

# 3D Rendering

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Princeton University  
COS 426, Spring 2008



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## Syllabus

I. Image processing

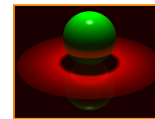
II. Modeling

III. Rendering

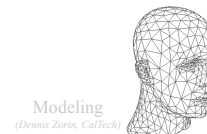
IV. Animation



Image Processing  
*(Rusty Coleman, CS426, Fall99)*



Rendering  
*(Michael Bostock, CS426, Fall99)*



Modeling  
*(Dennis Zoran, CalTech)*

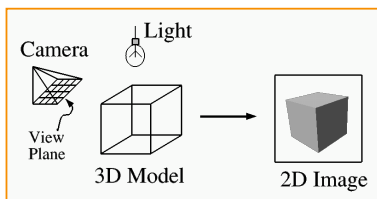


Animation  
*(Angel, Plate 1)*

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## What is 3D Rendering?

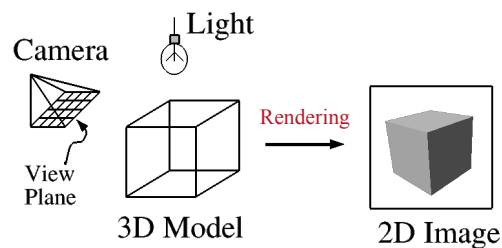
- Topics in computer graphics
  - Imaging = representing 2D images
  - Modeling = representing 3D objects
  - Rendering = constructing 2D images from 3D models
  - Animation = simulating changes over time



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## What is 3D Rendering?

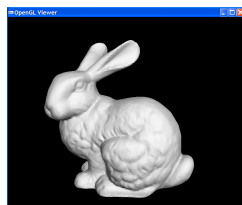
- Construct image from 3D model



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## 3D Rendering Scenario I

- Interactive
  - Images generated in fraction of a second ( $<1/10$ ) as user controls rendering parameters (e.g., camera)
    - Achieve highest quality possible in given time
    - Useful for visualization, games, etc.

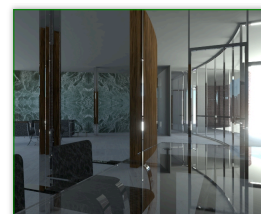


meshview

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## 3D Rendering Scenario II

- Batch
  - One image generated with as much quality as possible for a particular set of rendering parameters
    - Take as much time as is needed (minutes)
    - Useful for photorealism, movies, etc.



jensen

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## 3D Rendering Example



Pixar

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## 3D Rendering Issues



- What issues must be addressed by a 3D rendering system?

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## 3D Rendering Issues



- What issues must be addressed by a 3D rendering system?
  - Camera
  - Visible surface determination
  - Lights
  - Reflectance
  - Shadows
  - Indirect illumination
  - Sampling
  - etc.

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## 3D Rendering Issues



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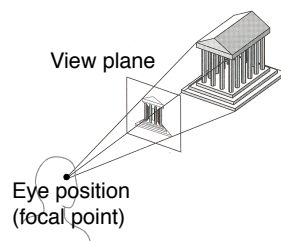
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## Camera Models



- The most common model is pin-hole camera
  - All captured light rays arrive along paths toward focal point without lens distortion (everything is in focus)
  - Sensor response proportional to radiance

Other models consider ...  
Depth of field  
Motion blur  
Lens distortion

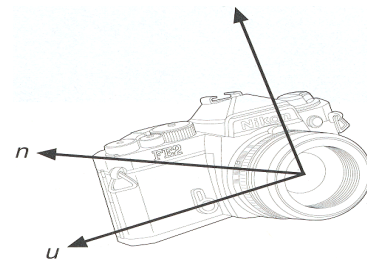


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## Camera Parameters



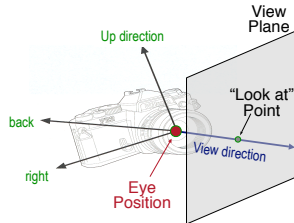
- What are the parameters of a camera?



