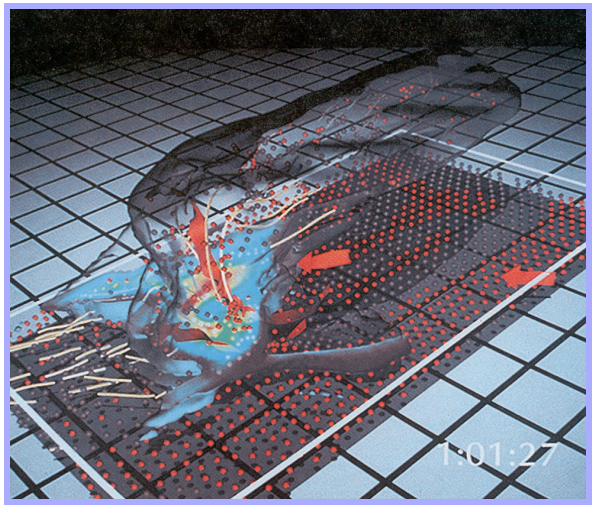
Rumination on illumination (computer graphics)

COS 116, Spring 2012

Adam Finkelstein

Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art



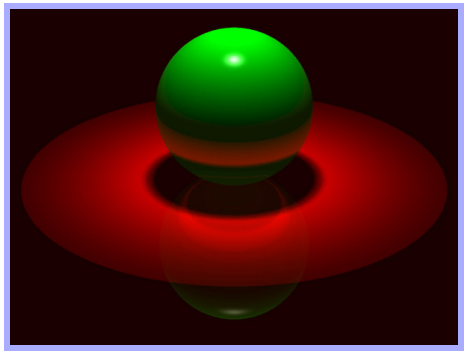
Inside a Thunderstorm
(Bob Wilhelmson, UIUC)

Boeing 777 Airplane

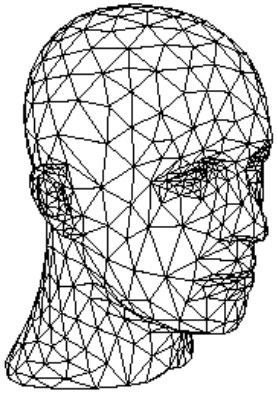
Overview

I. Images
II. Modeling
III. Rendering
IV. Animation

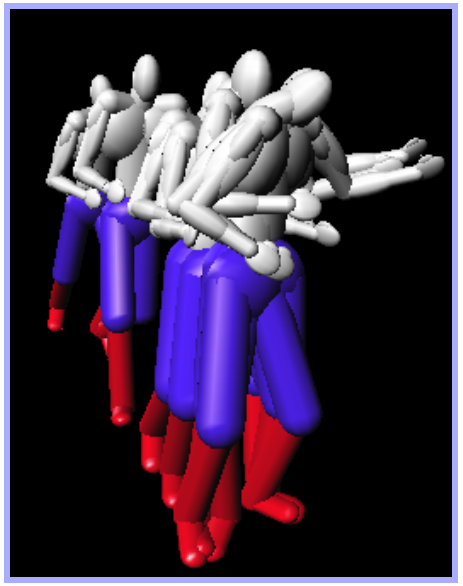
Image Processing
(Rusty Coleman, CS426, Fall99)



Rendering
(Michael Bostock, CS426, Fall99)



Modeling
(Dennis Zorin, CalTech)



Animation
(Jon Beyer, CS426, Spring04)

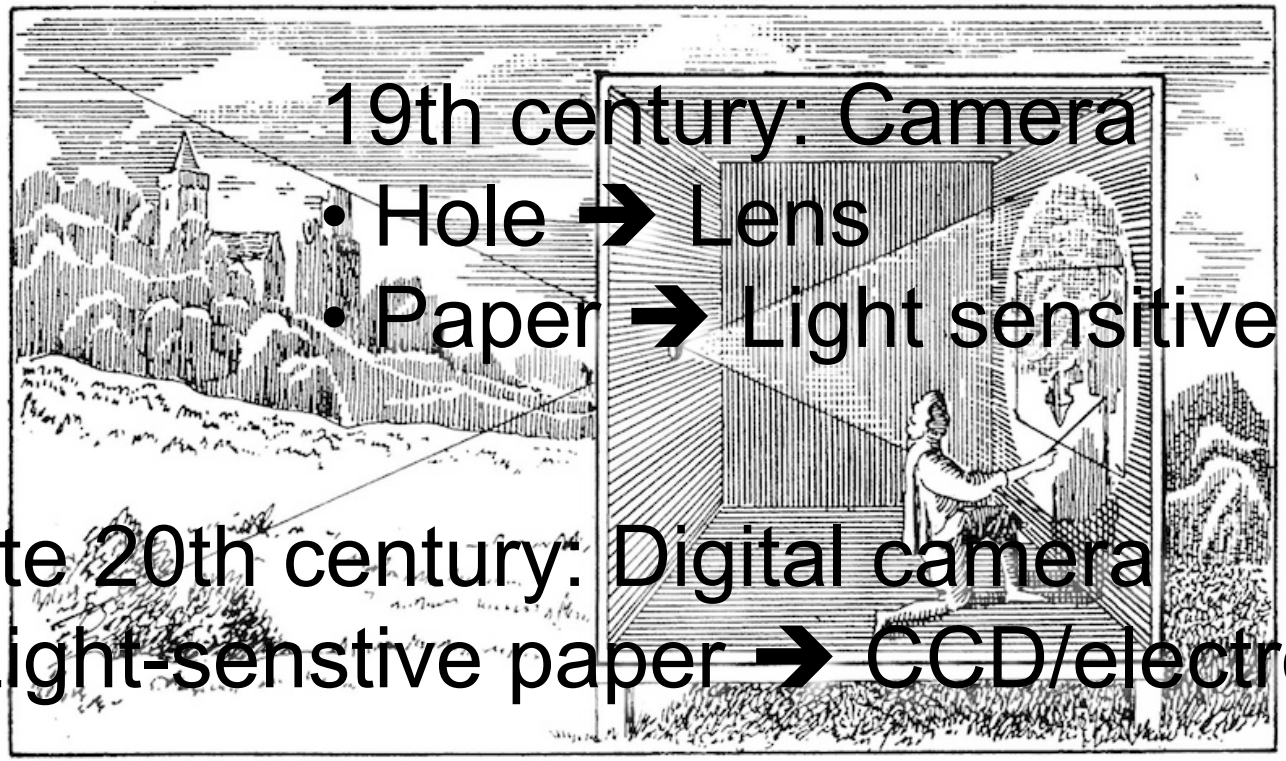
Part 1: Images

Q: What is an image?

Brief history of image capture

Camera obscura

- Known to Chinese 5thC. BC



19th century: Camera

- Hole ➔ Lens
- Paper ➔ Light sensitive

Late 20th century: Digital camera

- Light-senstive paper ➔ CCD/electronics

Digital images

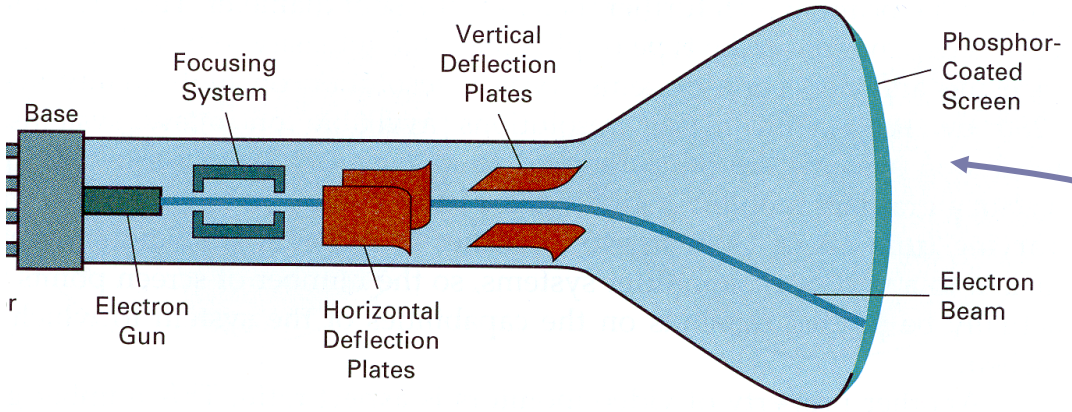
- Rectangular (2D) array of pixels

Continuous image

Digital image

Image Display

- Re-create continuous function from samples
  - Example: cathode ray tube (CRT)



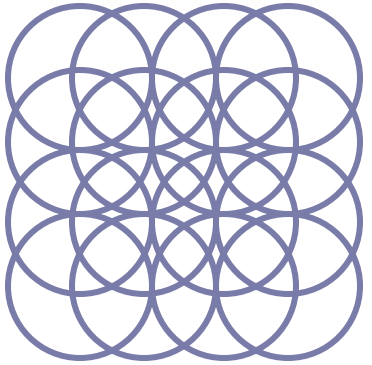
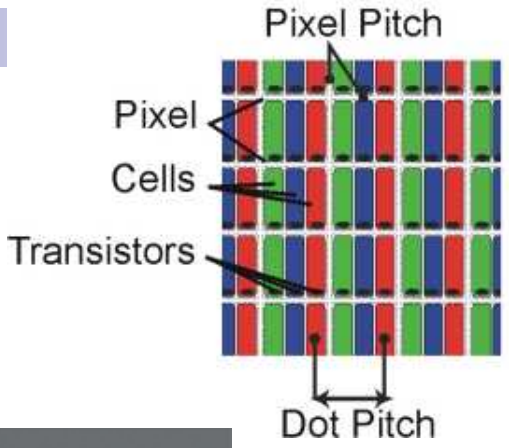
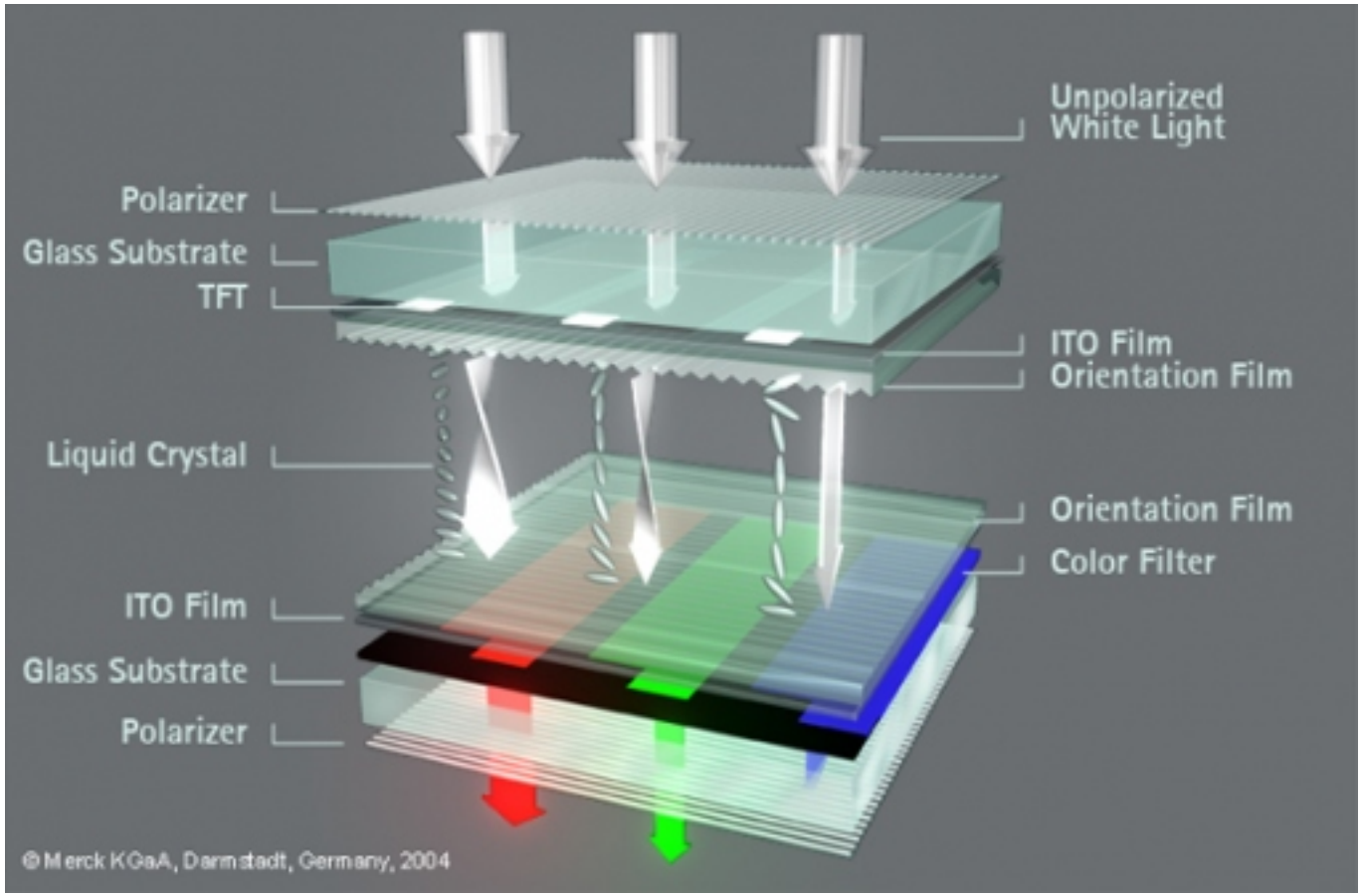


