CMSC 427: Computer Graphics

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Today's Class

- Whirlwind intro to graphics – basic steps
- This class: Fundamental issues underlying these.
- Class structure and logistics

Computer Graphics: Possible Definitions

- Using computers to create images?
- Creating realistic images of the world
- Also creating semi-realistic images
- Information visualization

Realistic Images

- Geometry
- Lighting/Intensities
- Motion

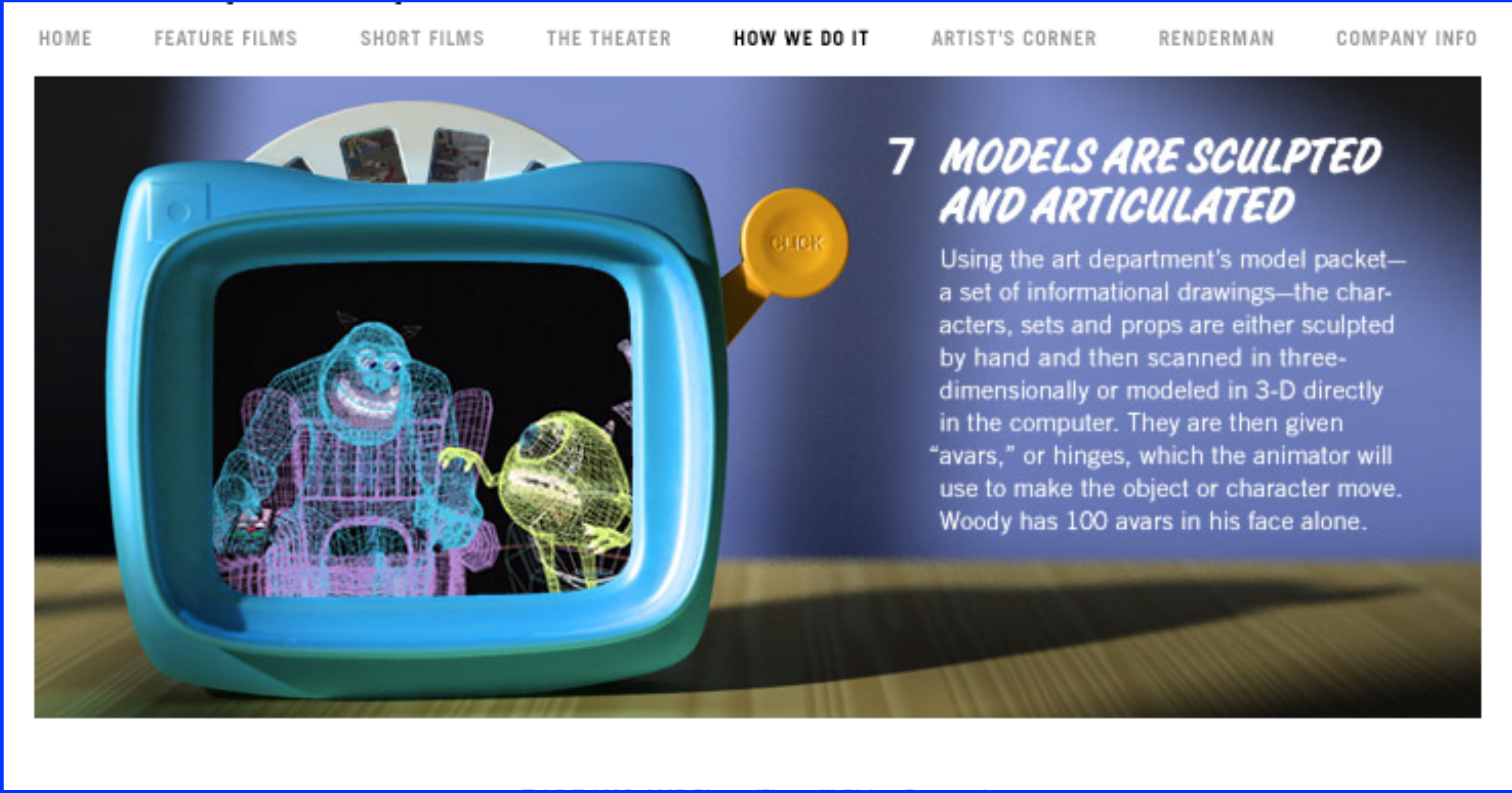
Geometry

- 3D Models
- Projection
- Visibility

Graphics steps

- Modeling
- Rendering
- Lighting
  - Including variations in surface properties
- Motion
- Non-realistic images

