CS 433/433H, 533

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

Office Hours (by electronic sign up):
Thursday 10-11
Friday 2-2:45

login: public
pw: meetkobus

Why graphics?

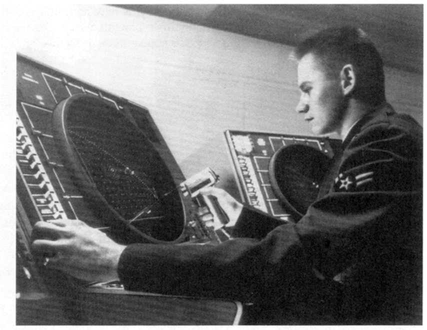
- Presenting an alternative world
- Visual interfaces
- Enhancing our view of the existing world

Presenting an alternative world

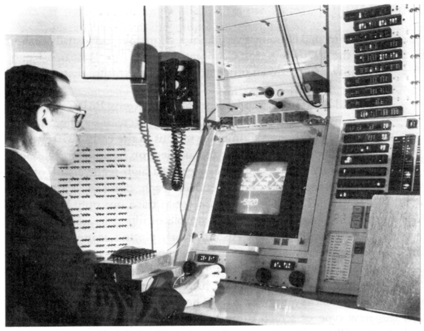
- For training
  - Landing expensive aircraft
- For amusement
  - Games; movies
- For aesthetic pleasure
  - Computer art
- For understanding
  - Visualize data sets in an accessible way

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 author what is displayed (‘63 thesis, Ivan Sutherland)



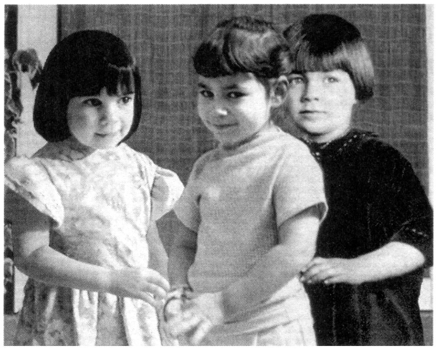
SAGE - aircraft target selection - 1958, from Spalter



Sketchpad, c 1955, from Spalter

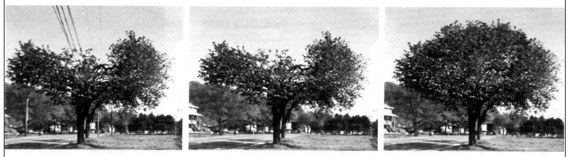
Computer Art

- 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

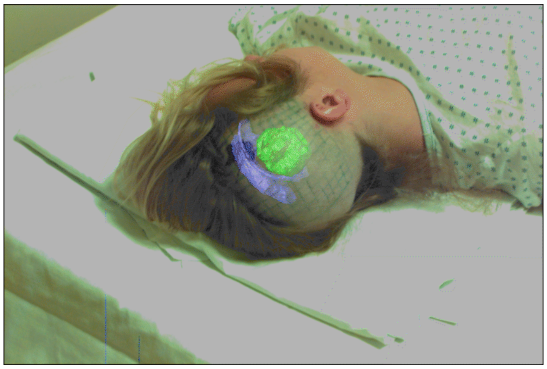
You Wish, from Tree Fix, 1997, Michele Turre



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

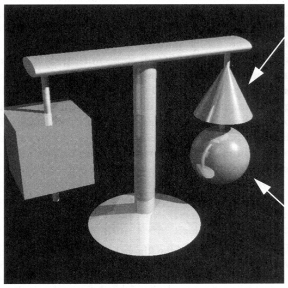
From Eric Grimson’s research group at MIT



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

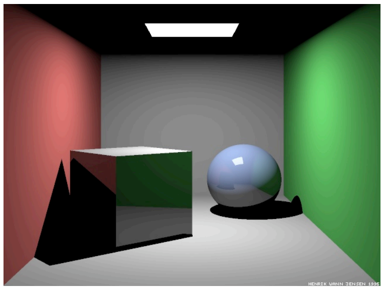


```
trans [
scale 1.03 1.03 1.03
translate -1.55 0.29 0
object cube [
diffuse 0.9 1 0.9
ambient 0.06 0.05 0.07
specular 0.9 0.9 0.9
reflect 0.38 0.38 0.38
shine 30
]
]
```