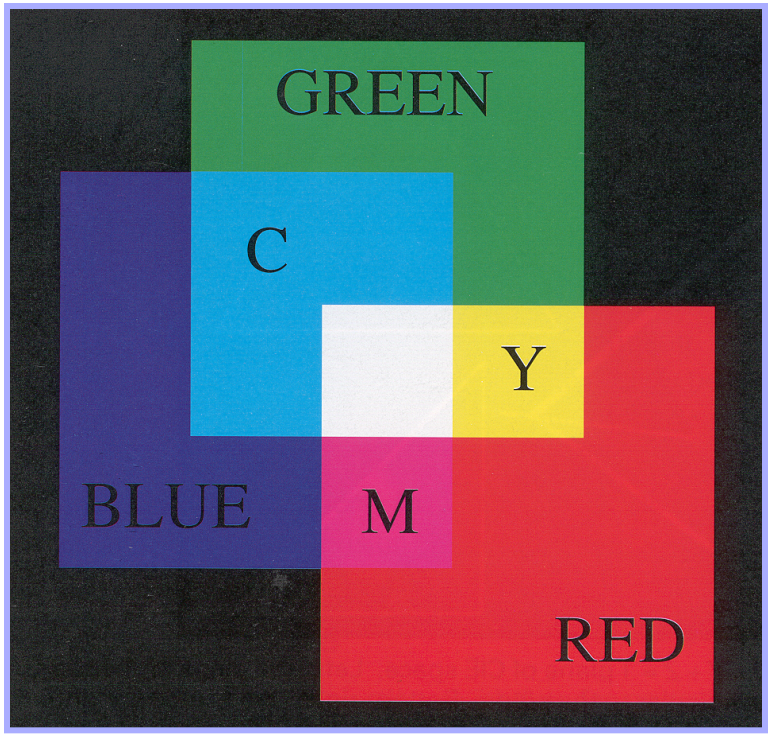
Image is reconstructed by displaying pixels with finite area of color

LCD Screen


Pixel Pitch
Pixel
Cells
Transistors
Dot Pitch


Unpolarized
White Light
Polarizer
Glass Substrate
TFT
ITO Film
Orientation Film
Liquid Crystal
Orientation Film
Color Filter
ITO Film
Glass Substrate
Polarizer
© Merck KGaA, Darmstadt, Germany, 2004

RGB Color Model



Colors are additive

Plate II.3 from FvDFH

R	G	B	Color
0.0	0.0	0.0	Black
1.0	0.0	0.0	Red
0.0	1.0	0.0	Green
0.0	0.0	1.0	Blue
1.0	1.0	0.0	Yellow
1.0	0.0	1.0	Magenta
0.0	1.0	1.0	Cyan
1.0	1.0	1.0	White
0.5	0.0	0.0	?
1.0	0.5	0.5	?
1.0	0.5	0.0	?
0.5	0.3	0.1	?

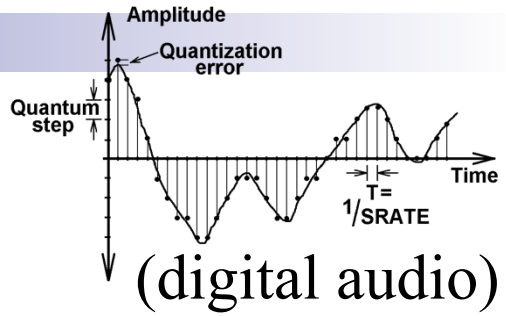
What is an Image?

- Rectangular (2D) array of pixels

Continuous image

Digital image

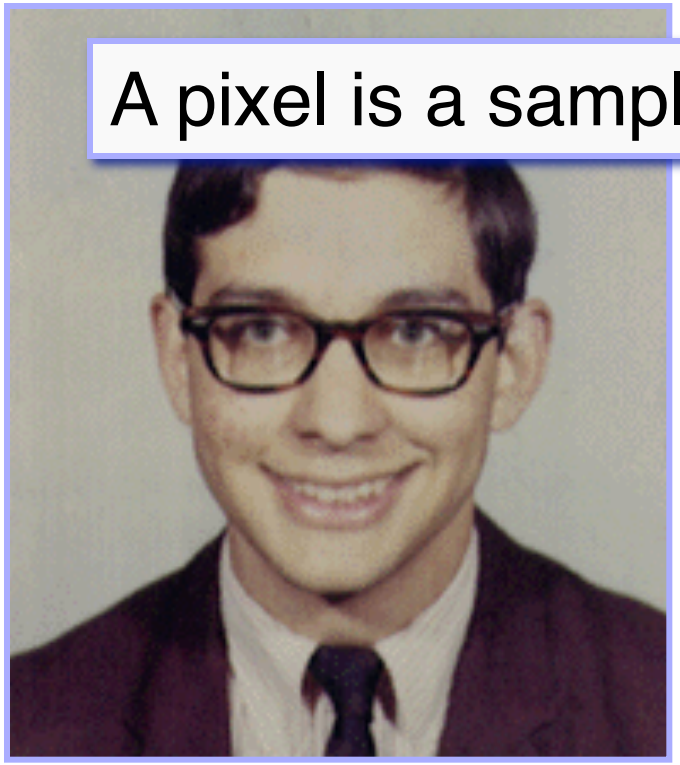
What is an Image?



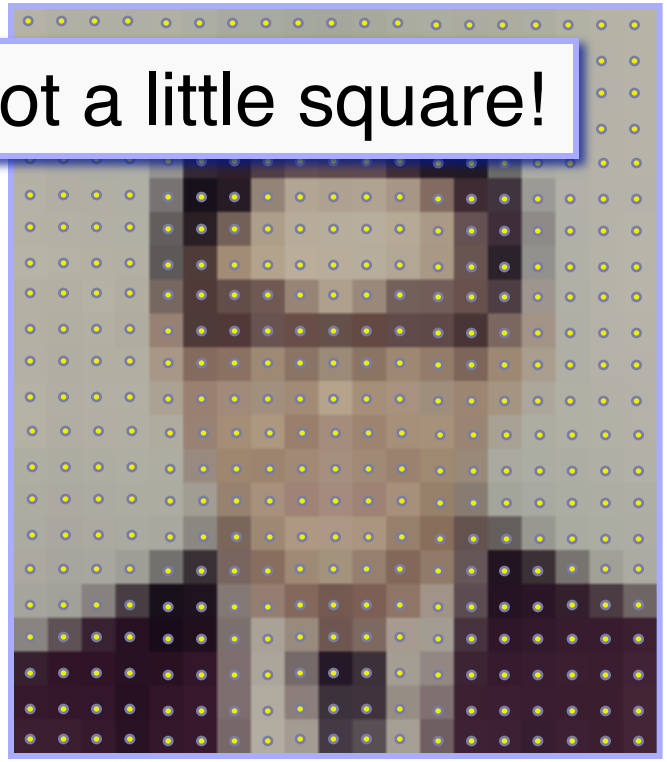
(digital audio)

- Rectangular (2D) array of pixels

A pixel is a sample, not a little square!

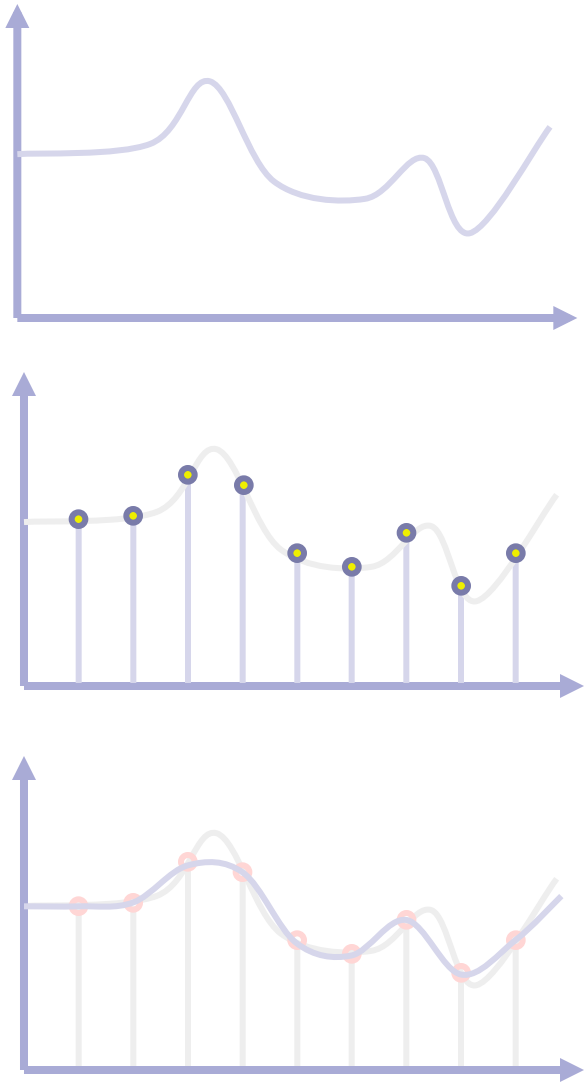


Continuous image



Digital image

Sampling and Reconstruction



Sampling
(e.g. digital camera)

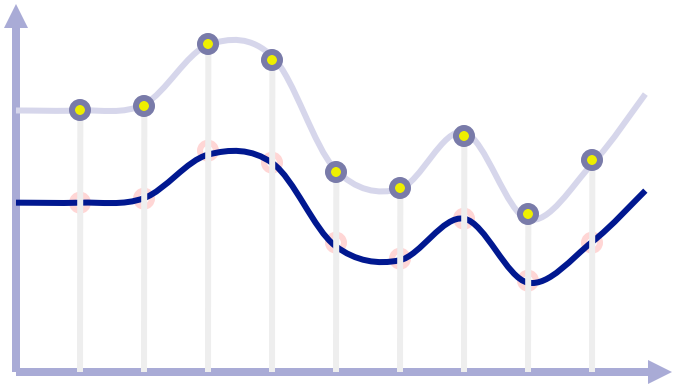
Reconstruction
(e.g. CRT)

Adjusting Brightness

- Simply scale pixel components
  - Must clamp to range (e.g., 0 to 1)

Original

Brighter

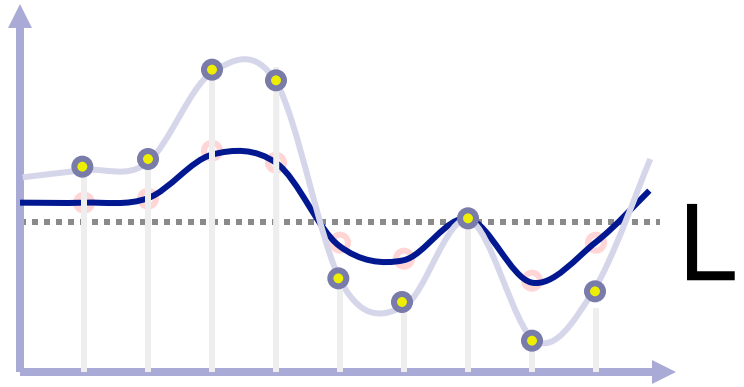


Adjusting Contrast

- Compute average luminance L for all pixels
  - L = 0.30*r + 0.59*g + 0.11*b
- Scale deviation from L for each pixel
  - Must clamp to range (e.g., 0 to 1)

Original

More Contrast



Scaling the image

- Resample with fewer or more pixels (mathy theory…)

Original

1/4X resolution

4X resolution

Image Warping

- Move pixels of image (resampling)

Source image

Warp

Destination image

Image Morphing

[Beier & Neeley]

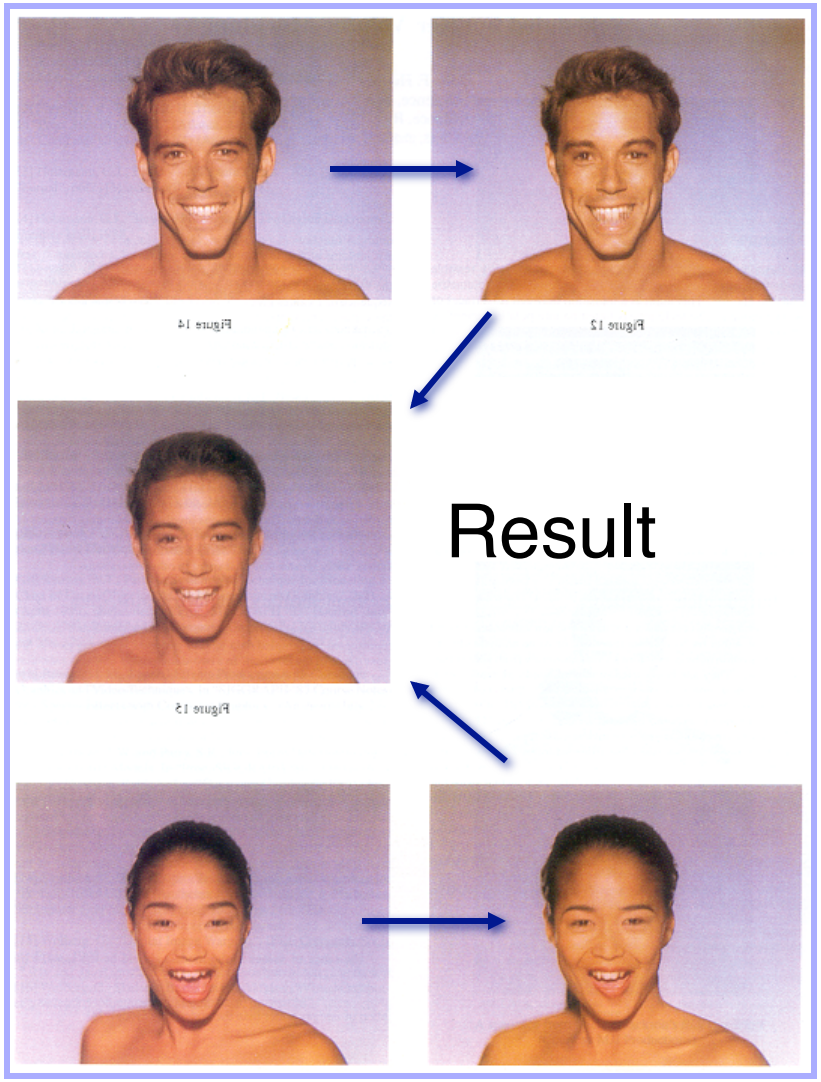
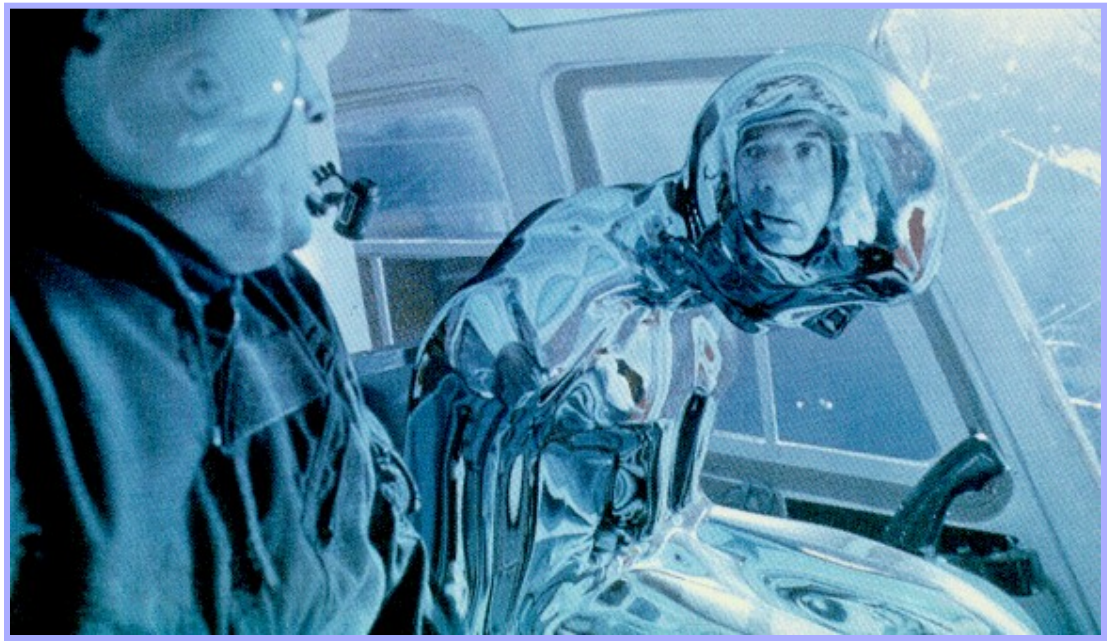


