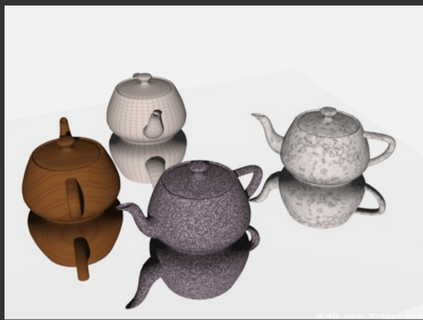
CSE168: Rendering Algorithms



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Overview

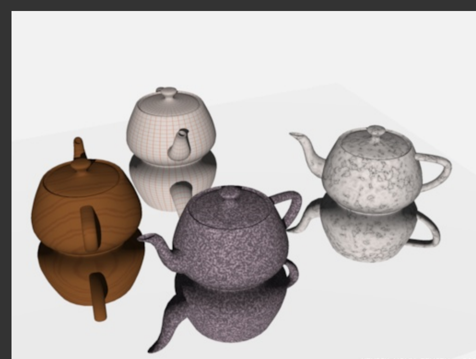
- What is this course about?
- Practical details
- Basic vector math

This course

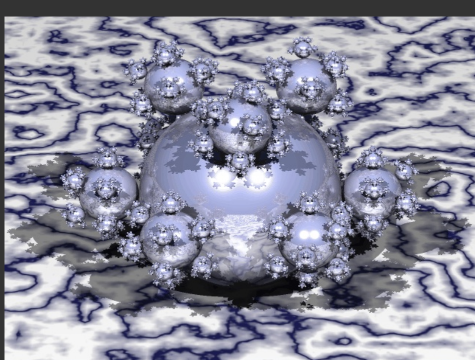
Algorithms for creating photorealistic images.

- Physics of light
- Rendering algorithms

Images



Images



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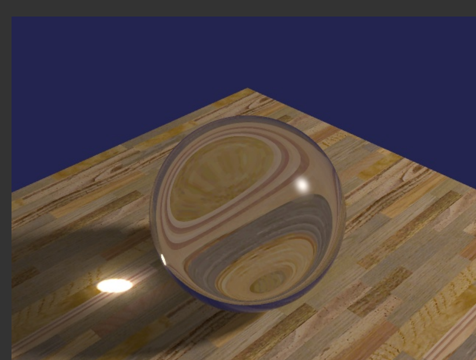

Images

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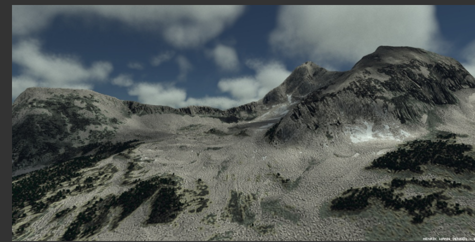
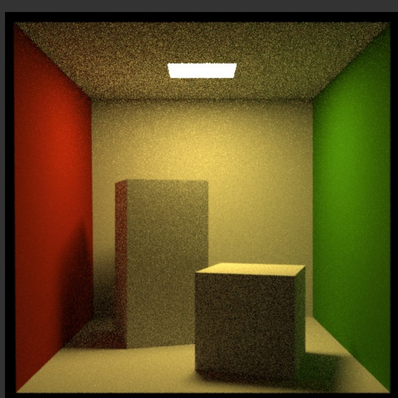


Images



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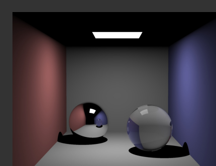
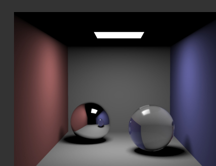
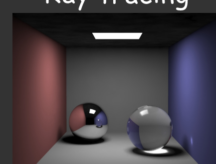


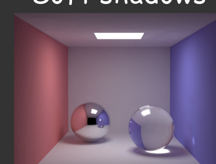
Ray tracing



Soft shadows



Caustics



Global illumination

What you should know

- Basic 3d graphics (OpenGL)
- Programming in C++

What you will learn

- Rasterization
- Ray tracing
- Geometry
- Shading
- Acceleration structures
- Global illumination

Syllabus Part 1

- Basic ray tracing
- Intersection algorithms
- Shading
- Acceleration structures