Create 3D Models



www.pixar.com

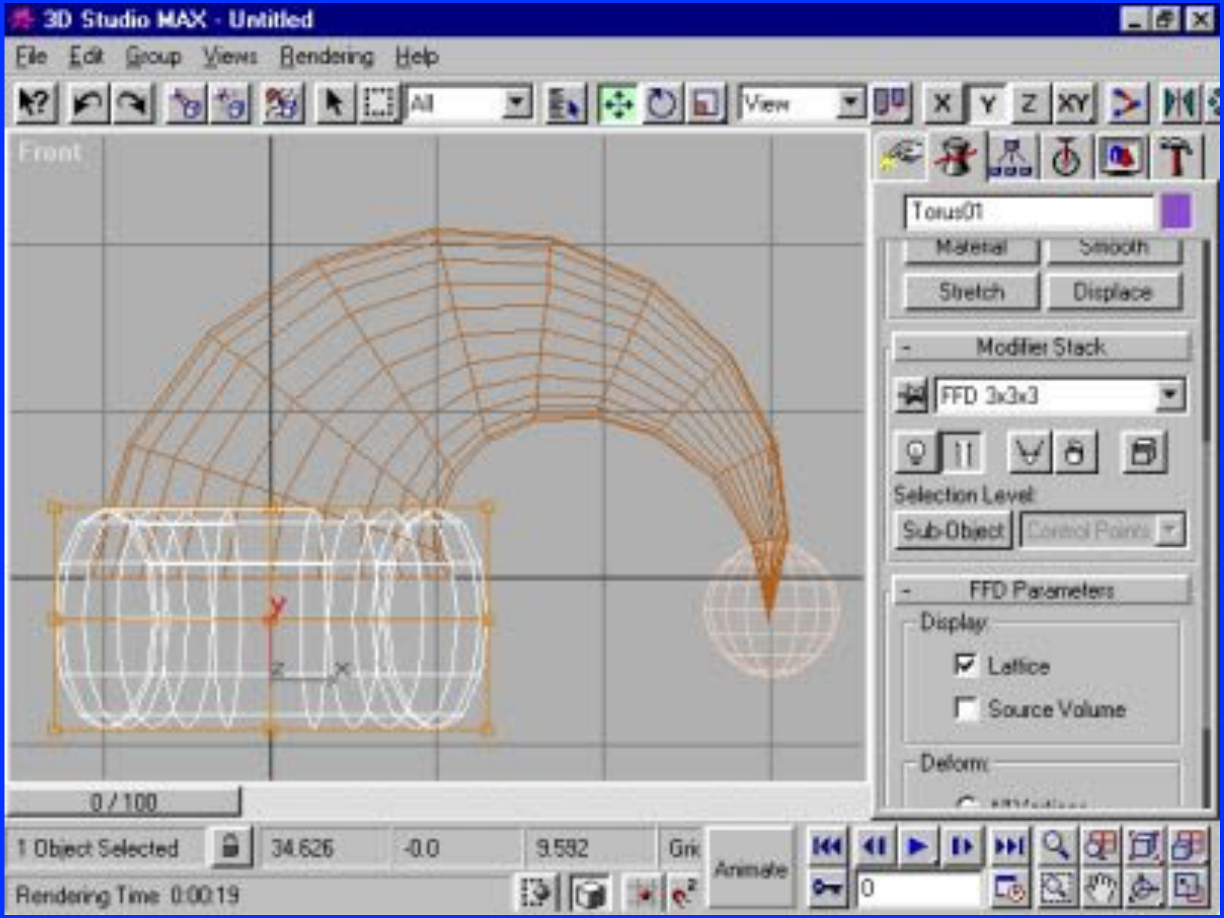
3D Models - Scanning

(http://graphics.stanford.edu/projects/mich/).

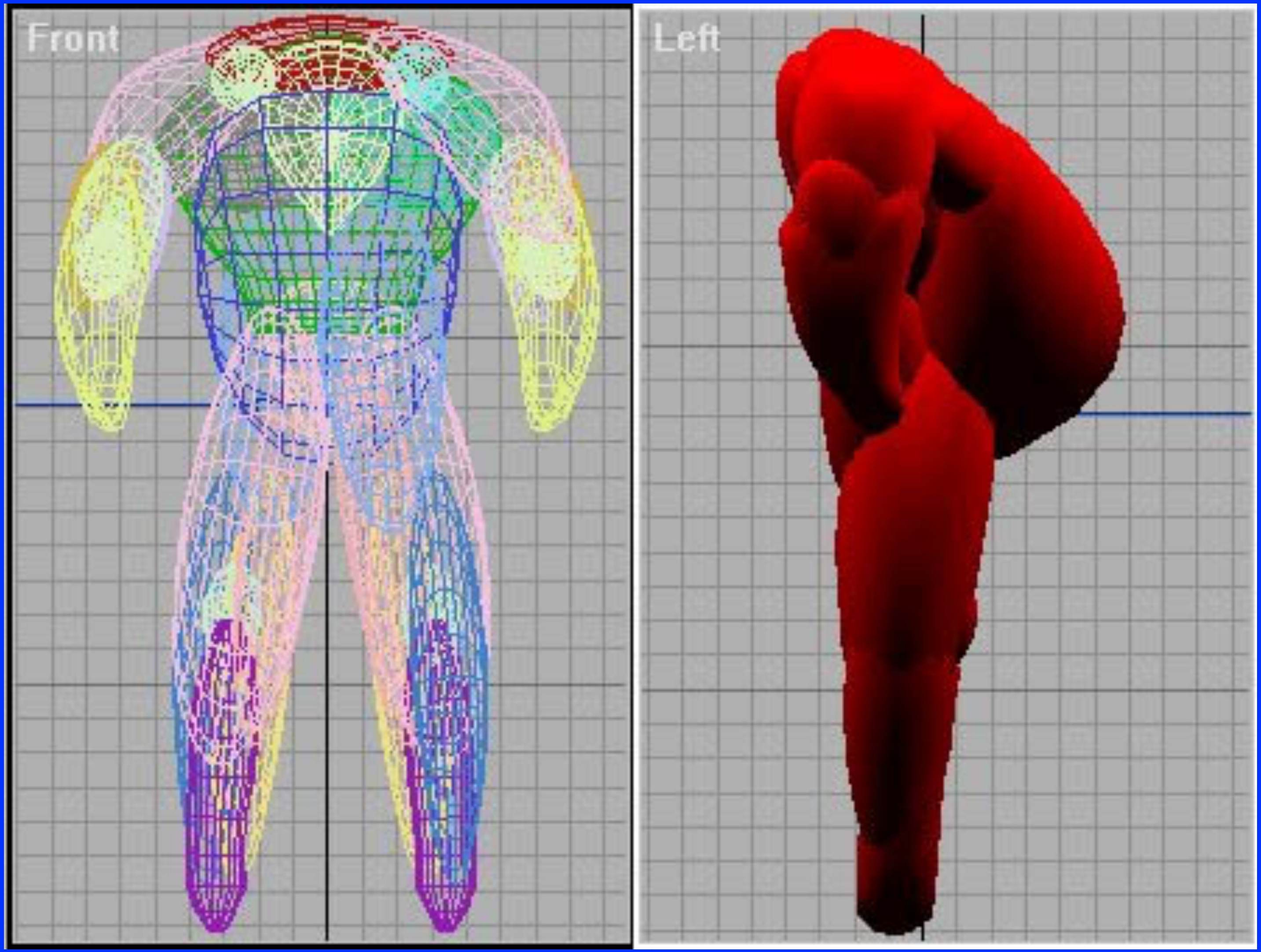
Scanned Model

On the left is a photograph of Michelangelo's David.
On the right is a computer rendering made from a geometric model.
(http://graphics.stanford.edu/projects/mich/).

