CS 433/433H, 533

Instructor: Kobus Barnard
TA: Leonard Brown

Plan for today
- What is graphics? Why study it?
- Syllabus issues
- Math warm up

Why graphics?

- Presenting an alternative world
- Visual interfaces
- Enhancing our view of the existing world (visualization)

Presenting an alternative world

- For training
  - Landing expensive aircraft
- For amusement
  - Games; movies
- For aesthetic pleasure
  - Computer art
- For understanding
  - Visualize data sets in an accessible way

Interaction

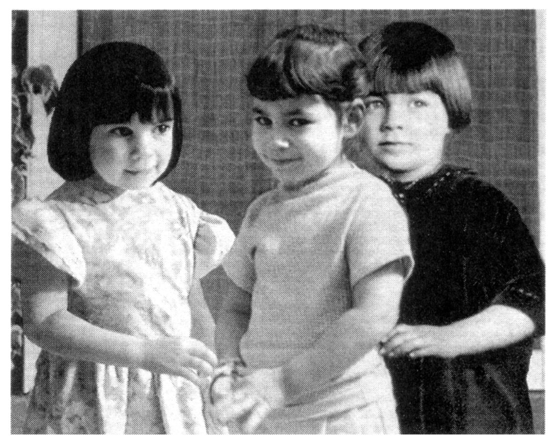
- Key to the games industry
- Key to most current user interfaces
- Idea dates back to ‘55, at least
- Sketchpad was the first interactive graphics system where user could manipulate what is displayed (‘63 thesis, Ivan Sutherland)

Sketchpad, c 1955, from Spalter

SAGE - aircraft target selection - 1958, from Spalter

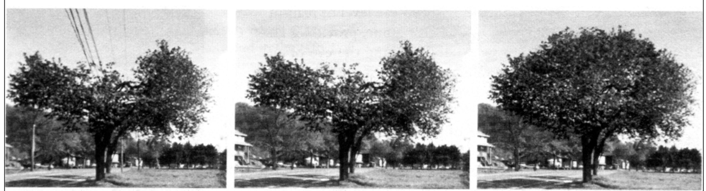
Computer Art

- 2D graphics to create and manipulate images
  - Image editing and composition tools
  - Computer paint programs
  - User interfaces are improving - pressure sensitive tablets, etc.
- 3D virtual reality for new ways of expression



Me, My Mom and My Girl at Three, 1992, Michele Turre

You Wish, from Tree Fix, 1997, Michele Turre



Enhancing the existing world

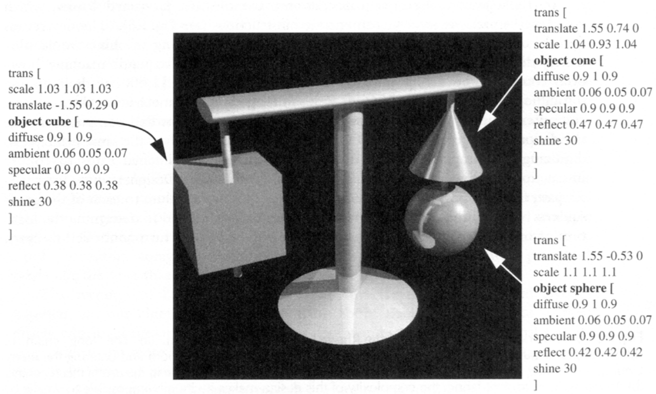
- Mix models with the real world
  - Movies!
- Allow operation planning
  - Neurosurgery
  - Plastic surgery
- Add information to a surgeons view to improve operation
  - Neurosurgery

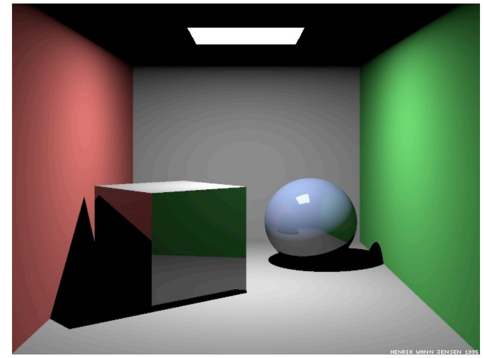
From Eric Grimson's research group at MIT

What is graphics?