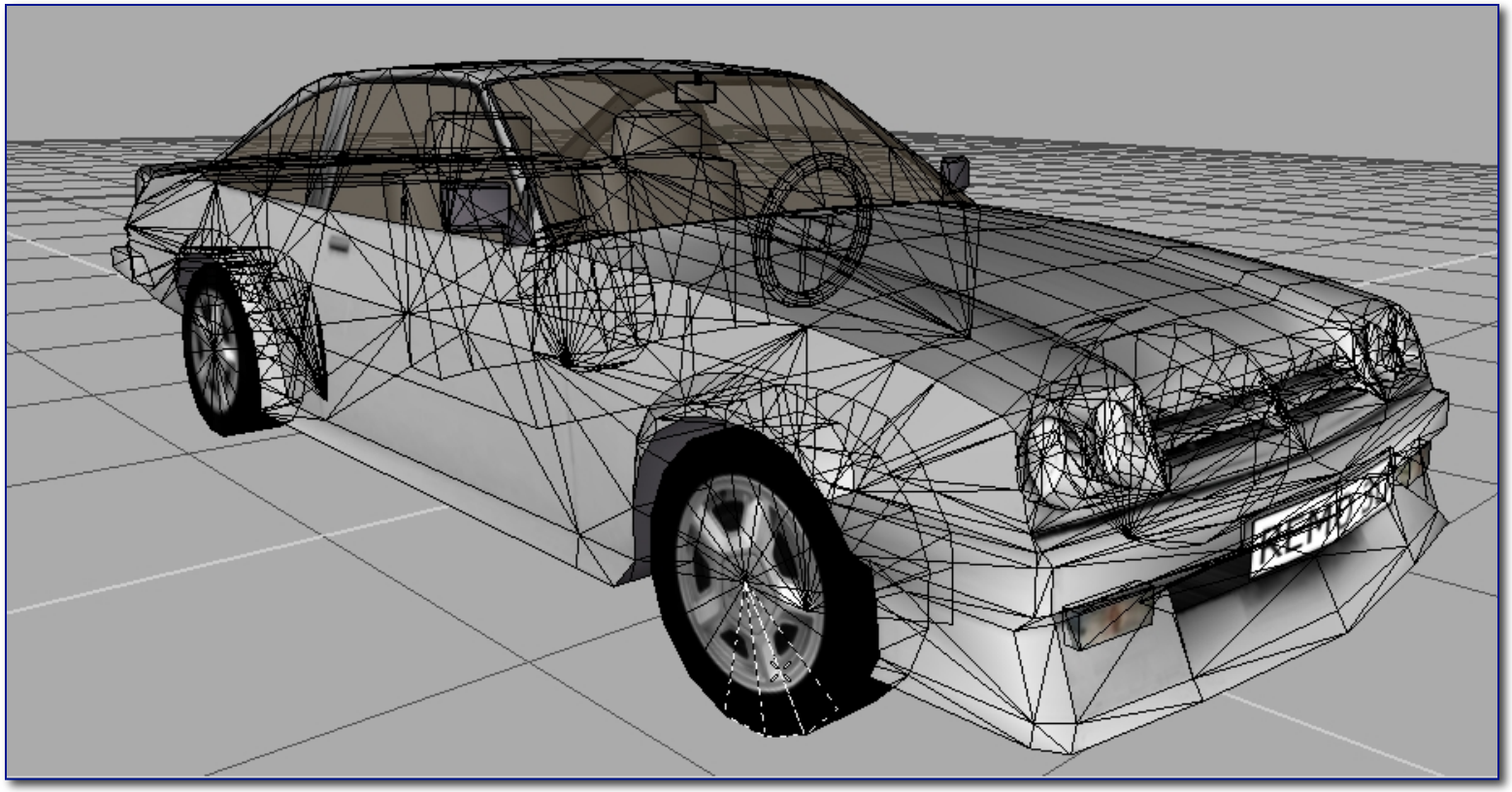
Image Morphing

- Another example, T2, uses 3D graphics…



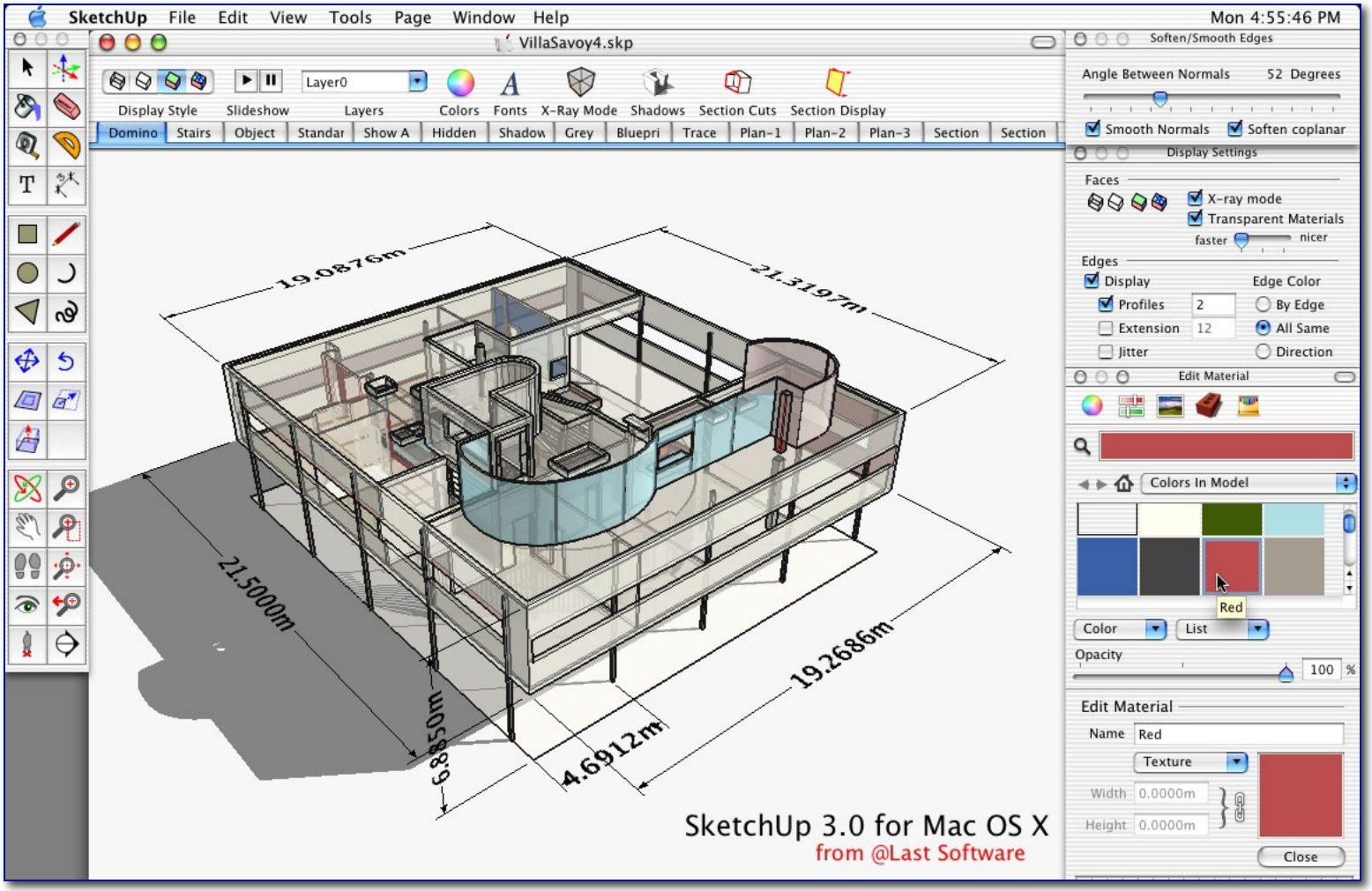
Part II: Modeling

- How to construct and represent shapes (in 3D)



(Remo3D)

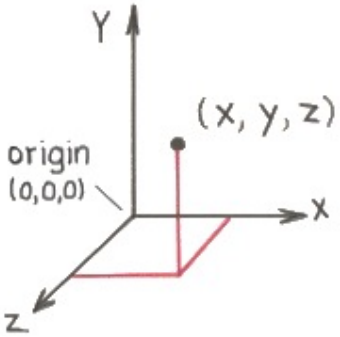
Modeling in SketchUp (demo)

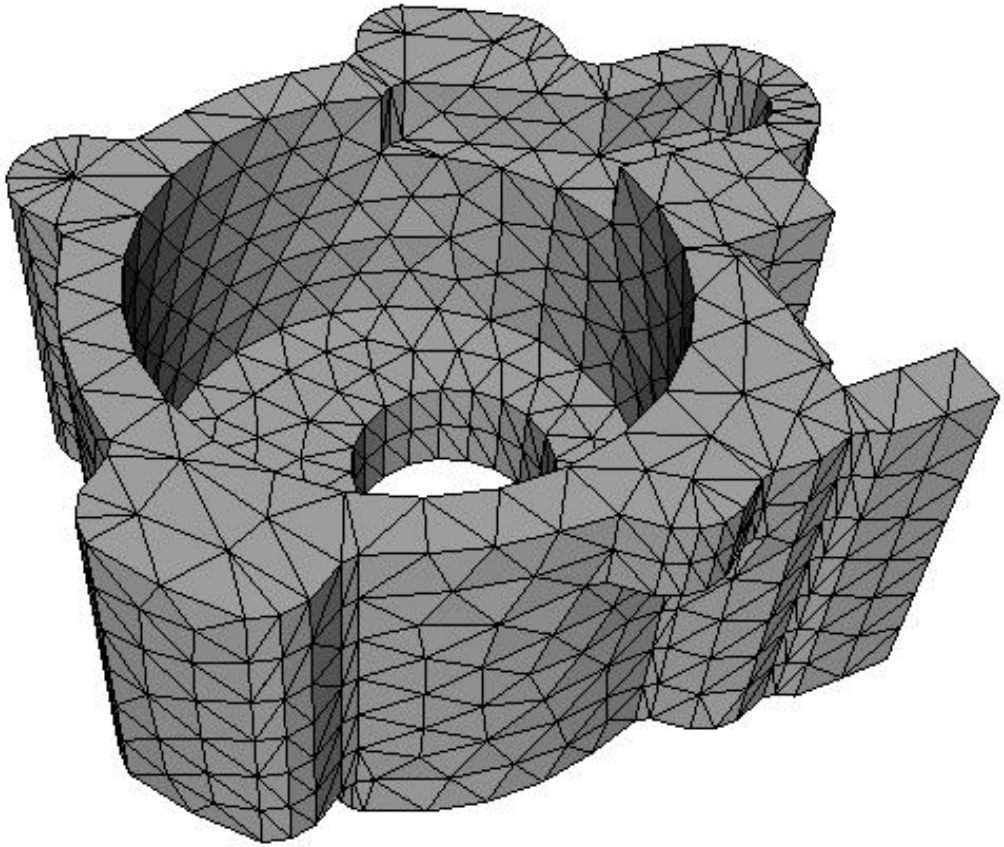


Model representation

- Most common: list of triangles
  - Three vertices in 3D

    (x_1, y_1, z_1)
    (x_2, y_2, z_2)
    (x_3, y_3, z_3)





Part III: Rendering

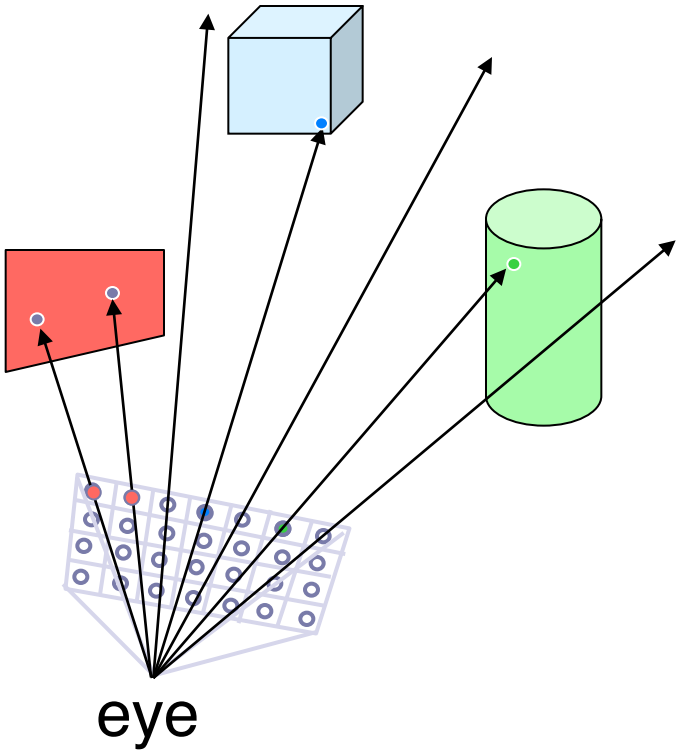
- Direct illumination
  - One bounce from light to eye
  - Implemented in graphics cards
  - OpenGL, DirectX, …
- Global illumination
  - Many bounces
  - Ray tracing