Build Models on Computer



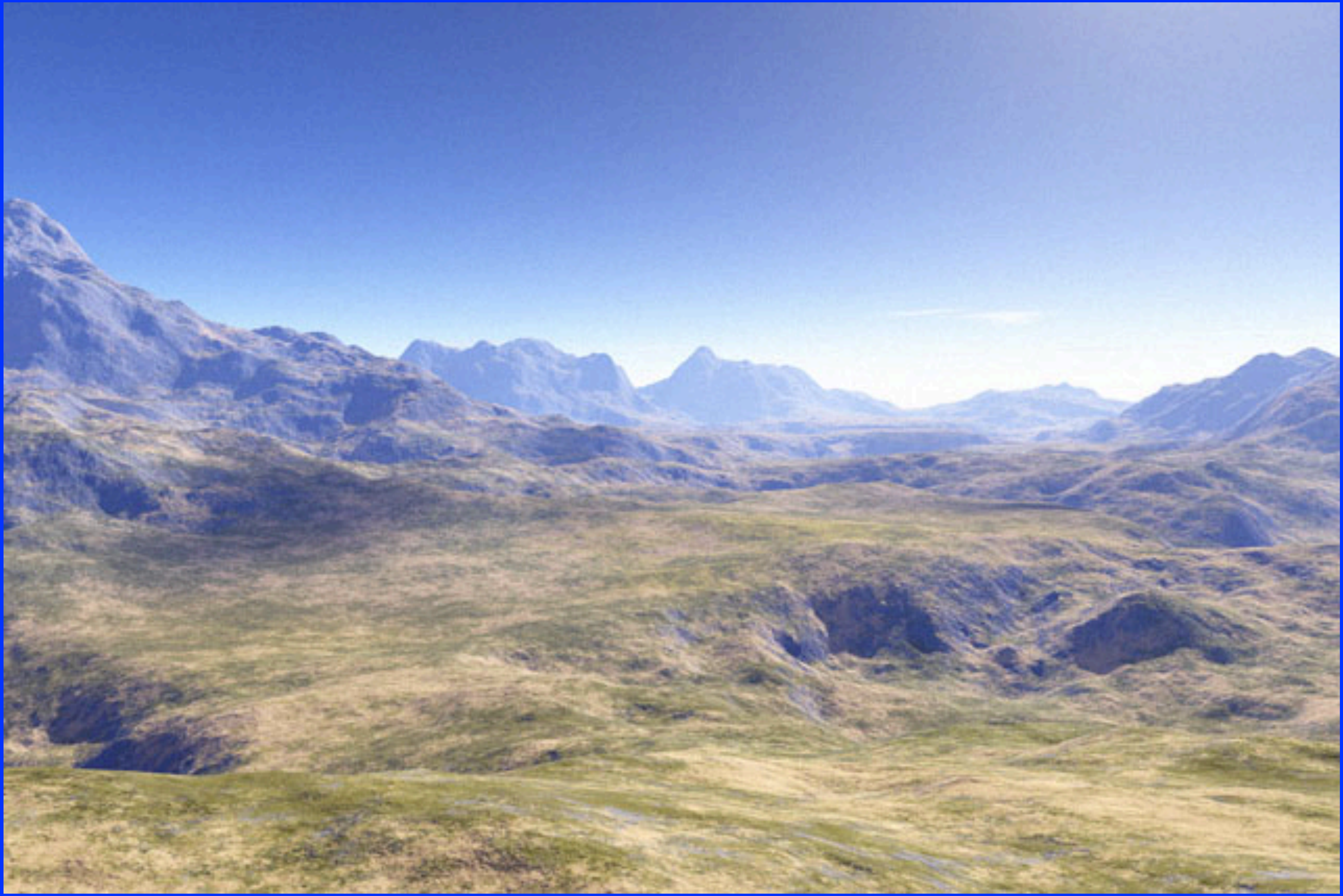
Visualmagic.awn.com/html/tutorials/santa.html


Front
Left

3D models - Generated

Realistic modeling and rendering of plant ecosystems: Oliver Deussen1 Pat Hanrahan2 Bernd Lintermann3 Radom´ır Mˇech4 Matt Pharr2 Przemyslaw Prusinkiewicz4

http://graphics.stanford.edu/papers/ecosys/ecosys.pdf



Fractal Landscape, Wikipedia

Geometry – Projection, Visibility

https://www.youtube.com/watch?v=OE7zhVSVfYY

Lighting

- Modeling Lighting
- Reflectance
- Texture
- Shadows (visibility)
- Interreflections

Lighting

(from Debevec)

Light

Source emits photons

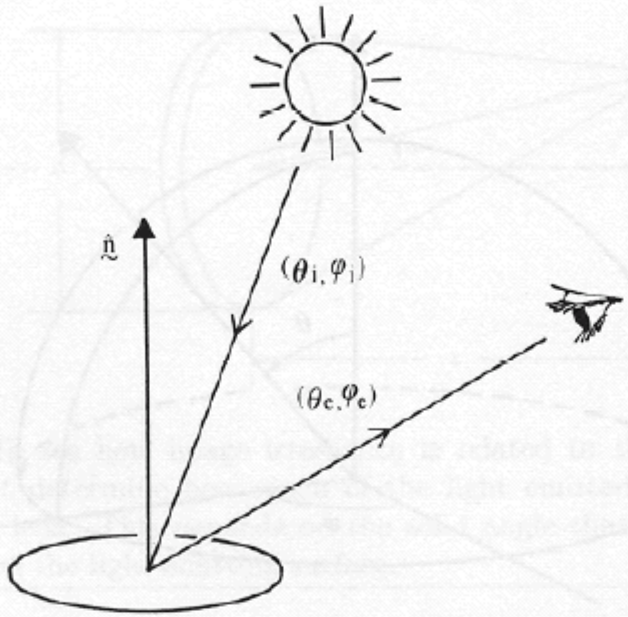
Photons travel in a straight line

And then some reach the eye/ camera.

When they hit an object they:

- bounce off in a new direction
- or are absorbed
- (exceptions later).