- Mathematical model of world --> images
- Main technical activities are **modeling the world** and **rendering**
- Modeling may either be in support of artists/actors who provide the content, and/or, physics based models to make things look real.

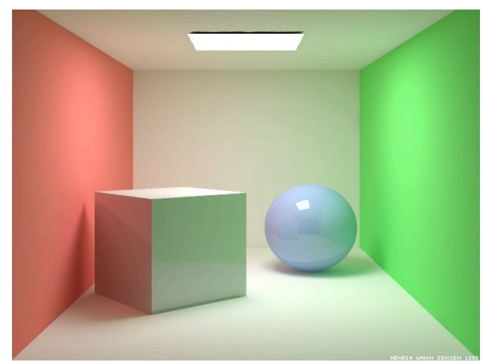
Rendering takes a model to a picture





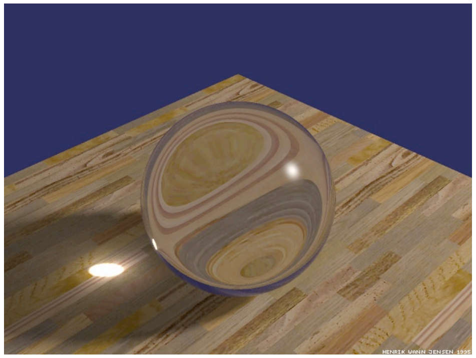
Ray-traced Cornell box, due to Henrik Jensen,
http://www.gk.dtu.dk/~hwj

Ray-traced snowmen, due to David Forrester,
CS433, Fall 2005



Radiosity Cornell box, due to Henrik Jensen,
http://www.gk.dtu.dk/~hwj, rendered with ray tracer

Refraction caustic



Henrik Jensen, http://www.gk.dtu.dk/~hwj

More examples

Selected images from hof.povray.org

Course Outline

(not exactly in order!)

- Intro (1 week)
  - Math warm up
  - OpenGL intro
- Rendering (6 weeks)
  - Proceeding from a geometrical model to an image Involves understanding
    - Displays
    - Geometry
    - Cameras
    - Visibility
    - Illumination
  - Technologies
    - the rendering pipeline
    - ray tracing
- Modeling (2 weeks)
  - Producing a geometrical, or other kind of model that can be rendered.
  - Involves understanding
    - Yet more geometry
    - A little calculus
- Misc (2 weeks)
  - colour
  - animation
  - advanced rendering
- Exam, review, guest, etc (2 week, equivalent)

What is this course really like?

The course targets **fundamentals**. It is not about any particular "API". I will introduce OpenGL in the first week, but it is **not** an OpenGL course.

The assignments are relatively substantive.

Many of the concepts will be expressed mathematically.

Syllabus Issues

Other than passwords, everything that you need to know should be available at:

www.cs.arizona.edu/classes/433/fall07

Instructor

Instructor: Kobus Barnard

Email: kobus @ cs

Please put CS433 in the subject line
Mail will likely be bounced to TA

Web: kobus.ca (link to class under teaching)

Office: GS 927

Office hours*

By electronic sign up: kobus.ca/calendar

Tuesday	1:00 to 1:30	and	5:00 to 5:30
Thursday	1:00 to 1:30	and	5:00 to 5:30
Friday	4:00 to 4:30		

Office hours not subscribed 24 hours in advance are subject to cancellation

Calendar access off campus
login: me
pw: pw4cal

To make an appointment
login: public
pw: meetkobus

*Please give the TA a chance before seeing me on technical issues.