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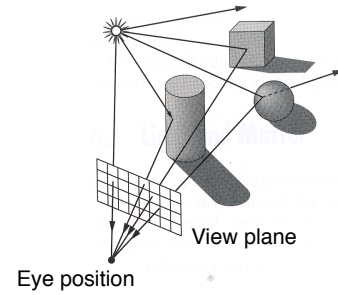
## Pinhole Camera Parameters

- Position
  - Eye position ( $p_x, p_y, p_z$ )
- Orientation
  - View direction ( $d_x, d_y, d_z$ )
  - Up direction ( $u_x, u_y, u_z$ )
- Aperature
  - Field of view ( $xfov, yfov$ )
- Film plane
  - "Look at" point
  - View plane normal



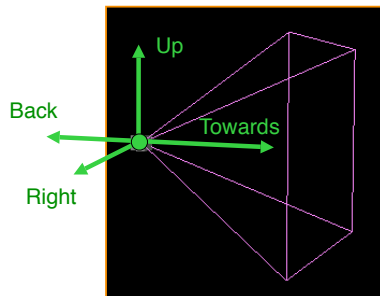
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## View Plane



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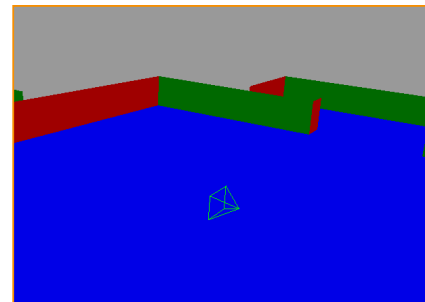
## View Frustum



View Frustum

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## View Frustum Example



View frustum inside simple scene

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## 3D Rendering Issues

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  - etc.

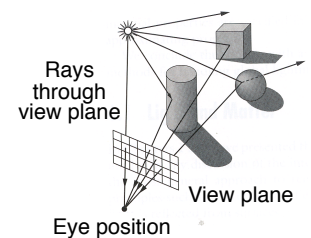
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## Visible Surface Determination

- The color of each pixel on the view plane depends on the radiance emanating from visible surfaces

How find visible surfaces?

Simplest method is ray casting

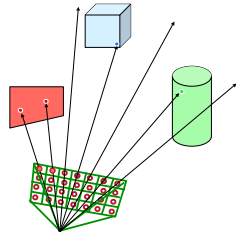


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## Ray Casting



- For each sample ...
  - Construct ray from eye position through view plane
  - Find first surface intersected by ray through pixel
  - Compute color of sample based on surface radiance

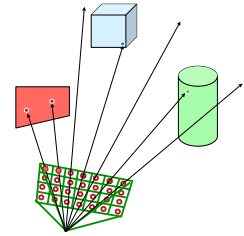


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## Ray Casting



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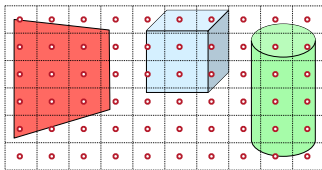


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## Ray Casting



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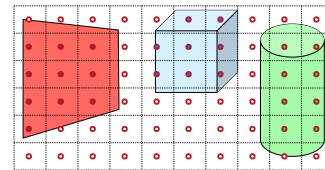


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## Visible Surface Determination

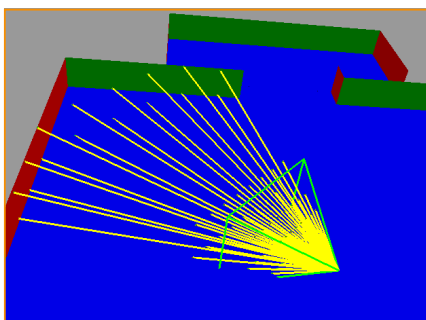


- For each sample ...
  - Construct ray from eye position through view plane
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## Ray Casting Example



Rays from camera in simple scene

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## 3D Rendering Issues



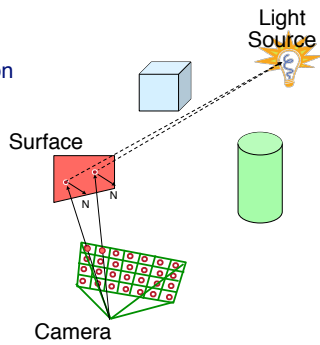
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  - etc.