BRDF

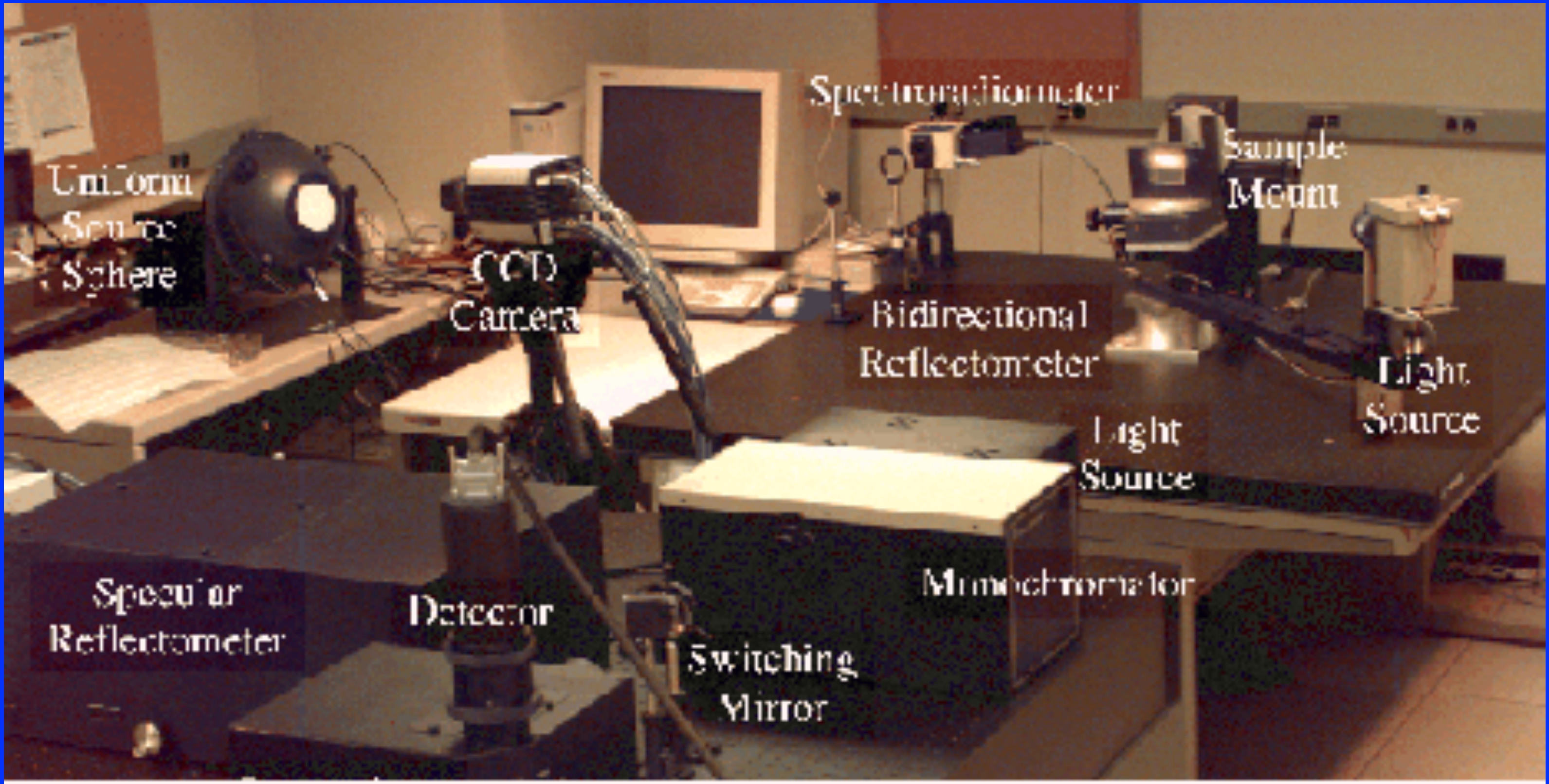


Horn, 1986

Figure 10-7. The bidirectional reflectance distribution function is the ratio of the radiance of the surface patch as viewed from the direction (θ_e, ϕ_e) to the irradiance resulting from illumination from the direction (θ_i, ϕ_i).

$$BRDF = f(\theta_i, \phi_i, \theta_e, \phi_e) = \frac{L(\theta_e, \phi_e)}{E(\theta_i, \phi_i)}$$

Measuring BRDF



Skin Reflectance

BRDF

BSSRDF

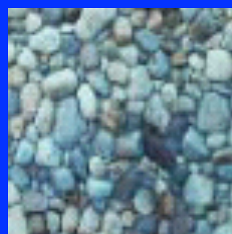
http://graphics.stanford.edu/papers/bssrdf/

(Jensen, Marschner, Levoy, Hanrahan)