Direct Illumination
(Chi Zhang, CS 426, Fall99)

Ray Tracing
(Greg Larson)

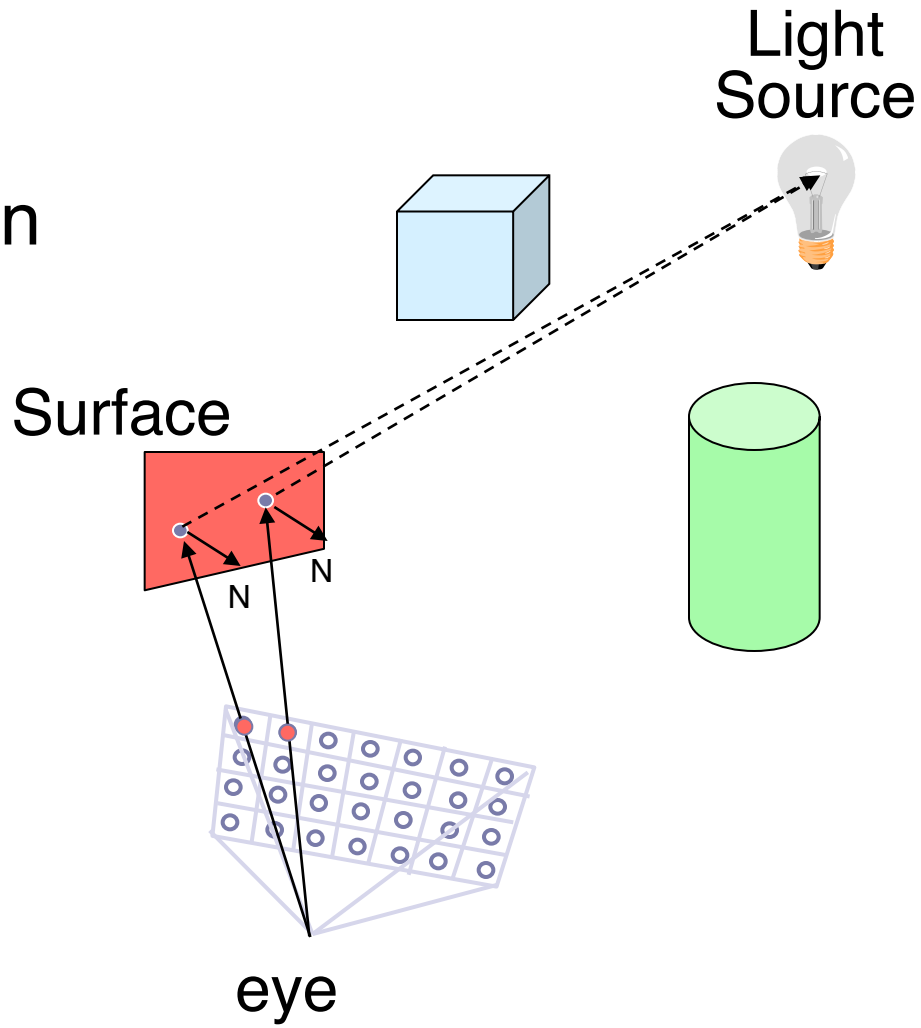
Ray Casting

- A (slow) method for computing direct illumination
- For each sample:
  - Construct ray from eye through image plane
  - Find first surface intersected by ray
  - Compute color of sample based on surface properties



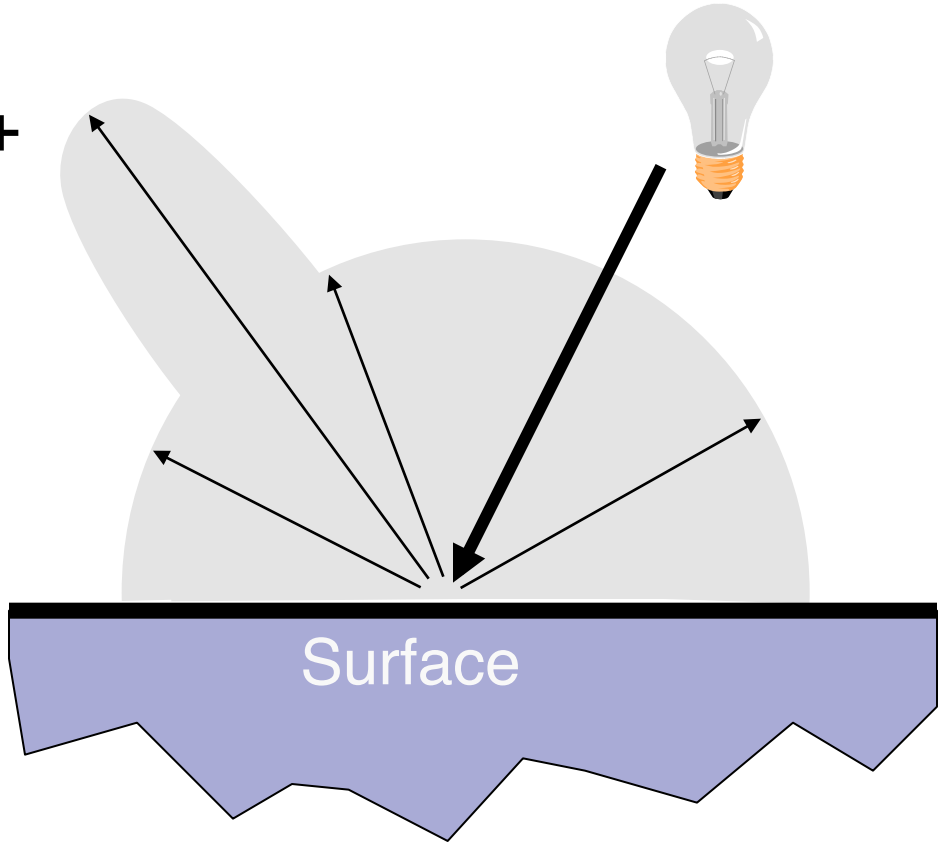
Lighting Simulation

- Lighting parameters
  - Light source emission
  - Surface reflectance



Simple Reflectance Model

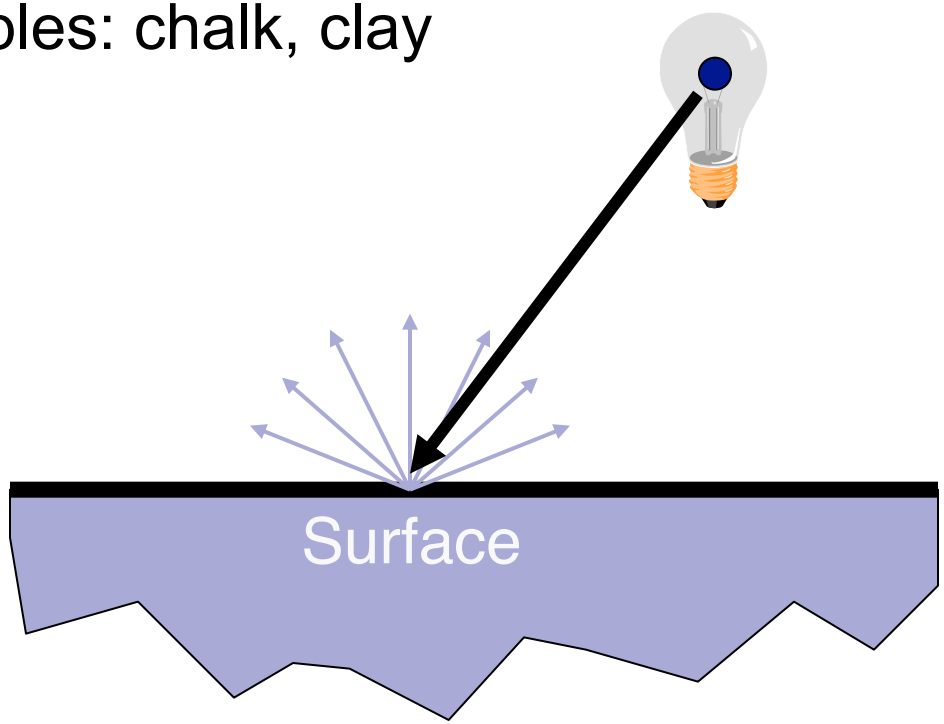
- Simple analytic model:
  - diffuse reflection +
  - specular reflection +
  - ambient lighting