Teaching Assistant

TA: Leonard Brown

Email: ldbrown @ cs

Office Hours: MW 12:30 -- 1:30

Office Location: Gould Simpson 710-B

Notes

Notes will be distributed in “chunks”.

Notes will have some missing “answers” identified by a “?” for you to think about and/or fill in as we go along.

After each lecture, the part that was actually covered that day will be put on line (with the “answers”).

Text

Hearn and Baker (optional)

What you need to know is in the notes. However the above text provides a different view with a relatively friendly style.

See on-line syllabus for additional recommended books.

Web Pages

Web page: www.cs.arizona.edu/classes/433/fall07

For remote access to restricted items (slides, assignments):
login: me
pw: graphics4fun

Grading, etc.

Assignments (70%)
Quizzes (10%) (Best 2 out of 3)
Final (20%)

Projects can be substituted for assignments (with permission).

Grad students will have **extra** assignment parts and will have to do more of the exam for the same grade.

Honors students need to do 4 grad student parts (or project).

Grading, etc.

Assignments (70%)
Quizzes (10%) (Best 2 out of 3)
Final (20%)

Assignments need to be done individually (no teams).

Late policy (10% off per day until 5 days late, then 0)

We will check assignments for duplication

Extra Credit

For those that cannot get enough of a good thing:

The TA will give modest extra credit (up to a max of 10%)

The **maximum** credit for all assignments combined is 75/70

Warning: The "base" assignments are already time consuming. Extra parts are not expected. Extra credit is NOT a good way to attempt to improve your GPA. Bonus marks exists so that the TA can acknowledge extra work and innovation.

Platforms and Languages

Programs must be in C/C++ for linux.

If you develop on windows, you must check that your code compiles and runs on linux.

Computer Resources

Please do "Apply"--it is needed for CAT card access to graphics lab.

Graphics "lab" (Eight linux machines in GS 920)

I need your E-mail--check it on the list; if you are not on the list because your paperwork has not yet percolated through the system, add your name and E-mail at the bottom of the list.

Math Prerequisites

We will develop mathematical ideas as we go, but solid understanding requires at least one of the following

- The prerequisites
- Extra studying
- Good overall math background and/or aptitude

You are responsible for making up any deficiencies in your preparation

Quick Math Review

We will discuss the underlying math further as it comes up. Today we "warm up" and give a flavour.

Math topics relevant to this course:

Geometry, especially cartesian geometry
(equations for lines, planes, circles, etc)
Linear Algebra
(Matrix representation of transformations)
Calculus
(Fit smooth curves through points; sampling)

Quick Math Review

Usual 2D and 3D Euclidian geometry
(Will also use 4D vectors, no difference in linear algebra)

Cartesian coordinates--algebraic representation of points in 2D space (x,y), and 3D space (x,y,z)

Somewhat interchangeably, the point represents a **vector** from the origin to that point.

A vector is used to define either a direction in space, or a specific location relative to the origin.

Basic Vector Operations (**must know**)

Let $\mathbf{X} = (x_1, x_2, x_3) \quad and \quad \mathbf{Y} = (y_1, y_2, y_3)$

Sum $\mathbf{X}+\mathbf{Y} = (x_1 + y_1,\ x_2 + y_2,\ x_3 + y_3)$

Difference $\mathbf{X}-\mathbf{Y} = (x_1 - y_1,\ x_2 - y_2,\ x_3 - y_3)$

Scale $a\mathbf{X} = (x_1, x_2, x_3) = (ax_1, ax_2, ax_3)$

Magnitude $|\mathbf{X}| = \sqrt{x_1^2 + x_2^2 + x_3^2}$

Representations for lines and segments

Cartesian representation

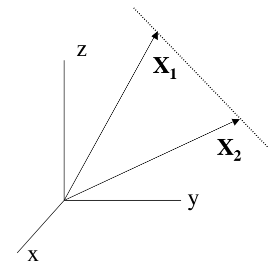
$$m = \frac{y_1 - y_0}{x_1 - x_0} = \frac{y - y_o}{x - x_o} \quad \Rightarrow \quad y = mx + b$$

Analogous formula for a line in 3D?

