CPSC 314
Computer Graphics

Wolfgang Heidrich

People

Instructor:
- Wolfgang Heidrich

TA(s):
- Bradley Atcheson

Course Organization

Components:
- Lectures
- Homework problems
- Labs
- Programming assignments (3+1)
- Quizzes (2)
- Final

Required skills:
- Assignments: demanding programming problems
- Exams: math heavy, lots of linear algebra, some calculus, algorithms

Course Organization

Grades and Grading
- Programming assignments: 35% (10% each)
  - *5% for assignment 0*
- Quizzes: 25%
  - *(10% for first quiz)*
- Final: 40%

Homework problems
- NOT graded
- BUT: essential preparation for quizzes/final
- Solutions discussed in lab sessions

Course Organization

Programming assignments:
- C++, Windows or Linux
- OpenGL graphics library / GLUT for user interface
- Labs: ICICS 011
  - *Linux machines*
  - *All assignments need to run on these machines*

Collaboration policy:
- No collaboration on programming assignments
- Reference all external resources

Course Organization

Up-to-date information:
- http://www.ugrad.cs.ubc.ca/~cs314
- WebCT (follow link from course home page)
  - *Bulletin board*
  - *Reporting of grades*

Books

Textbook:

- Shirley: Fundamentals of Computer Graphics, 2nd edition, AK Peters
  - *Recommended, but not required*
  - *We are not going to follow this text very closely*

Other Books:

- Foley, vanDam, Feiner, Hughes: Computer Graphics, Principles and Practice
  2nd Edition in C, Addison Wesley
- Woo, Neider: OpenGL Programming Guide Version 1.2, Addison Wesley
  - *This one is online: see course page*

Learning OpenGL

This is a graphics course using OpenGL

- Not a course on OpenGL

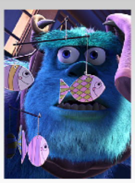
Learning API mostly on your own

- Only minimal lecture coverage
  - *Basics, some of the tricky bits*
- Also: ask in the labs
- OpenGL Red Book
- many tutorial sites on the web
  - *nehe.gamedev.net*

What is Computer Graphics?

Create or manipulate images with computer

- this course: algorithms for image generation

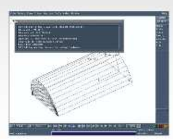


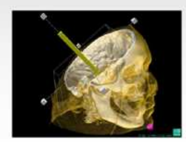
What is CG used for?

Graphical user interfaces

- Modeling systems
- Applications

Simulation & visualization

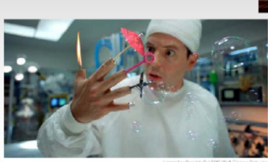




What is CG used for?

Movies

- Animation
- Special effects



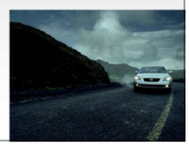
What is CG used for?

Computer games

What is CG used for?

Images

- Design
- Advertising
- Art



Real or CG?

http://www.autodesk.com/eng/etc/fakeorfoto/quiz.html

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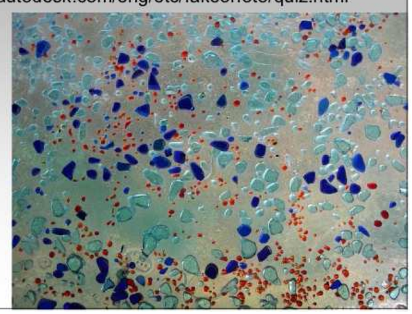


Real or CG?

http://www.autodesk.com/eng/etc/fakeorfoto/quiz.html

Real!

What This Course Is About

Topics covered

- Fundamental algorithms of computer graphics
- Interactive graphics:
  - *The rendering pipeline*
    - Abstract model for the functioning of graphics hardware and interactive graphics systems
  - *Color spaces and reflection models*
  - *Shadow algorithms*
- Ray-tracing
- (Global illumination)

What This Course is NOT About

Topics NOT covered:
- Artistic and design issues
- Usage of commercial software packages
- Applications (i.e. game design)

Topics covered with little detail:
- Animation, Geometric Modeling
  - *These have separate undergrad classes*
  - *CPSC 424 (Geometric Modeling) next year*

Syllabus

Overview

The Rendering Pipeline (1)
- Geometry transformations, linear, affine, and perspective transformations
- Lighting/illumination
- Clipping of lines and polygons
- Vertex arrays, triangle strips, display lists

Syllabus

The Rendering Pipeline (2)
- Scan conversion of lines and polygons
- Shading and interpolation
- Texture mapping

The Rendering Pipeline (3)
- Modern hardware features
- Vertex shaders / register combiners etc.