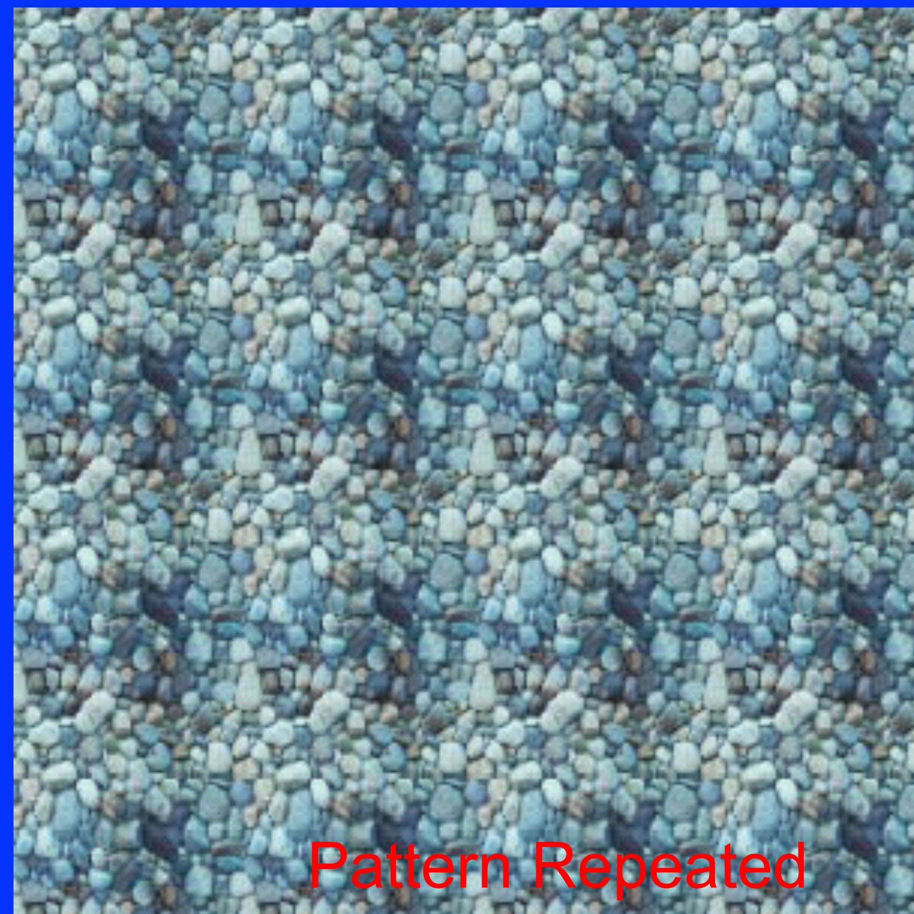
Hair

http://graphics.stanford.edu/papers/hair/hair-sg03final.pdf

Texture



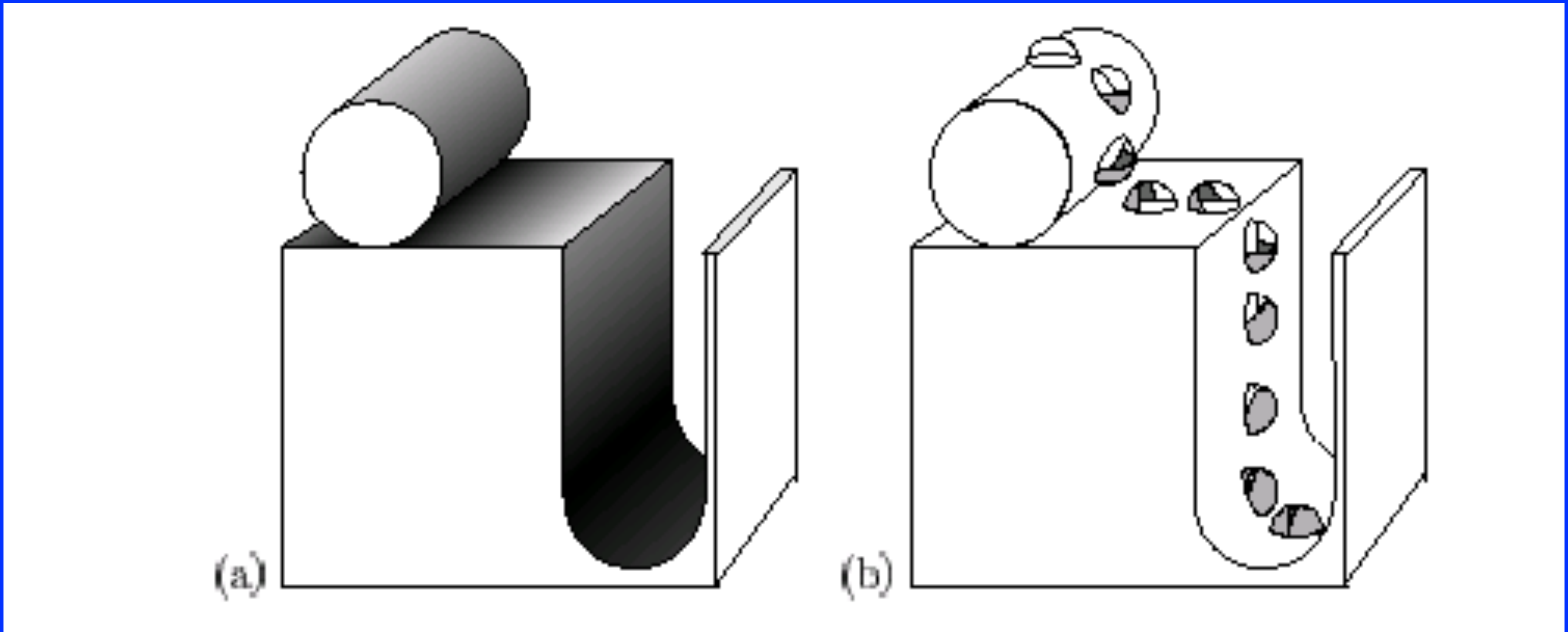
Photo



Texture

Photo

Shadows



(from Langer and Zucker)

Interreflections

Falling Water model, Bruce Walter thesis.
http://www.graphics.cornell.edu/%7Ebjw/bwthesis.pdf

Motion Capture

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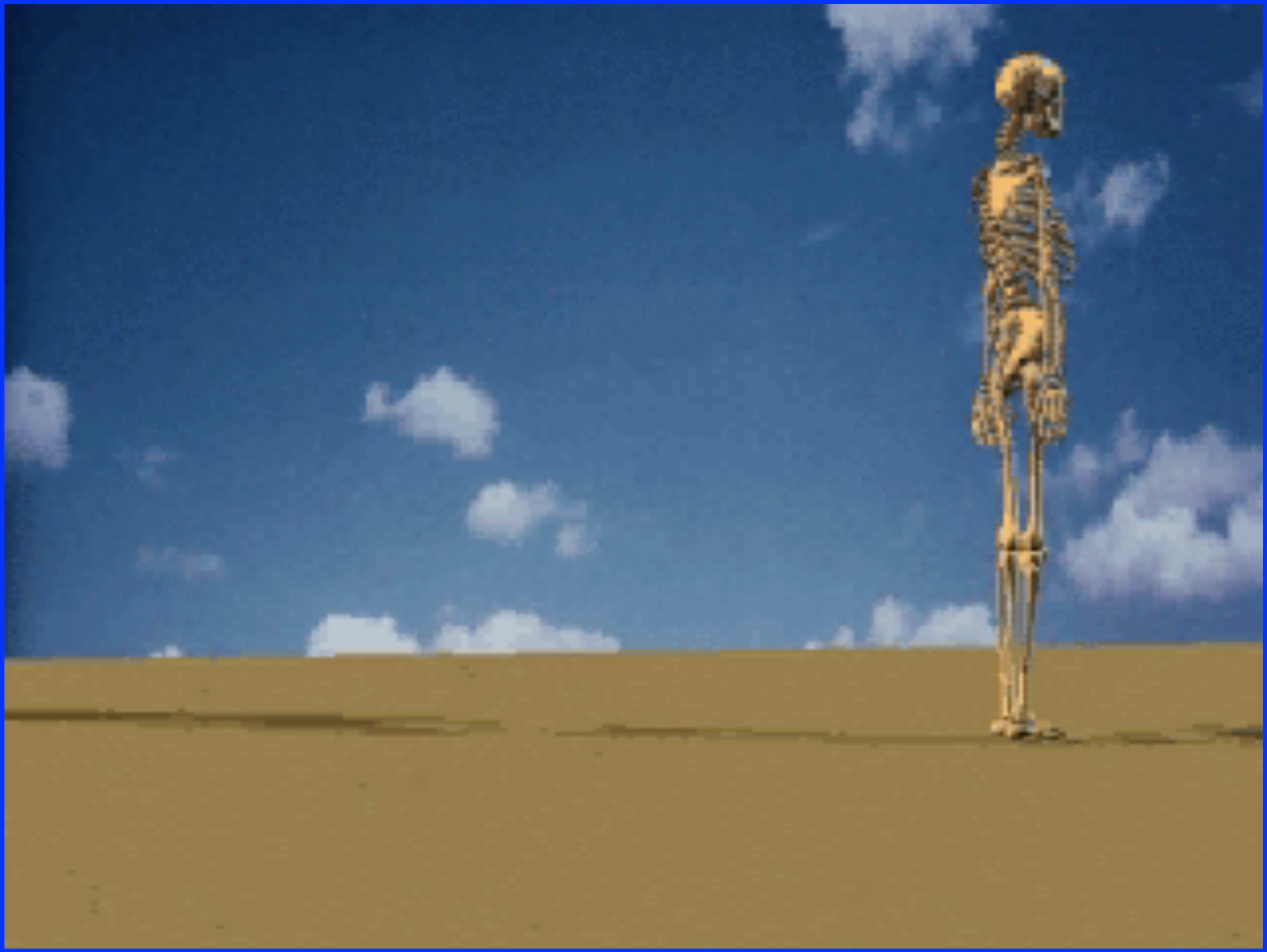


(Terzopoulos)