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## Lighting Simulation

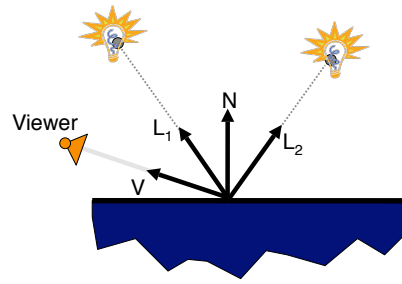


- Lighting parameters
  - Light source emission
  - Surface reflectance
  - Atmospheric attenuation
  - Camera response



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## Lighting Simulation

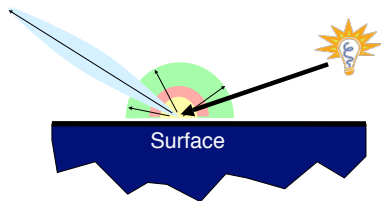


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## OpenGL Reflectance Model

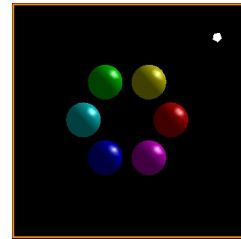


- Simple analytic model:
  - diffuse reflection +
  - specular reflection +
  - emission +
  - "ambient"



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## Lighting Example



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## 3D Rendering Issues



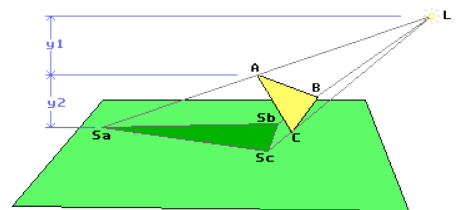
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## Shadows



- Occlusions from light sources

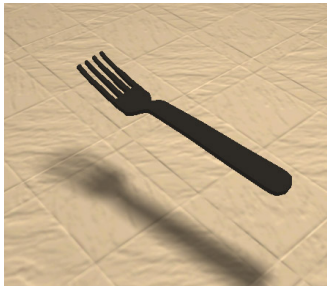


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## Shadows



- Occlusions from light sources
  - Soft shadows with area light source



Moller

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## Shadows



Herf

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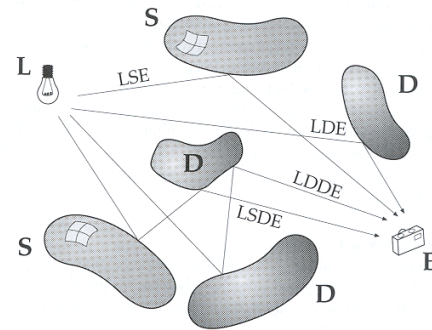
## 3D Rendering Issues



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## Path Types

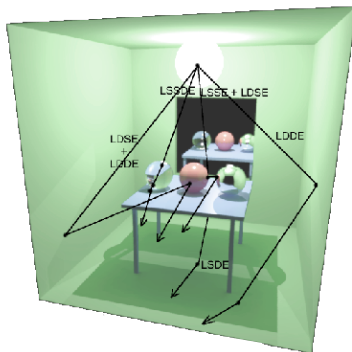


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## Path Types



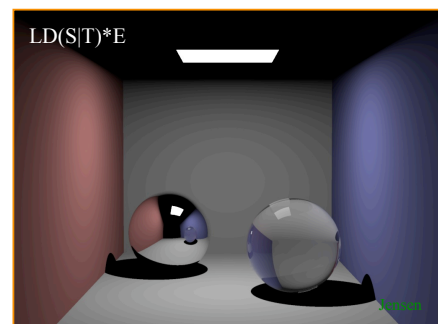
- OpenGL
  - LDE
- Ray tracing
  - LD(SIT)\*E
- Path tracing
  - L(DISIT)\*E
- Radiosity
  - LD\*E



