c
glBegin(GL_TRIANGLES);
    glVertex3f(-1.0f, -0.5f, -4.0f);
    glVertex3f( 1.0f, -0.5f, -4.0f);
    glVertex3f( 0.0f,  0.5f, -4.0f);
glEnd();
```

- Note the API-calls!
More Pimitives

- GL_POINTS
- GL_LINES
- GL_LINE_STRIP
- GL_LINE_LOOP
- GL_TRIANGLES
- GL_TRIANGLE_STRIP
- GL_TRIANGLE_FAN
- GL_QUADS
- GL_QUAD_STRIP
- GL_POLYGON
OpenGL

- 2D Graphics
- 3D Graphics
- Shading & Illumination
- Projections
- Clipping
- Texture Mapping
- And a lot more!
Programmable Shaders

- OpenGL in software is relatively slow
  - Phong shading is not supported (was invented in the mid 70’s!!)
- Phong Shading is easy to implement using shaders
- Shaders are FAST!
The End

- Remember to Study the chapters in the textbook
- Prepare for practicals
- Play arround with OpenGL!
  - Make your own Game!?