Syllabus Part 2

- Advanced shading
- Texturing
- Procedural texturing

Syllabus Part 3

- Global illumination
- Monte Carlo ray tracing
- Anti-aliasing
- Photon mapping
- Volume rendering

Programming assignments

0 Warmup

1 Ray tracing

2 Fast ray tracing

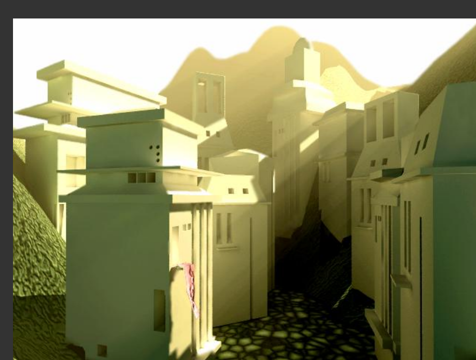
3 Shading and global illumination

3 Render a realistic image

Grading

- Project 0: 5%
- Project 1: 10%
- Project 2: 20%
- Project 3: 15%
- Project 4: 30%
- Midterm: 20%

Previous images



Cyrus Jam --- The Gloaming

Previous images

Josh Wills --- Whisky

Previous images

Craig Donner --- Lucy in the deep

Previous images

Arash Keshmirian --- Free Flying

Previous images

Sameer Agarwal --- Sponza Atrium

Previous images

Siddhartha Saha --- Chess in the morning

Previous images

Wojciech Jarosz --- A cluttered desk

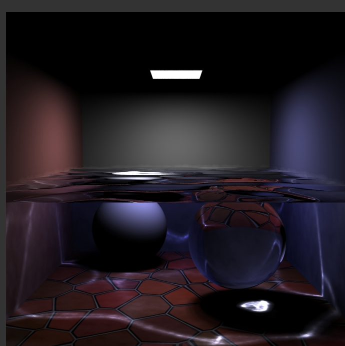
Previous images

Alex Kozlowski - Carousel at night

Previous images

Will Chang - The joy of environment maps

Previous images



Alex Goldberg --- A Cornell box with water

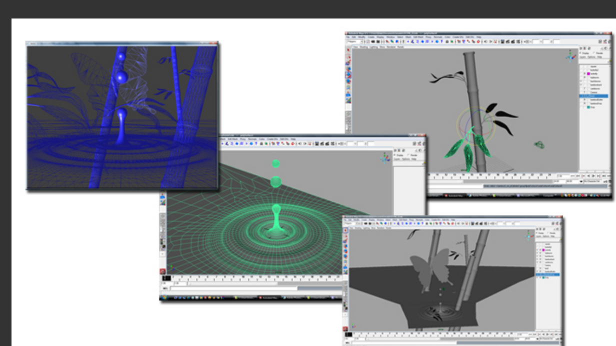
Previous images

Toshiya Hachisuka --- A Programmers Kitchen

Previous images

Iman Sadeghi --- A Butterfly

Previous images



Iman Sadeghi --- Butterfly Modeling

Practical details

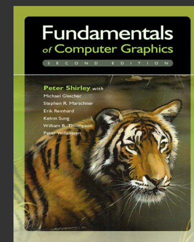
Class webpage:
http://graphics.ucsd.edu/courses/cse168_s08/

Class webboard:
http://webboard.ucsd.edu/

TA:
Wojciech Jarosz <cse168-ta@graphics.ucsd.edu>

LAB:
EBU3B b250

Practical details



Second edition this year!
Chapters 1-6 should be known material...

Questions?

Basic vector math

A vector:

$$\vec{a} = [x\ y\ z]$$

Dot product:

$$\vec{a} \cdot \vec{b} = ||\vec{a}||\,||\vec{b}||\,\cos\theta$$

Cross product:

$$\vec{n} = \vec{a} \times \vec{b}$$

$$||\vec{n}|| = ||\vec{a}||\,||\vec{b}||\,\sin\theta$$

Transformations

A transformation matrix:

$$T = \begin{bmatrix} x_{11} & x_{21} & x_{31} & x_{41} \\ x_{12} & x_{22} & x_{32} & x_{42} \\ x_{13} & x_{23} & x_{33} & x_{43} \\ x_{14} & x_{24} & x_{34} & x_{44} \end{bmatrix}$$

A 4D vector:

$$\vec{a} = [x\ y\ z\ w]$$

A point has $w \neq 0$ and a vector has $w = 0$.