None really. The analogous 3D formula is a plane. You can get a line by intersecting two of them, but this is not what you want to do in practice!

Representations for lines and segments

Vector representation



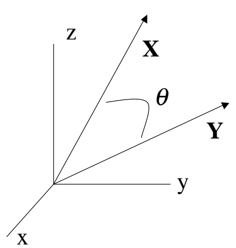
$$t\mathbf{X_1} + (1-t)\mathbf{X_2}$$

Works in any dimension

Simplifies representing *segments*

More Vector Operations

Dot Product (any number of dimensions)

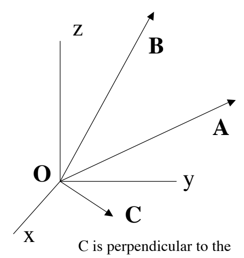


$$\mathbf{X} \bullet \mathbf{Y} = (x_1 y_1 + x_2 y_2 + x_3 y_3)$$
$$= |\mathbf{X}||\mathbf{Y}|\cos\theta$$

Orthogonal $\Leftrightarrow$ $\mathbf{X} \bullet \mathbf{Y} = 0$

More Vector Operations

Vector (cross) product (3D)



C is perpendicular to the plane that contains O, A, B

$\mathbf{C} = \mathbf{A} \times \mathbf{B}$

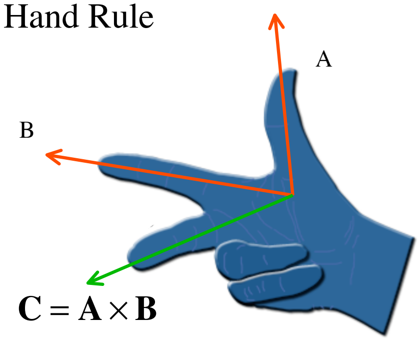
$\mathbf{C} \perp \mathbf{A}$ *and* $\mathbf{C} \perp \mathbf{B}$

C points in the direction given by the right hand rule

$|\mathbf{C}| = |\mathbf{A}||\mathbf{B}|\sin\theta$

$$\begin{pmatrix} \mathbf{C_x} \\ \mathbf{C_y} \\ \mathbf{C_z} \end{pmatrix} = \begin{pmatrix} \mathbf{A_y B_z} - \mathbf{A_z B_y} \\ \mathbf{A}_z\mathbf{B}_x - \mathbf{A}_x\mathbf{B}_z \\ \mathbf{A}_x\mathbf{B}_y - \mathbf{A}_y\mathbf{B}_x \end{pmatrix}$$

Right Hand Rule



To get the direction right, you need to align the fingers of the right hand with the corresponding vectors in the order shown.

Representations for planes (1)

A plane passes through a point and has a given "direction"

Direction of plane is given by its normal

$$(\mathbf{X}-\mathbf{X_0})\bullet\hat{\mathbf{n}}=\mathbf{0} \quad \Rightarrow \quad \mathbf{ax}+\mathbf{by}+\mathbf{cz}=\mathbf{k}$$

A half space is defined by $(\mathbf{X}-\mathbf{X_0})\bullet\hat{\mathbf{n}}\geq 0$

Representations for planes (2)

Three points determine a plane

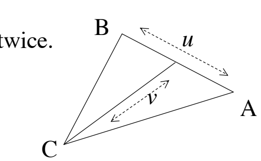
We can make it the same as previous approach---how?

- Choose one point, and get two vectors from that point to the other two points
- Use cross product to get the normal
- Use the normal and one of the points in the previous formula.

Representations for planes (3)

Direct vector representation (analog of parameterized form for line segments).

Apply the method for line segments twice.



$v(uA+(1-u)B)+(1-v)C$

Let $t=uv \;\; and \;\; s=v$

Then $C+t(A-B)+s(B-C)$

(linear combination of two vectors, offset by another)