Based on model proposed by Phong

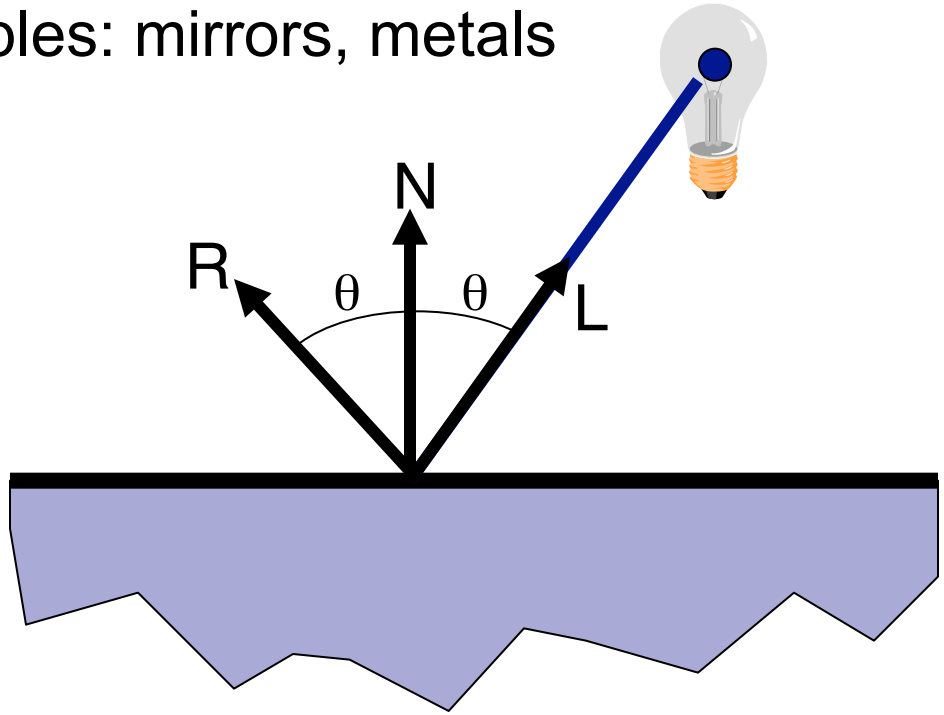
Diffuse Reflection

- Assume surface reflects equally in all directions
  - Examples: chalk, clay



Specular Reflection

- Reflection is strongest near mirror angle
  - Examples: mirrors, metals

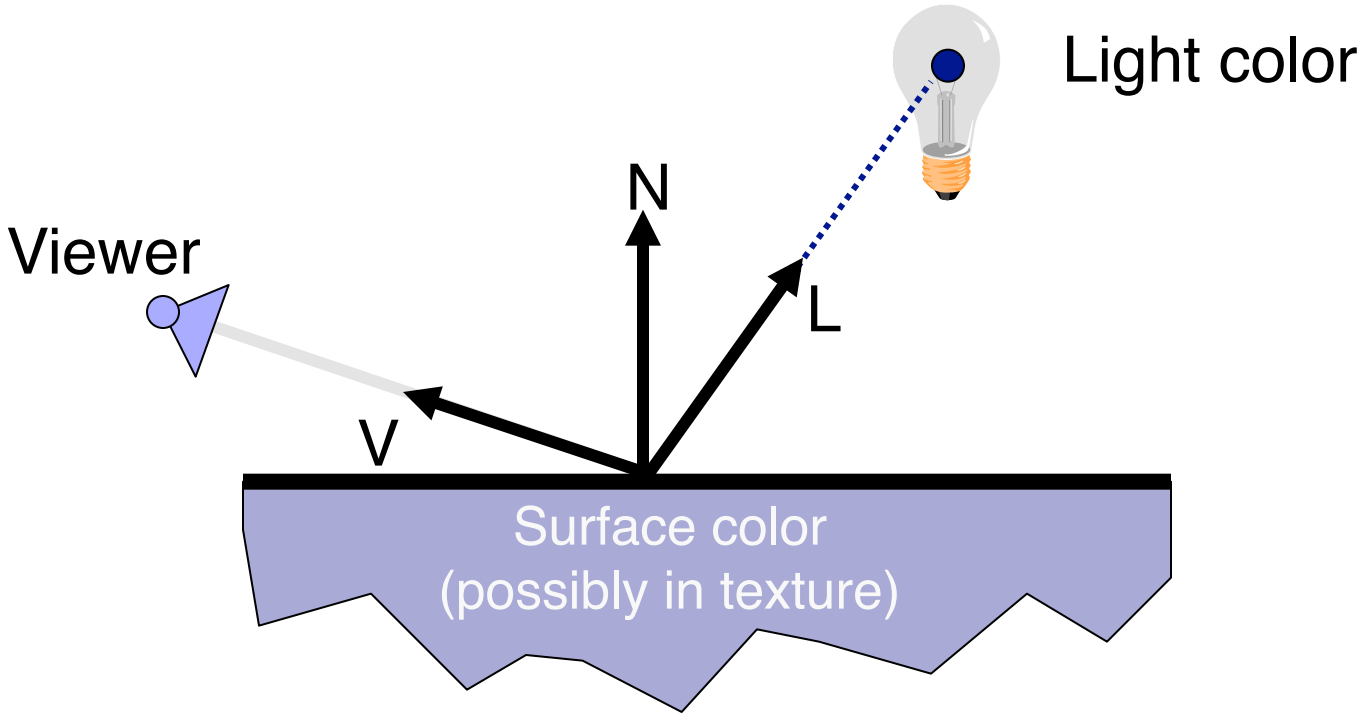


Ambient Lighting

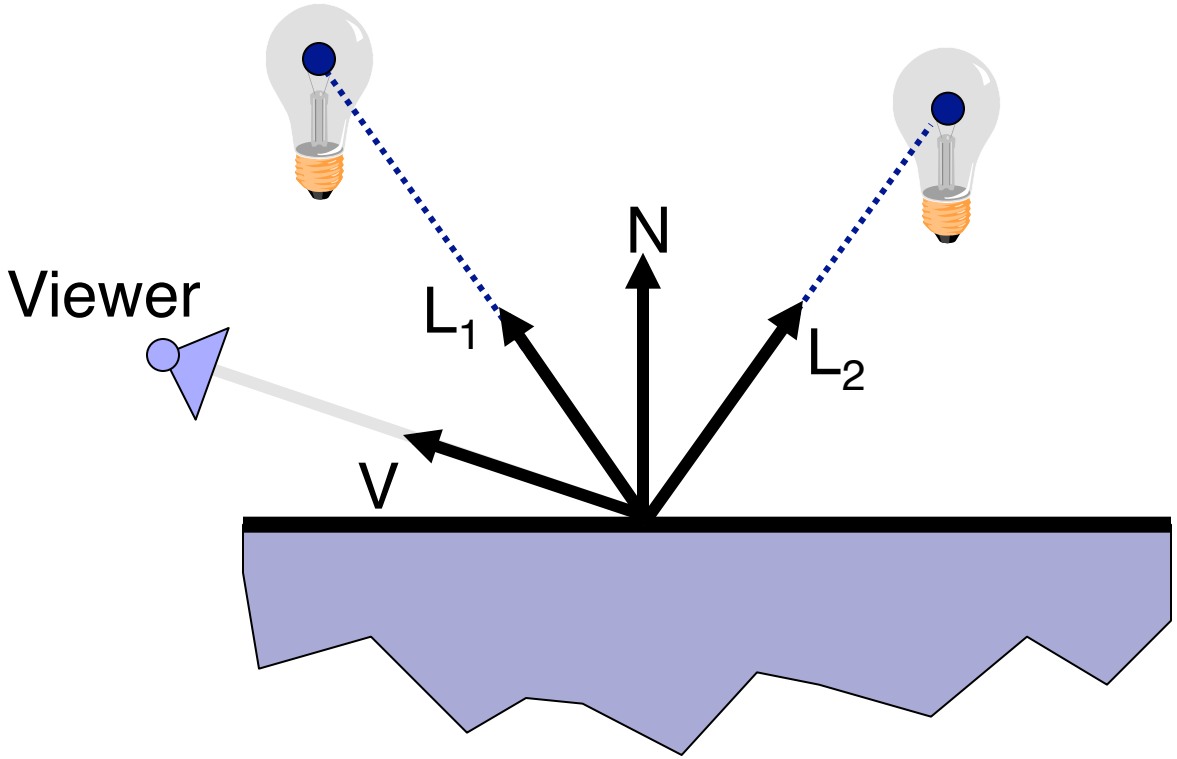
- Represents reflection of all indirect illumination

This is a total cheat (avoids complexity of global illumination)!

Combine colors of light & surface

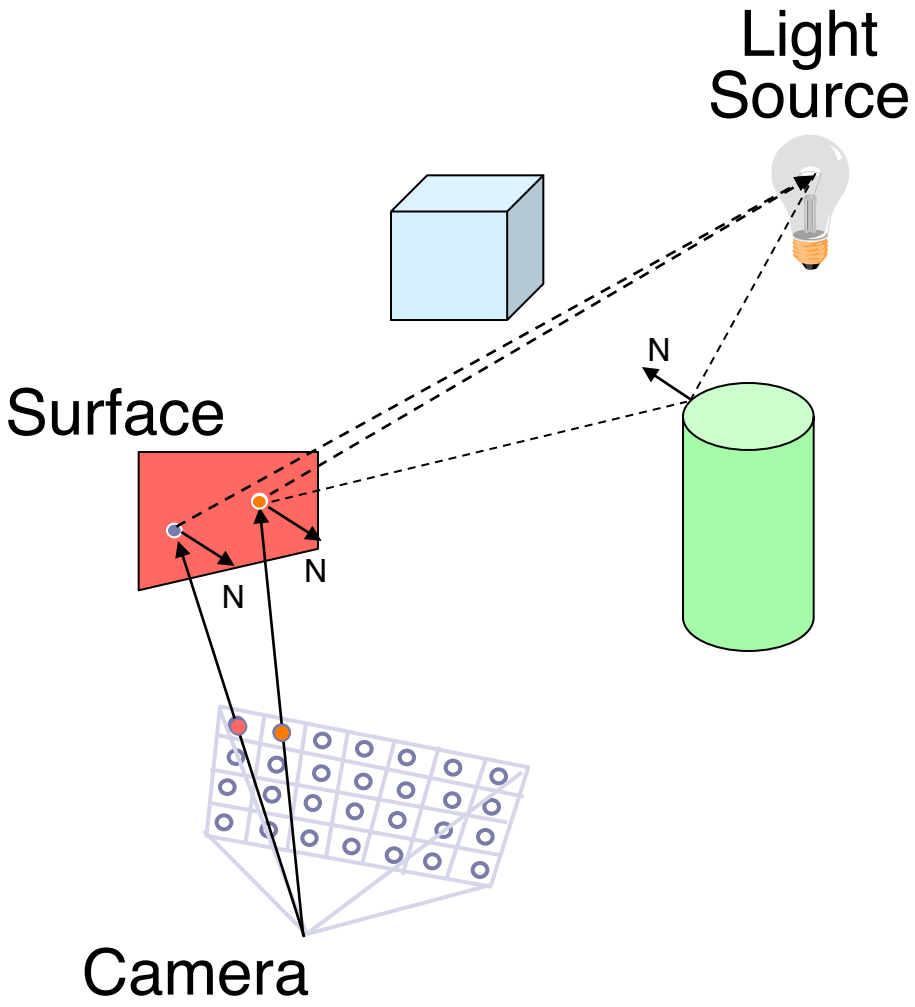


Sum For Multiple Lights



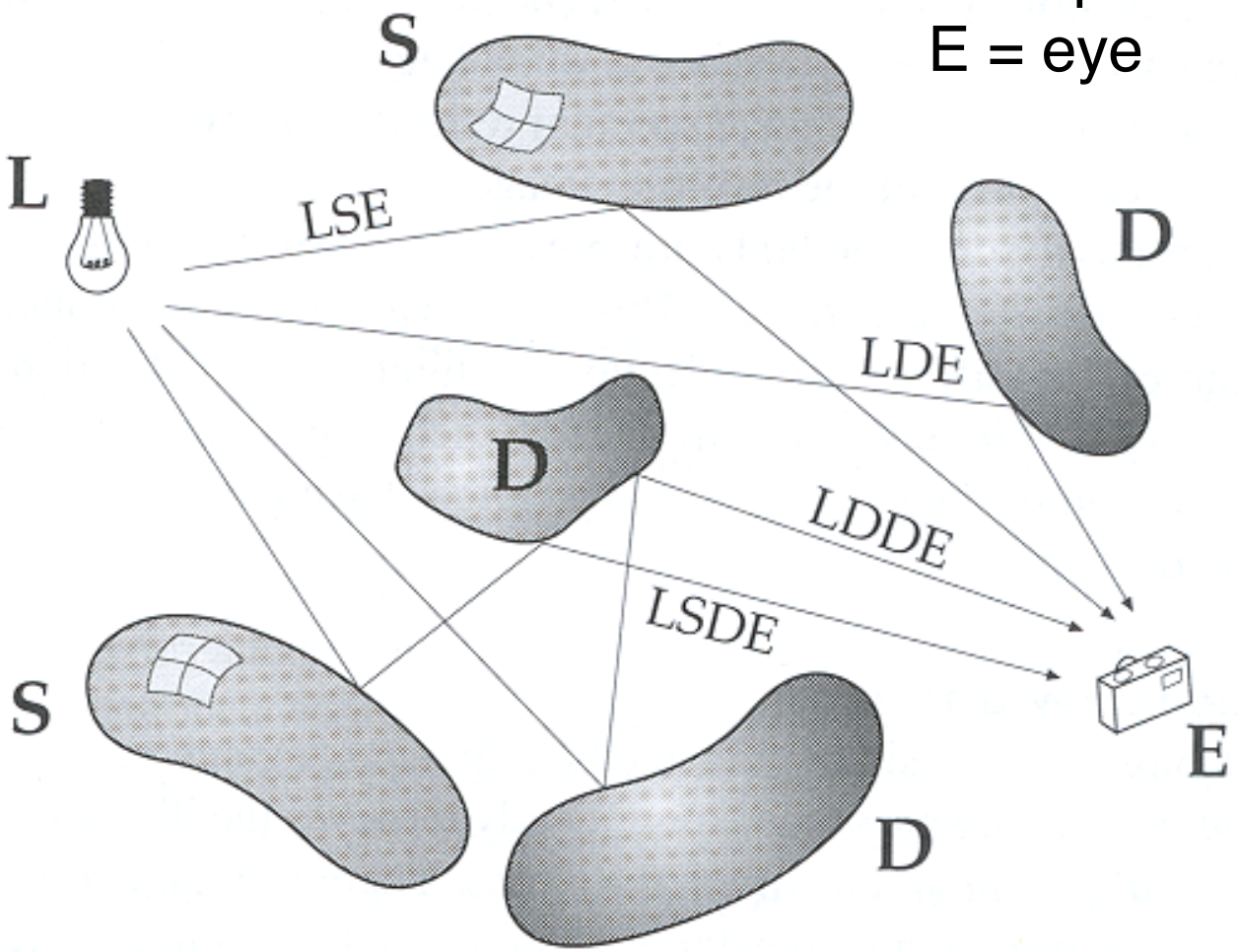
Lighting Simulation

- Direct illumination
  - Ray casting
  - Other methods
- Global illumination
  - Ray tracing
  - Other methods