Physically real motion

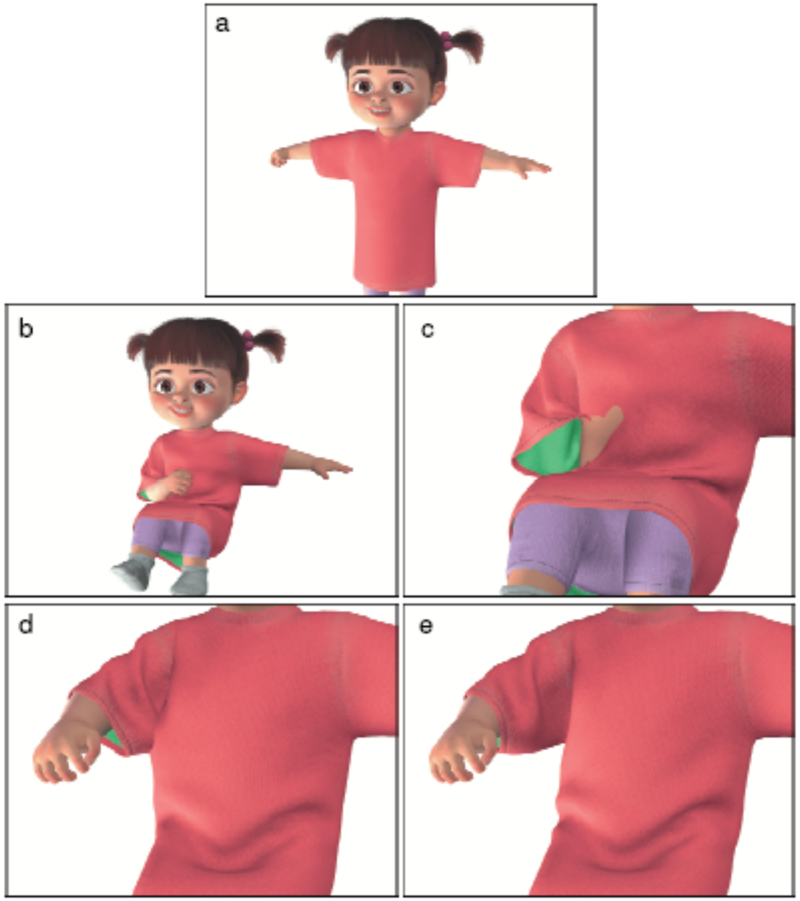
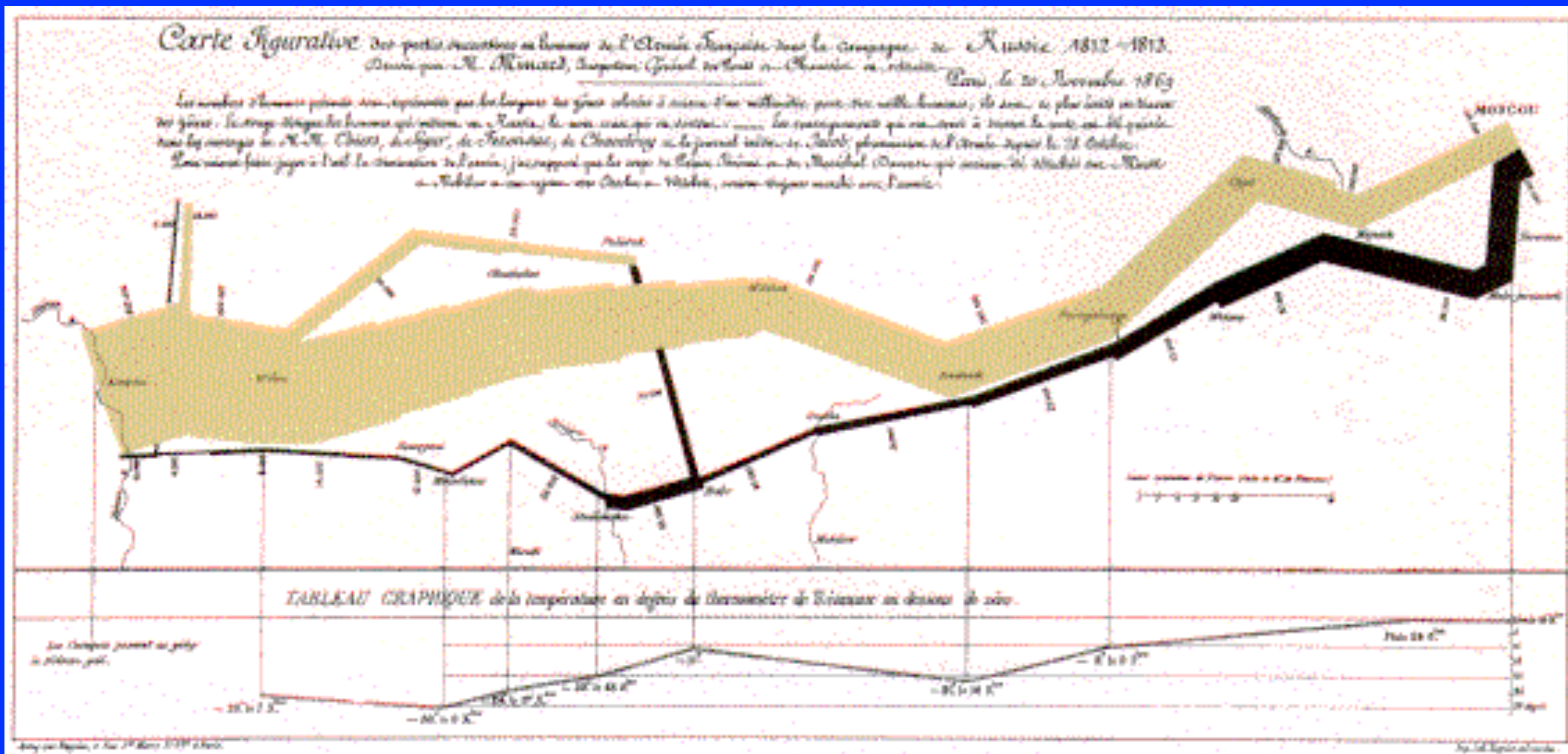


Figure 10: (a) Starting pose. (b) Arm moves in tightly. (c) Close-up view of (b) with right arm invisible. Note how the arm position forces cloth to intersect both itself and the body. (d) Without GIA, a cloth/cloth intersection persists as the arm pulls out, snagging the sleeve. (e) The same frame as (d), but using GIA, the cloth doesn't snag as the arm pulls out.