Syllabus

Color and reflection
- Color spaces and tristimulus theory
- Physical reflection models

Shadow Algorithms
- Shadow volumes and shadow maps

Ray-tracing

(Global illumination)
- Only if there is time

The Rendering Pipeline – An Overview

Wolfgang Heidrich

3D Graphics

Modeling:
- Representing object properties
  - *Geometry: polygons, smooth surfaces etc.*
  - *Materials: reflection models etc.*

Rendering:
- Generation of images from models
  - *Interactive rendering*
  - *Ray-tracing*

Animation:
- Making geometric models move and deform

Rendering

Goal:
- Transform computer models into images
- May or may not be photo-realistic

Interactive rendering:
- Fast, but until recently low quality
- Roughly follows a fixed patterns of operations
  - ➢ Rendering Pipeline

Offline rendering:
- Ray-tracing
- Global illumination

Rendering

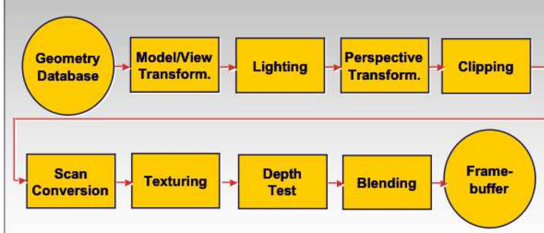
Tasks that need to be performed (in no particular order):
- Project all 3D geometry onto the image plane
  - *Geometric transformations*
- Determine which primitives or parts of primitives are visible
  - *Hidden surface removal*
- Determine which pixels a geometric primitive covers
  - *Scan conversion*
- Compute the color of every visible surface point
  - *Lighting, shading, texture mapping*

The Rendering Pipeline

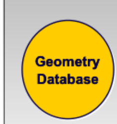
What is it? All of this:
- Abstract model for sequence of operations to transform a geometric model into a digital image
- An abstraction of the way graphics hardware works
- The underlying model for application programming interfaces (APIs) that allow the programming of graphics hardware
  - *OpenGL*
  - *Direct 3D*

Actual implementations of the rendering pipeline will vary in the details

The Rendering Pipeline

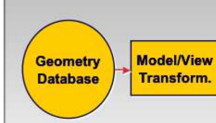


The Rendering Pipeline
Geometry Database



Geometry database:
- Application-specific data structure for holding geometric information
- Depends on specific needs of application
  - – *Independent triangles, connectivity information etc.*

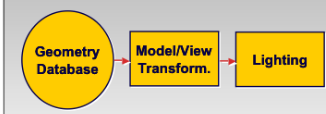
The Rendering Pipeline
Model/View Transformation



Modeling transformation:
- Map all geometric objects from a local coordinate system into a world coordinate system

Viewing transformation:
- Map all geometry from world coordinates into camera coordinates

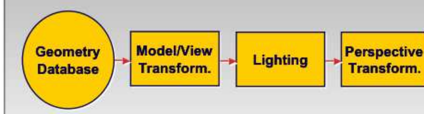
The Rendering Pipeline
Lighting



Lighting:

- Compute the brightness of every point based on its material properties (e.g. Lambertian diffuse) and the light position(s)

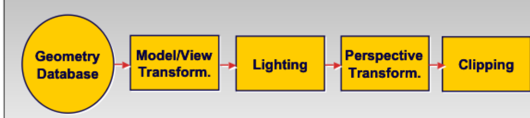
The Rendering Pipeline
Perspective Transformation



Perspective transformation

- Projecting the geometry onto the image plane
- Projective transformations and model/view transformations can all be expressed with 4x4 matrix operations