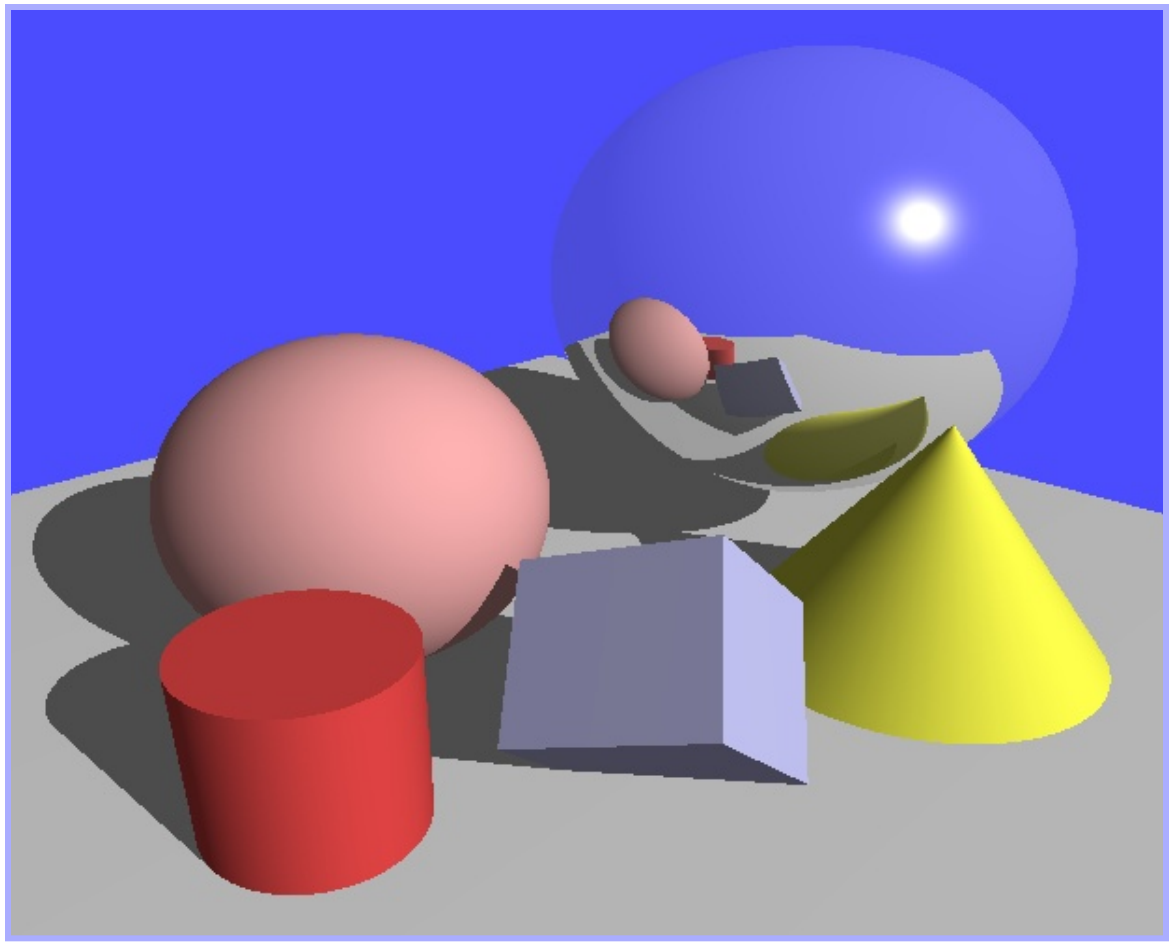


Path Types

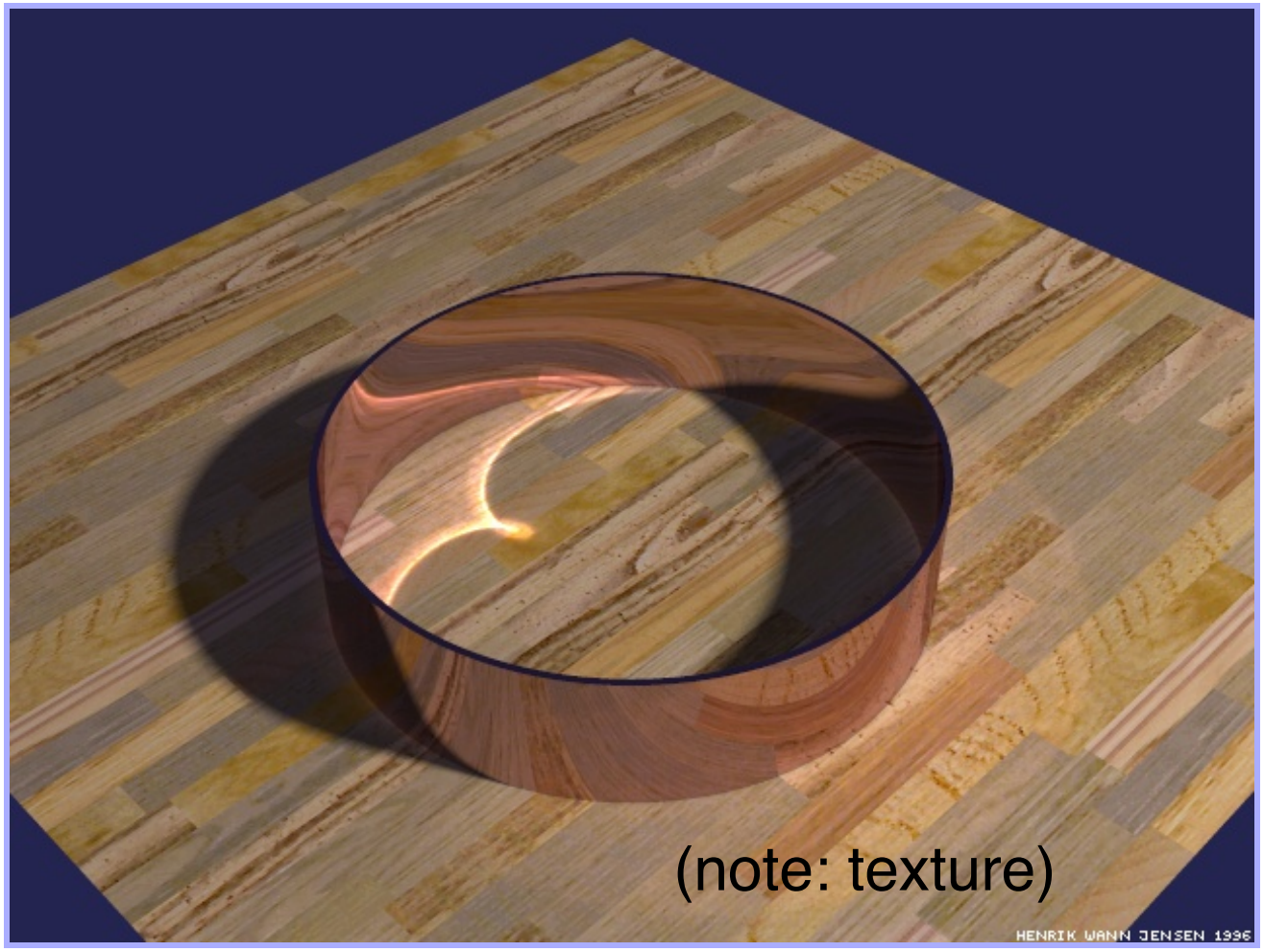
L = light
D = diffuse bounce
S = specular bounce
E = eye



Path Types?



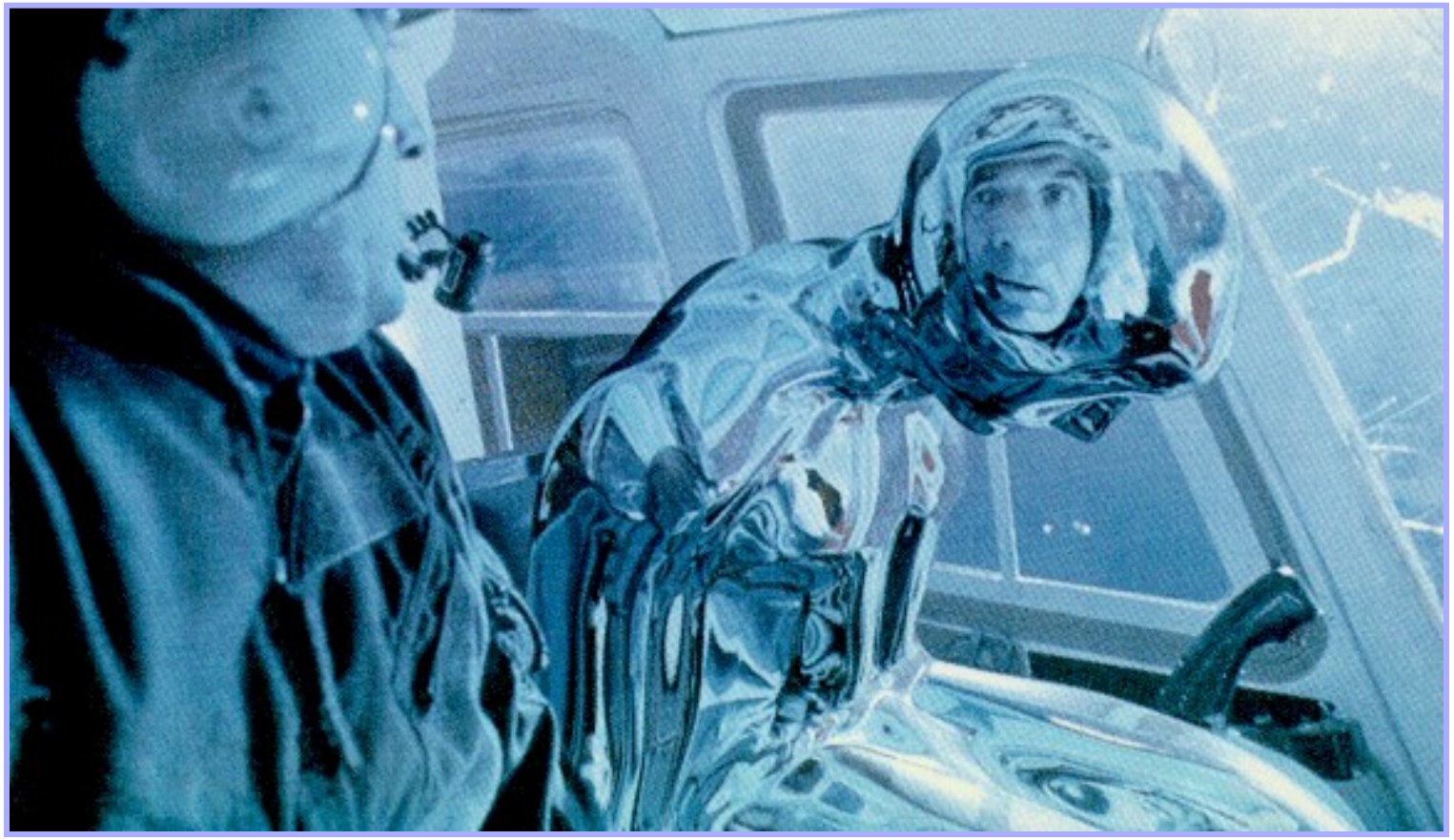
Ray Tracing



Ray Tracing

RenderPark

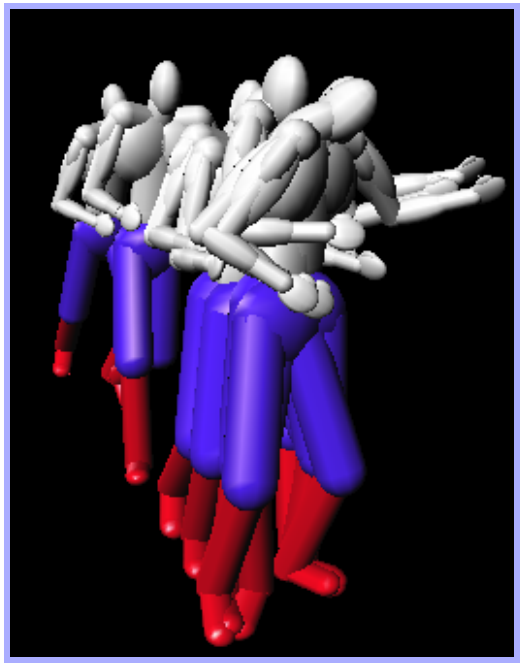
Ray Tracing



Terminator 2

Part IV: Animation

- Keyframe animation
  - Articulated figures
- Simulation
  - Particle systems



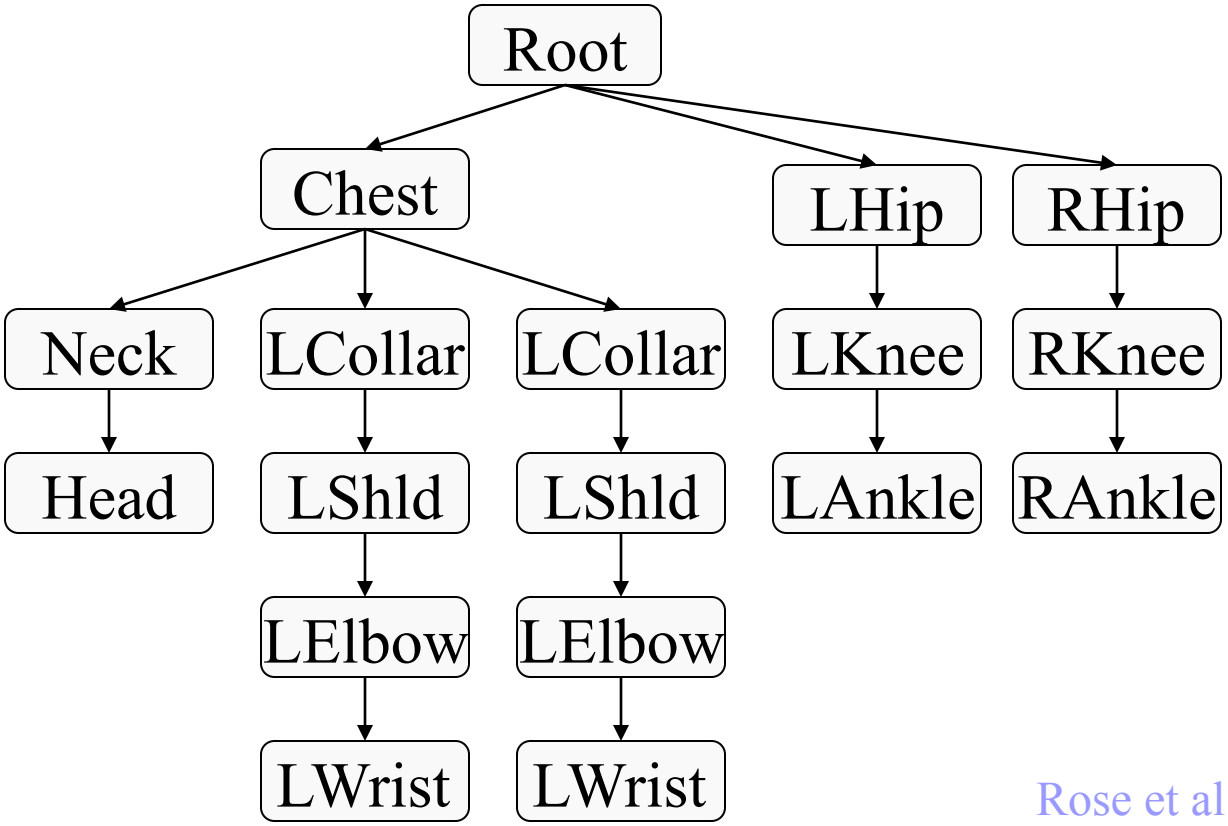
Animation

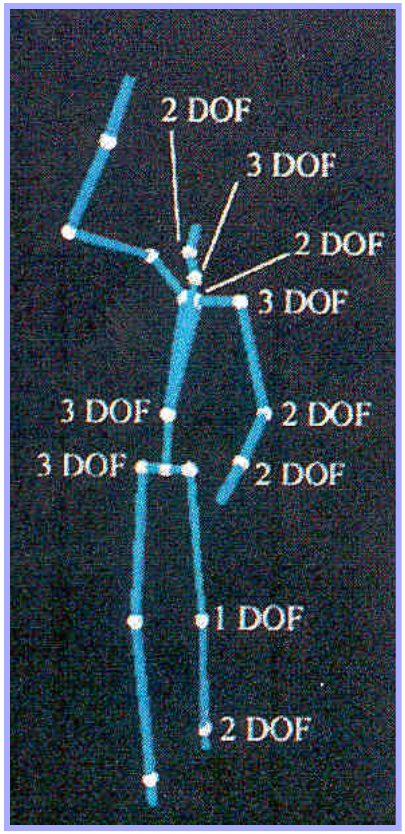
(Jon Beyer, CS426, Spring04)

Simulation

Articulated Figures

- Well-suited for humanoid characters





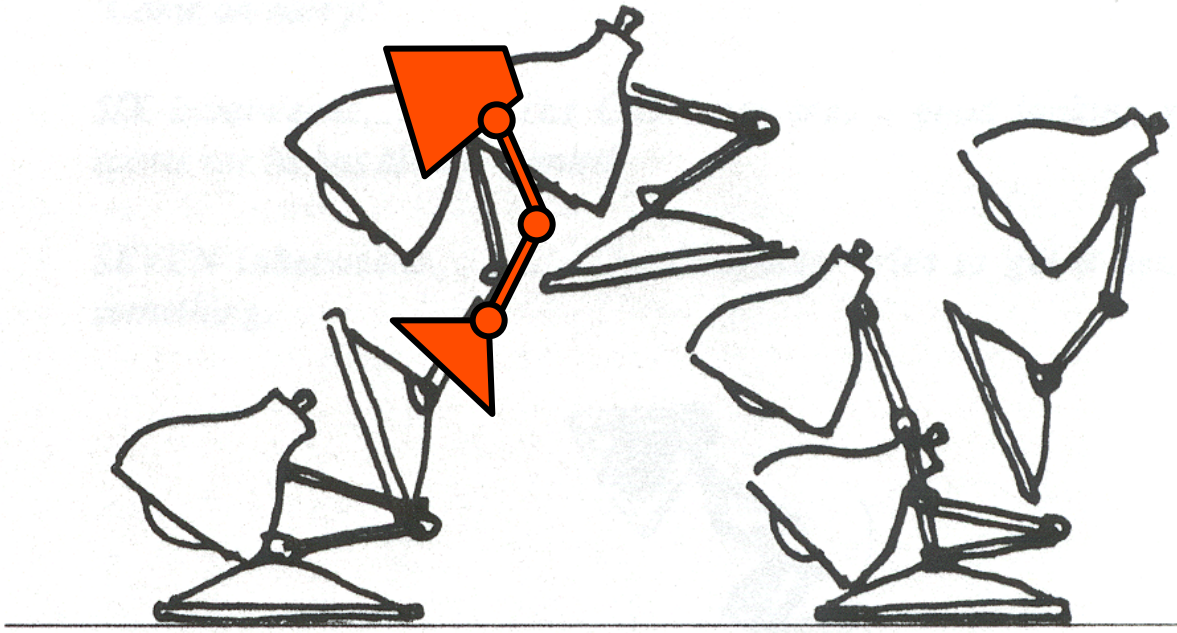
Rose et al. `96

Keyframe Animation: Luxo Jr.