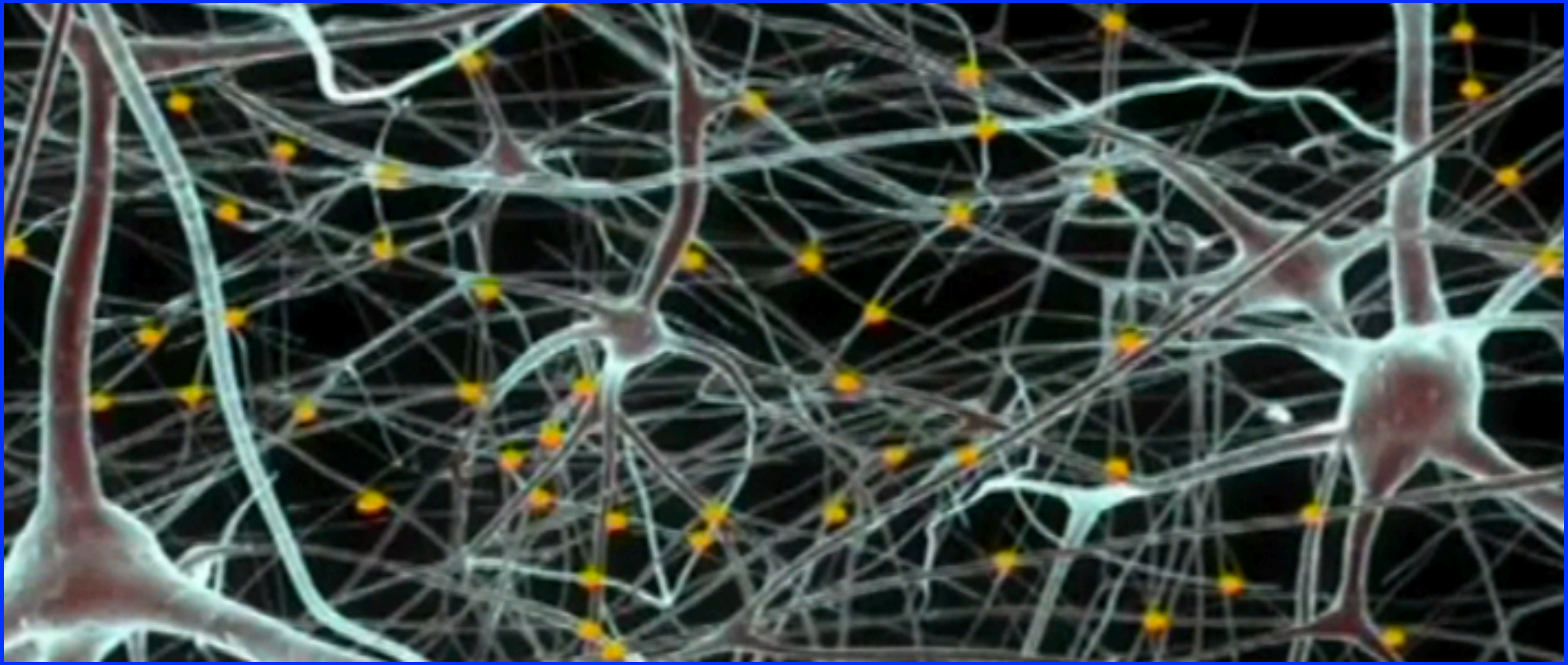
Images based on realism

(De Carlo and Santella)

Visualization – Pre-graphics



Visualization of Brain



Datavisualization.ch

Modern Applications

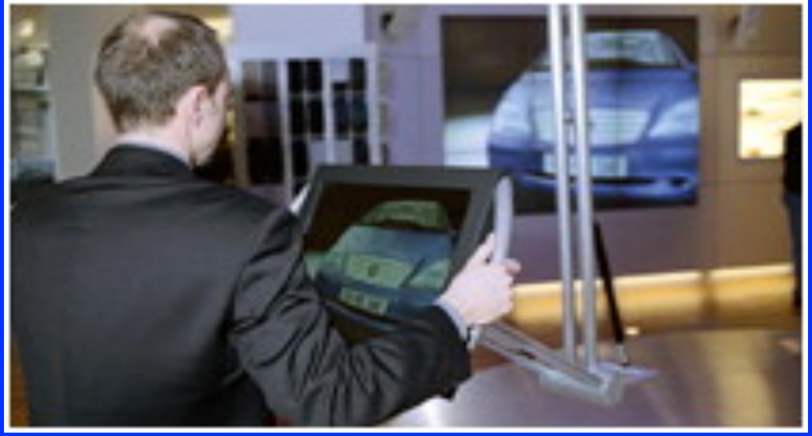
(slides courtesy of Prof. Varshney)

- Computer-Aided Design/Manufacturing
- Medicine
- Biochemistry
- Simulation
- Cartography
- Electronic publishing
- Computer Animation / Film Production
- Art
- Games
- Virtual/Augmented Reality