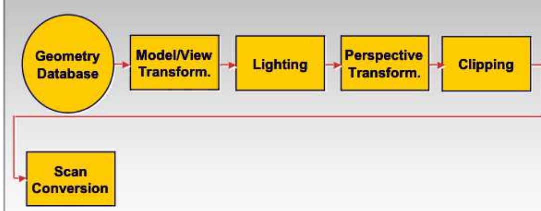
The Rendering Pipeline
Clipping



Clipping

- Removal of parts of the geometry that fall outside the visible screen or window region
- May require *re-tessellation* of geometry

The Rendering Pipeline
Scan Conversion

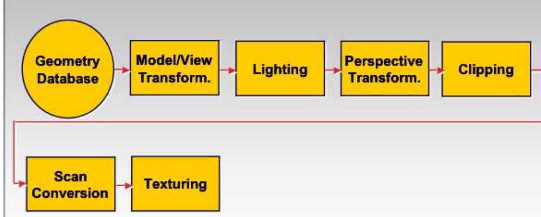


The Rendering Pipeline
Scan Conversion

Scan conversion

- Turning 2D drawing primitives (lines, polygons etc.) into individual pixels (*discretizing/sampling*)
- Interpolation of colors across the geometric primitive
- This yields a *fragment* (pixel data associated with a particular location in the final image and color values, depth, and some additional information)

The Rendering Pipeline
Texture Mapping

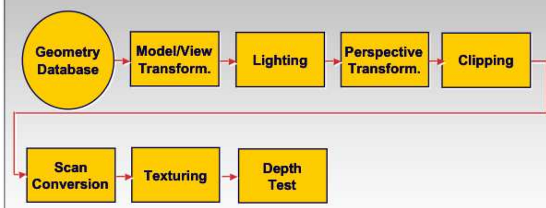


The Rendering Pipeline
Texture Mapping

Texture mapping

- "gluing images onto geometry"
- The color of every fragment is altered by looking up a new color value from an image

The Rendering Pipeline
Depth Test

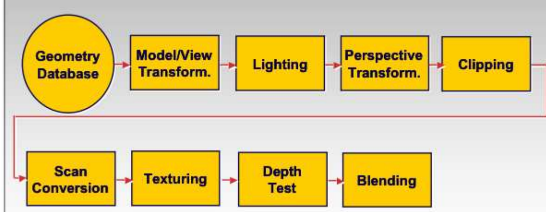


The Rendering Pipeline
Depth Test

Depth test:

- Removes parts of the geometry that are hidden behind other geometry
- Test is performed on every individual fragment
  - *we will also discuss other approaches later*

The Rendering Pipeline
Blending

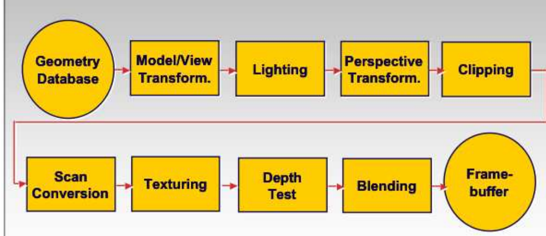


The Rendering Pipeline
Blending

Blending:

- Fragments are written to pixels in the final image
- Rather than simply replacing the previous color value, the new and the old value can be combined with some arithmetic operations (blending)
- The video memory on the graphics board that holds the resulting image and is used to display it is called the *framebuffer*

The Rendering Pipeline



Discussion

Advantages of a pipeline structure

- Logical separation of the different components, modularity
- Easy to parallelize:
  - *Earlier stages can already work on new data while later stages still work with previous data*
  - *Similar to pipelining in modern CPUs*
  - *But much more aggressive parallelization possible (special purpose hardware!)*
  - *Important for hardware implementations!*
- Only local knowledge of the scene is necessary

Discussion

Disadvantages:

- Limited flexibility
- Some algorithms would require different ordering of pipeline stages
  - *Hard to achieve while still preserving compatibility*
- Only local knowledge of scene is available
  - *Shadows*
  - *Global illumination*

Coming Up…

Tuesday, Sep 11:

- More details on the on the rendering pipeline

Thursday, Sep 13:

- Geometric transformations