Pixar

Keyframe Animation

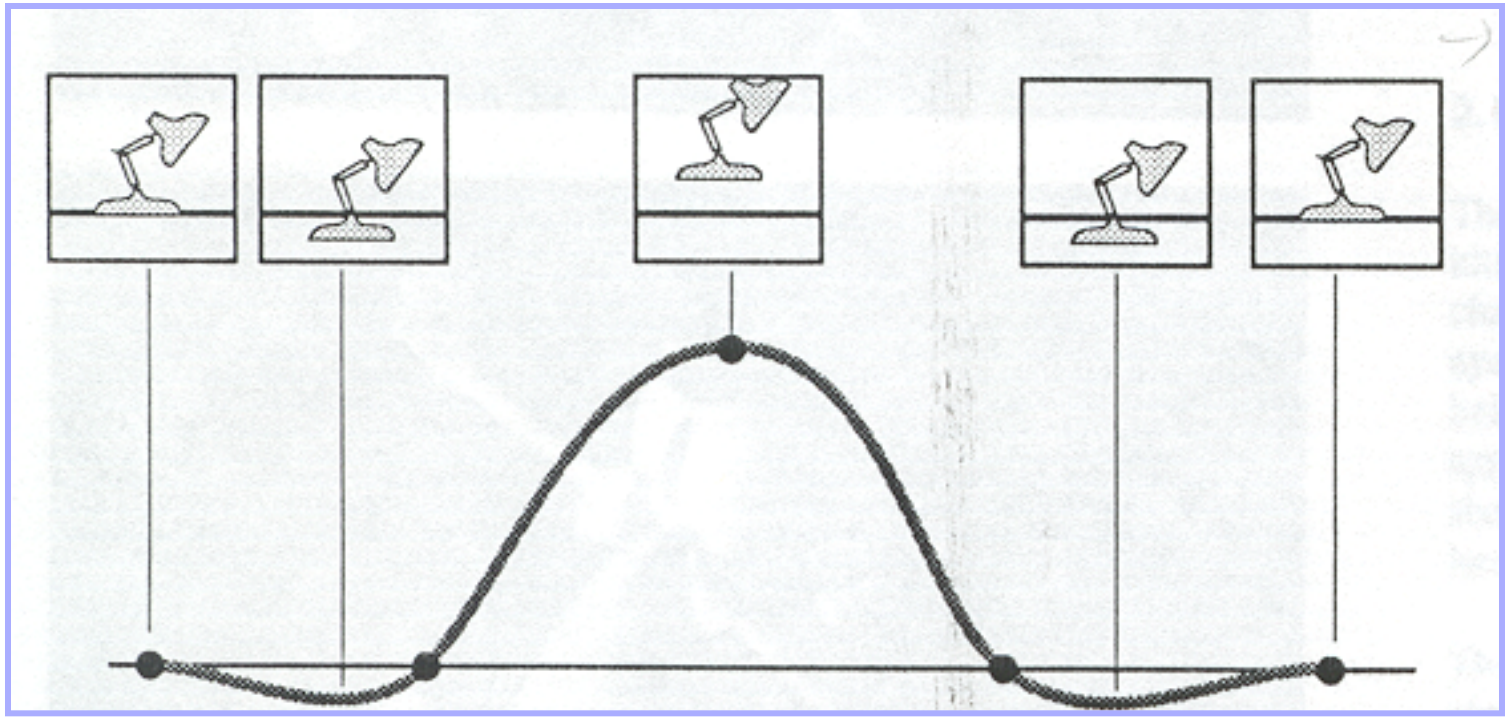
- Define character poses at specific times: “keyframes”
- “In between” poses found by interpolation



Lasseter `87

Keyframe Animation

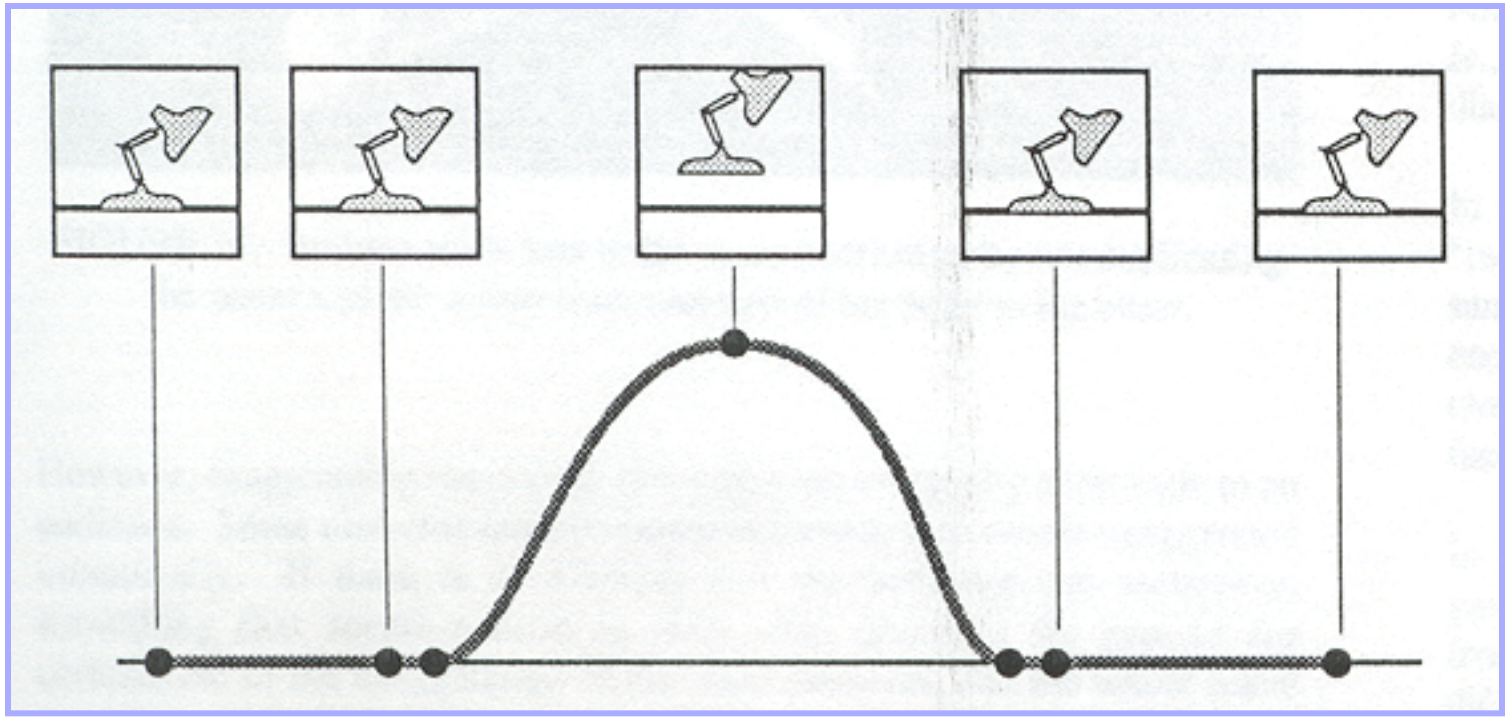
- Inbetweening: may not be plausible



Lasseter `87

Keyframe Animation

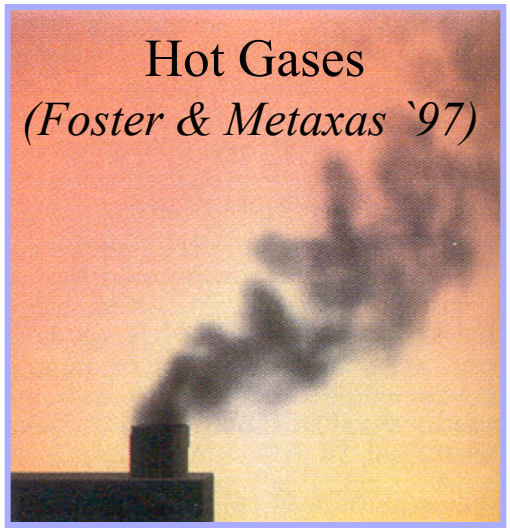
- Solution: add more keyframes

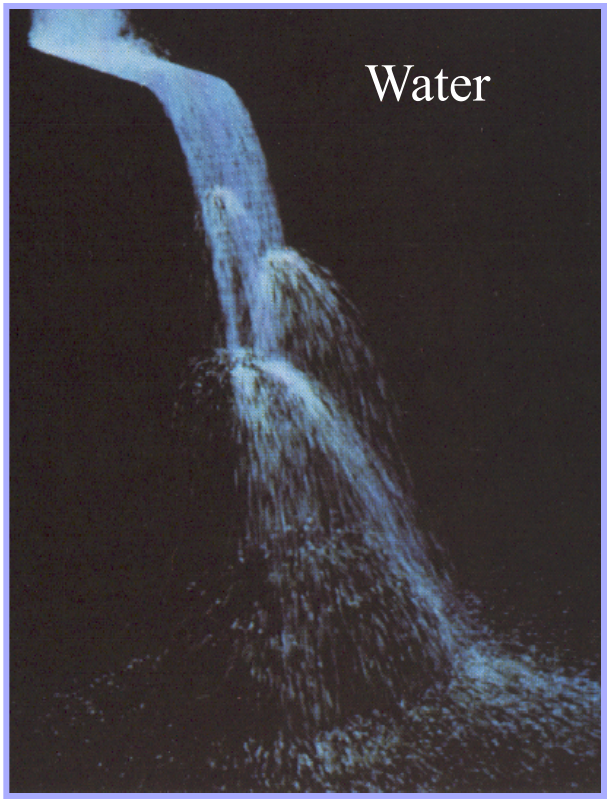


Lasseter `87

Simulation

- Animator cannot specify motion for:
  - Smoke, water, cloth, hair, fire





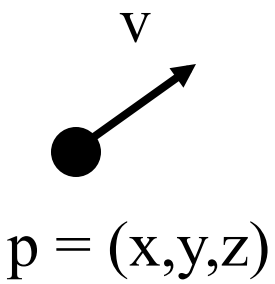
Cloth
(Baraff & Witkin `98)

Particle Systems

- Recall: “Game of Life”
- For each frame (time step):
  - Create new particles and assign attributes
  - Delete any expired particles
  - Update particles based on attributes and physics
    Newton’s Law: f=ma
  - Render particles

Particle Systems

- A particle is a point mass
  - Mass
  - Position
  - Velocity
  - Acceleration
  - Color
  - Lifetime

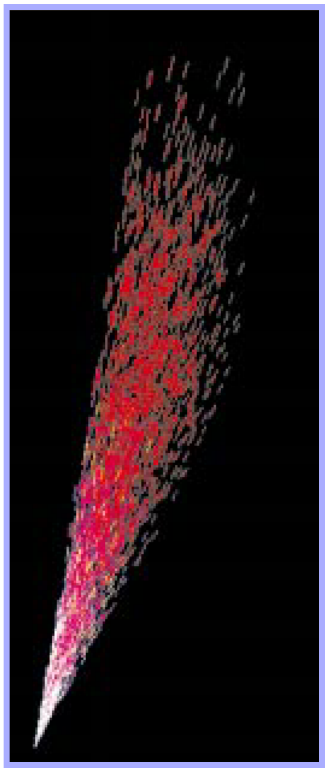


- Many particles to model complex phenomena
  - Keep array of particles

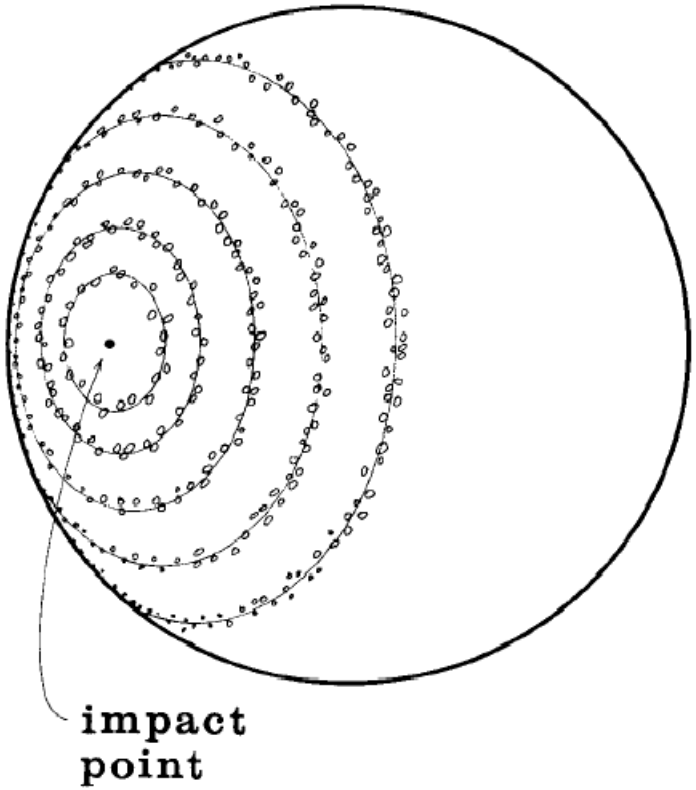
Creating/Deleting Particles

- Where to create particles?
  - Around some center
  - Along some path
  - Surface of shape
  - Where particle density is low
- When to delete particles?
  - Areas of high density
  - Life span
  - Random