Transformations

Transformation of a vector or a point:

$$\vec{b} = T \cdot \vec{a}$$

Transformations

Translation:

$$T_T = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformations

Scaling:

$$T_S = \begin{bmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformations

Rotation:

$$T_{R_z} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transformations

$$T = \begin{bmatrix} u_x & v_x & w_x & 0 \\ u_y & v_y & w_y & 0 \\ u_z & v_z & w_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

uvw form a basis for the transformed coordinate system.

Windowing transform

Map $[-1,1] \times [-1,1] \times [-1,1]$ to a screen with $n_x \times n_y$ pixels.

$$T_s = \begin{bmatrix} \frac{n_x}{2} & 0 & 0 & \frac{n_x}{2} \\ 0 & \frac{n_y}{2} & 0 & \frac{n_y}{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Simple orthographic projection

Project box with corners $\vec{b}$ and $\vec{t}$

$$T_o = \begin{bmatrix} \frac{2}{\vec{t}_x - \vec{b}_x} & 0 & 0 & 0 \\ 0 & \frac{2}{\vec{t}_y - \vec{b}_y} & 0 & 0 \\ 0 & 0 & \frac{2}{\vec{t}_z - \vec{b}_z} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -\frac{\vec{t}_x + \vec{b}_x}{2} \\ 0 & 1 & 0 & -\frac{\vec{t}_y + \vec{b}_y}{2} \\ 0 & 0 & 1 & -\frac{\vec{t}_z + \vec{b}_z}{2} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Orthographic view projection

Camera position: $\vec{e}$
Camera direction: $\vec{d}$
Camera up: $\vec{u_p}$

Orthonormal basis:

$$\vec{w} = -\frac{\vec{d}}{||\vec{d}||} \quad , \quad \vec{u} = \frac{\vec{u_p} \times \vec{w}}{||\vec{u_p} \times \vec{w}||} \quad , \quad \vec{v} = \vec{w} \times \vec{u}$$

Orthographic view projection

$$T_v = \begin{bmatrix} \vec{u}_x & \vec{u}_y & \vec{u}_z & 0 \\ \vec{v}_x & \vec{v}_y & \vec{v}_z & 0 \\ \vec{w}_x & \vec{w}_y & \vec{w}_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -e_x \\ 0 & 1 & 0 & -e_y \\ 0 & 0 & 1 & -e_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Perspective transform

$$T_p = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{\vec{b}_z+\vec{t}_z}{\vec{b}_z} & -\vec{t}_z \\ 0 & 0 & \frac{1}{\vec{b}_z} & 1 \end{bmatrix}$$

Multiply by b_z/z through homogenization.

$$T_{per} \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} = \begin{bmatrix} x \\ y \\ z\frac{\vec{b}_z+\vec{t}_z}{\vec{b}_z} - \vec{t}_z \\ \frac{z}{\vec{b}_z} \end{bmatrix} \rightarrow \begin{bmatrix} \frac{\vec{b}_z x}{z} \\ \frac{\vec{b}_z y}{z} \\ \vec{b}_z + \vec{t}_z - \frac{\vec{t}_z \vec{b}_z}{z} \\ 1 \end{bmatrix}$$

Complete transform

$$T = T_s T_o T_p T_v T_m$$

To transform a vertex $\vec{v}$

$$\vec{v}_h = T\vec{v}$$

Final pixel position: $(\frac{\vec{v}_{h,x}}{\vec{v}_{h,w}}, \frac{\vec{v}_{h,y}}{\vec{v}_{h,w}})$

Standard transform

Field-of-view $fov = \theta$
Symmetry $\vec{t}_x = -\vec{b}_x$ and $\vec{t}_y = -\vec{b}_y$
Aspect $a = \frac{n_x}{n_y} \quad \rightarrow \quad \vec{t}_x = a\vec{t}_y$

$$\tan\frac{\theta}{2} = \frac{\vec{t}_y}{\vec{b}_z}$$

Next time

- Triangle rasterization
- Handout of assignment 1