John Hart

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## Path Types

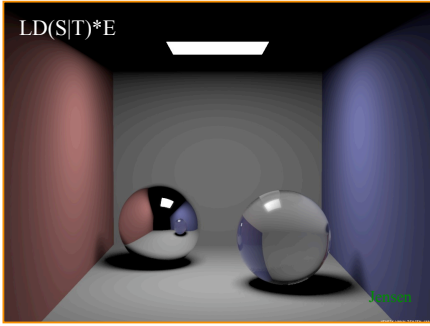


direct diffuse + indirect specular and transmission

Henrik Wann Jensen

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## Path Types

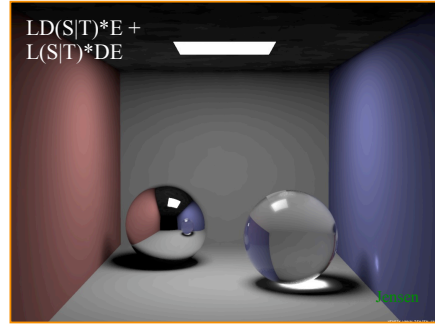


+ soft shadows

Henrik Wann Jensen

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## Path Types

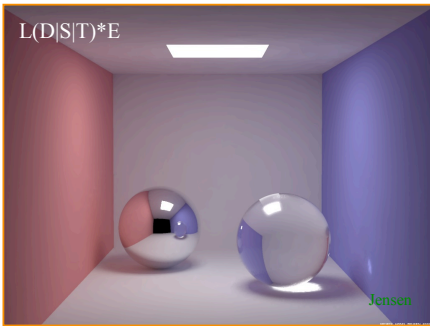


+ caustics

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## Path Types

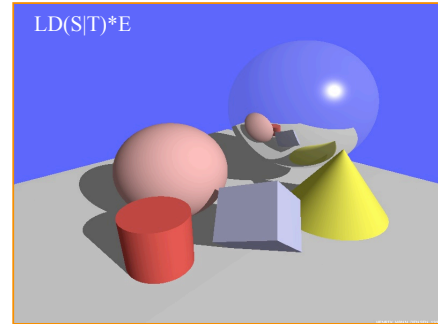


+ indirect diffuse illumination

Henrik Wann Jensen

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## Path Types?



Henrik Wann Jensen

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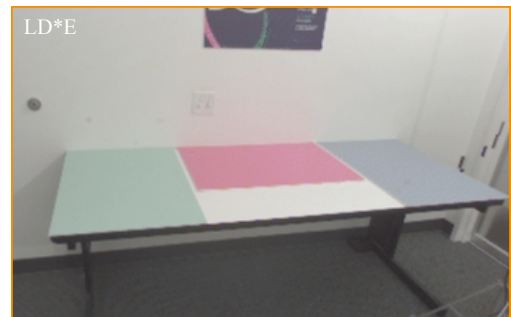
## Path Types?



Henrik Wann Jensen

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## Path Types?



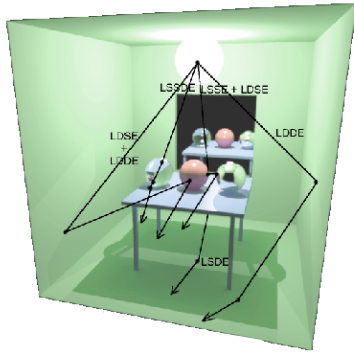
Paul Debevec

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## Path Types



- OpenGL
  - LDE
- Ray tracing
  - LDS\*E
- Path tracing
  - L(DIS)\*E
- Radiosity
  - LD\*E



John Hart

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## 3D Rendering Issues



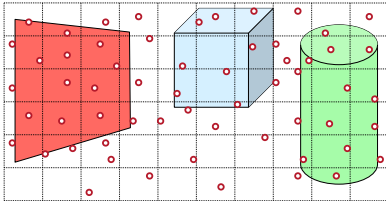
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## Sampling



- Scene can be sampled with any ray
  - Rendering is a problem in sampling and reconstruction



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## Summary



- Topics for upcoming lectures
  - Camera
  - Visible surface determination
  - Shadows
  - Reflectance
  - Indirect illumination
  - Sampling
  - etc.



Tricycle  
(James Percy, CS 426, Fall199)

For assignment #3, you will write a ray tracer!

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