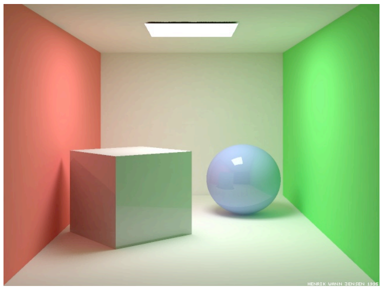
```
trans [
translate 1.55 0.74 0
scale 1.04 0.93 1.04
object cone [
diffuse 0.9 1 0.9
ambient 0.06 0.05 0.07
specular 0.9 0.9 0.9
reflect 0.47 0.47 0.47
shine 30
]
]
```

```
trans [
translate 1.55 -0.53 0
scale 1.1 1.1 1.1
object sphere [
diffuse 0.9 1 0.9
ambient 0.06 0.05 0.07
specular 0.9 0.9 0.9
reflect 0.42 0.42 0.42
shine 30
]
```

PCKTWTCH by Kevin Odhner, POVRay

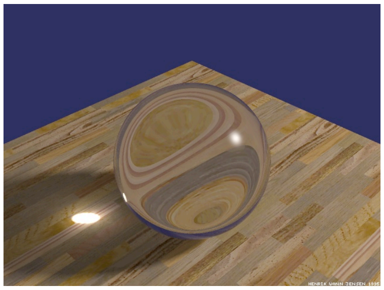


Ray-traced Cornell box, due to Henrik Jensen,
http://www.gk.dtu.dk/~hwj



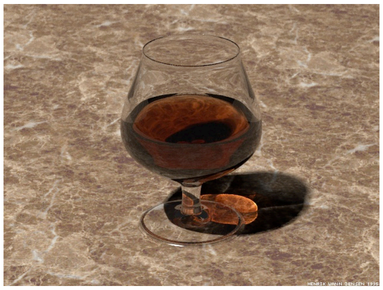
Radiosity Cornell box, due to Henrik Jensen,
http://www.gk.dtu.dk/~hwj, rendered with ray tracer

Refraction caustic



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

Refraction caustics



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

Course Outline

(not exactly in order!)

- Intro (1 week)
  - OpenGL intro
  - Math review
- 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 (3 weeks)
  - Producing a geometrical, or other kind of model that can be rendered.
  - Involves understanding
    - Yet more geometry
    - A little calculus
- Misc (2-3 weeks)
  - colour
  - animation
  - advanced rendering
- Exam, review (1 week, equivalent)

Grading, etc.

Assignments	**(60%)**
Pop quizzes	**(15%)**
Final	**(25%)**

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.

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

We will check assignments for duplication

Resources

TA:	Amy Platt
Email:	platt @ cs
Office Hours:	TBA

Text: Hearn and Baker (optional)

Web page: www.cs.arizona.edu/classes/433/fall05
For remote access to restricted items (slides, assignments):
login: me
pw: graphics4fun

Administrative

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.

Administrative

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

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

Check the class page regularly for announcements.
(http://www.cs.arizona.edu/classes/cs433/fall05/index.html)

Administrative

Further information is avalable on web page

(Especially “Syllabus” link)

Also previous versions of the class via “teaching link” on main web page (kobus.ca)

Possible bad things about this course

There is some math

You have to use unix and C/C++

No “reference” implementation

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 (we assume you can read a manual regarding fancy things that OpenGL can do).

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 (minimal)
  - (Fit smooth curves through points; aliasing)

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

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	$\lvert\mathbf{X}\rvert = \sqrt{x_1^2 + x_2^2 + x_3^2}$

Representations for lines and segments

Cartesian

Representations for lines and segments

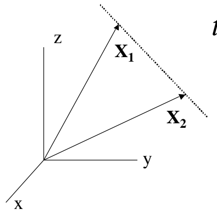
Cartesian

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

Question--what is the analogous formula for 3D?

Representations for lines and segments

Vector representation



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

Works in any dimension

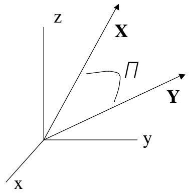
Simplifies representing *segments*

More Vector Operations

Dot Product (any number of dimensions)

More Vector Operations

Dot Product (any number of dimensions)

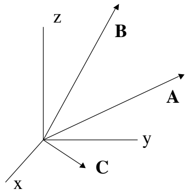


$$\mathbf{X} \bullet \mathbf{Y} = (x_1 y_1 + x_2 y_2 + x_3 y_3)$$
$$= |\mathbf{X}||\mathbf{Y}|\cos\theta$$

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

More Vector Operations

Vector (cross) product (3D)



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

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

Use Right Hand Rule

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

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

Representations for planes (1)

A plane passes through a point and has a given “direction”

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A plane passes through a point and has a given “direction”

Direction of plane is given by its normal

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

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

(Can make it the same as previous approach---how?)

Direct vector representation

Representations for planes (2)

Three points determine a plane

(Can make it the same as previous approach---how?)

Direct vector representation

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

$t = uv \quad and \quad s = v$

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

(linear combination of two vectors, offset by another)

Typical Graphics Problems

Which side of a plane is a point on?

Is a 3D point in a convex 2D polygon?