This is where person controls animation



Example: Wrath of Khan



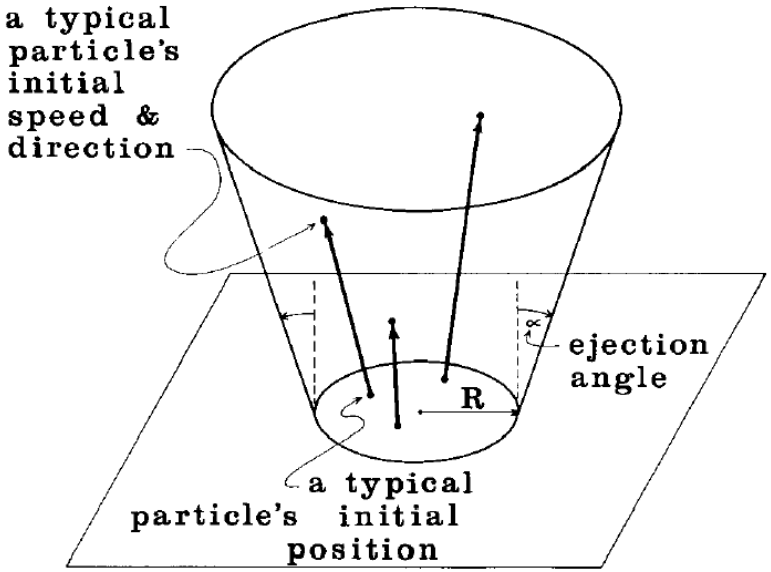
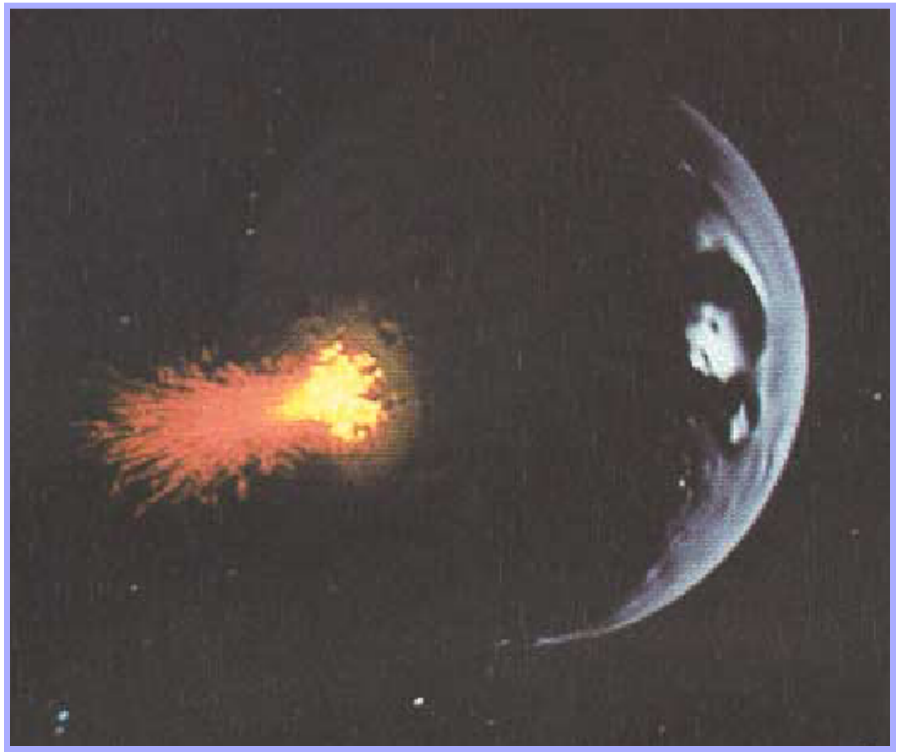
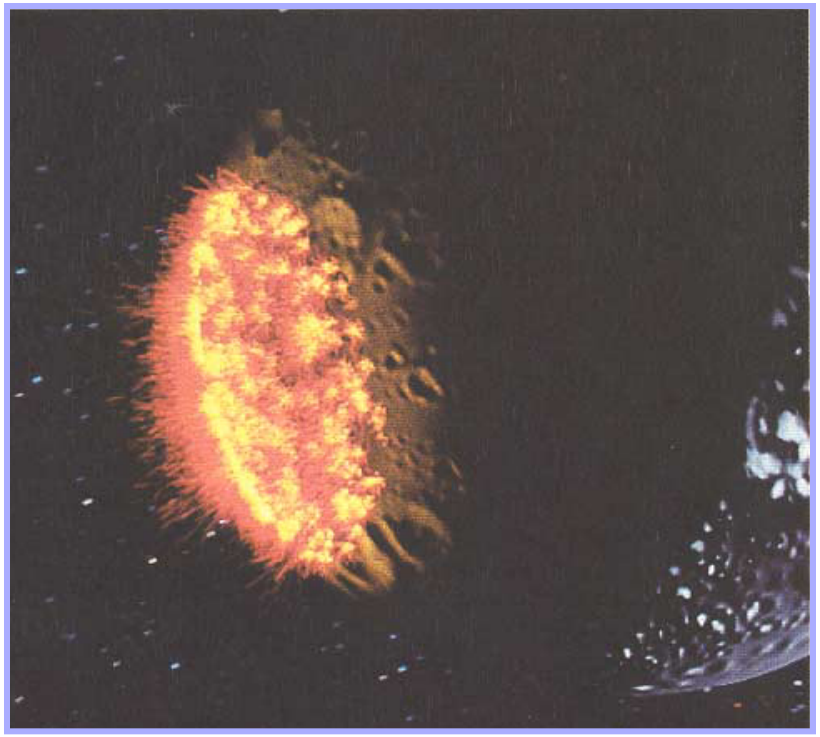


Fig. 2. Distribution of particle systems on the planet's surface.

Reeves

Example: Wrath of Khan





Reeves

Example: Wrath of Khan

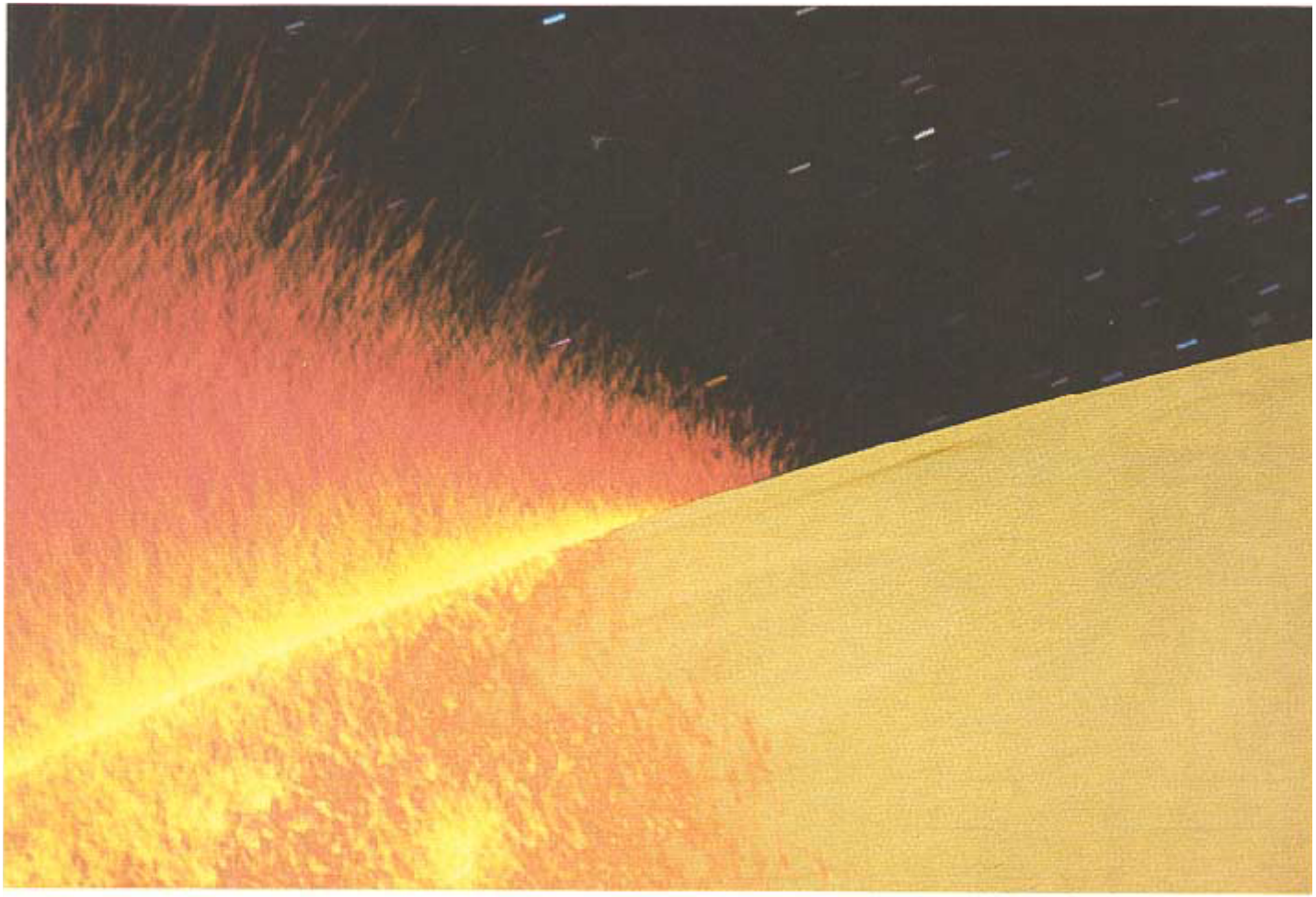
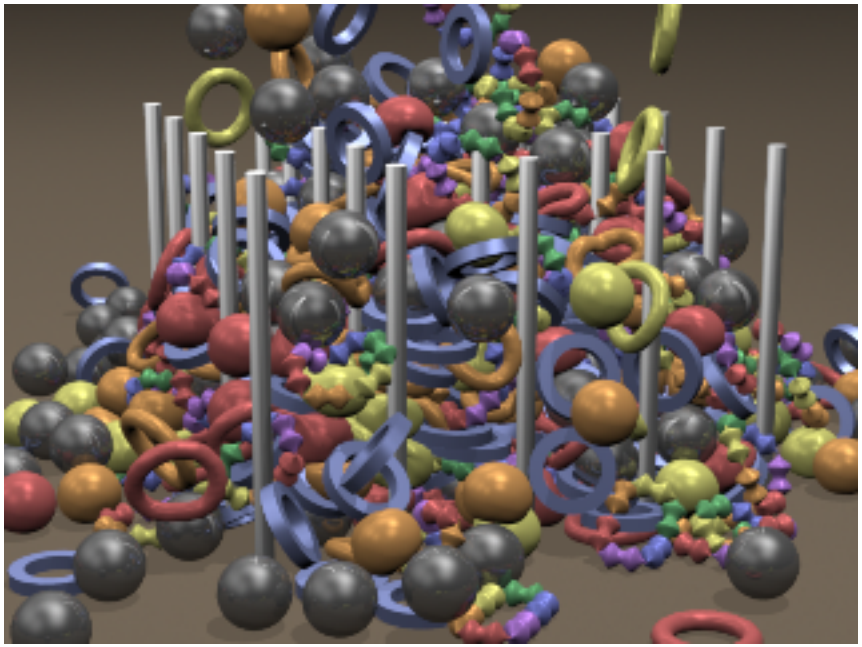


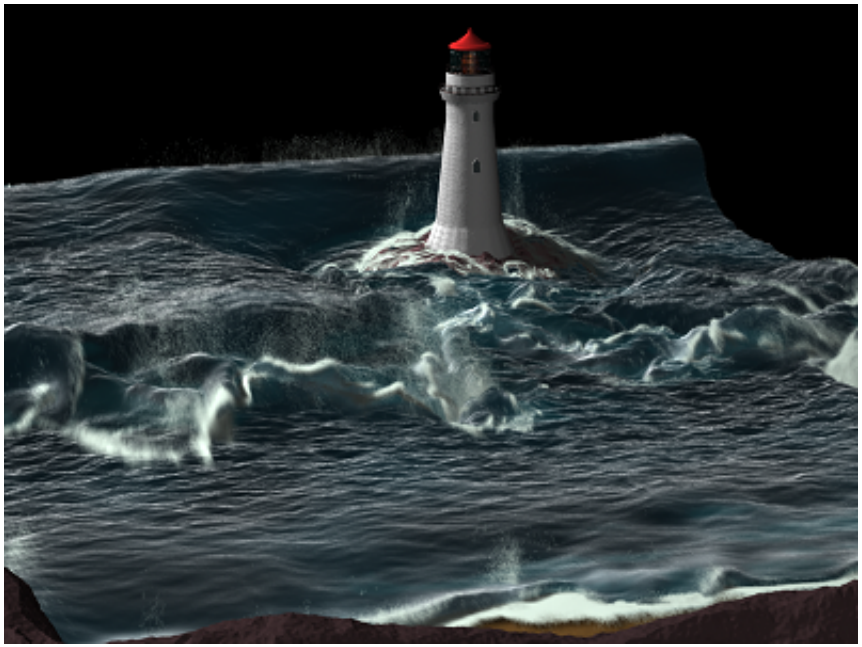
Fig. 7. Wall of fire about to engulf camera.

Reeves

Advances in simulation



Contact
(Fedkiw)



Fluids
(Fedkiw)