Film Production

Computer Games

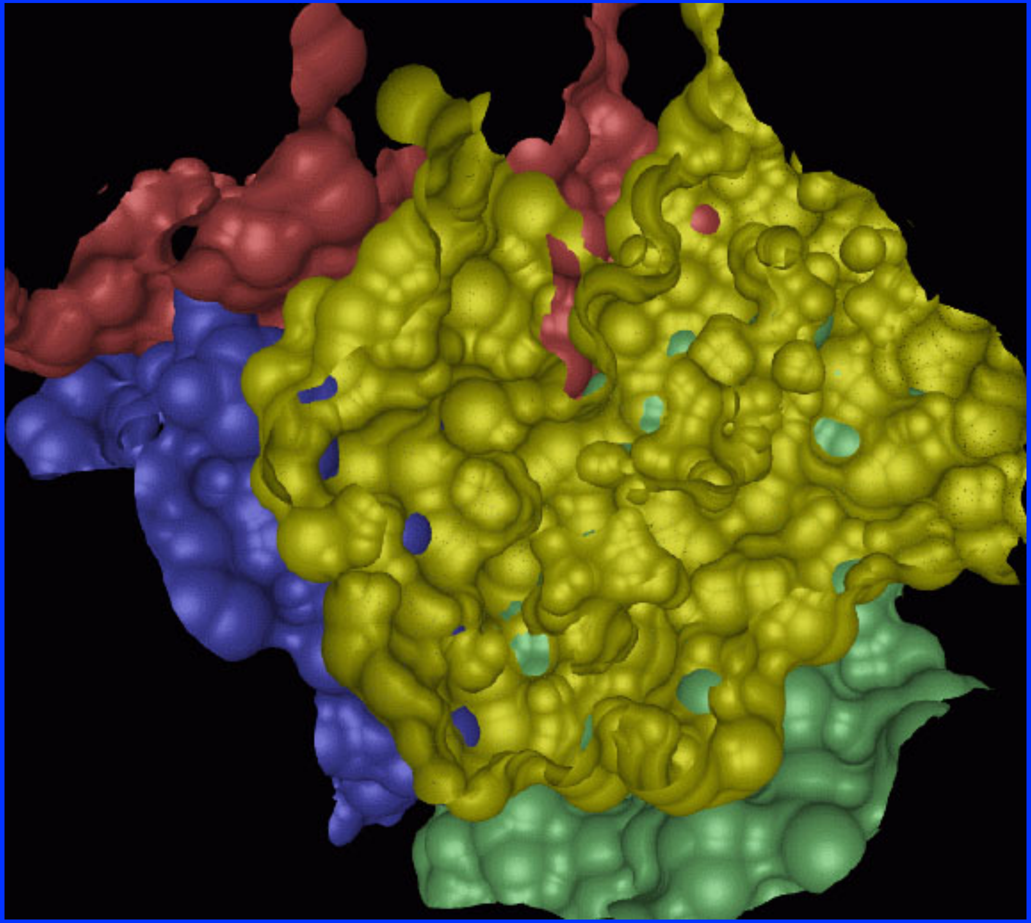
Computer-Aided Design



Virtual Car

Images courtesy Mercedes-Benz

Drug Design

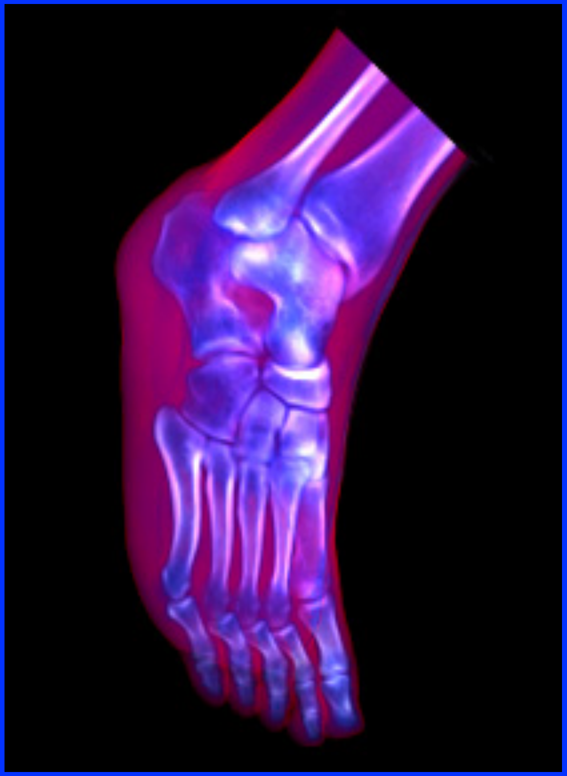


Complementarity of Transthyretin Domains

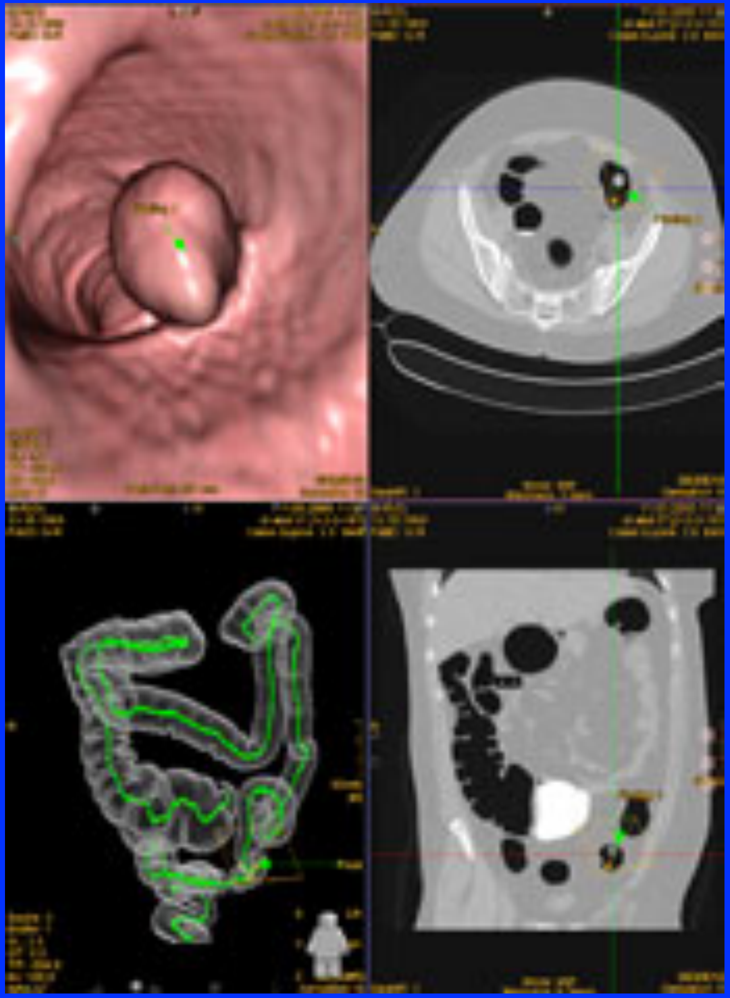
Architectural Walkthroughs

Image Courtesy
Lightscape

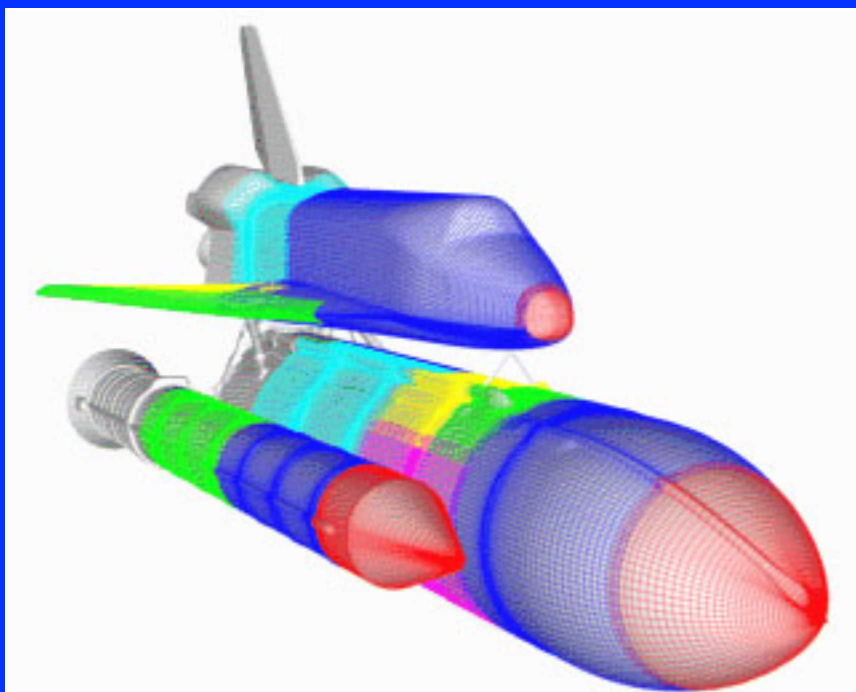
Medical Imaging

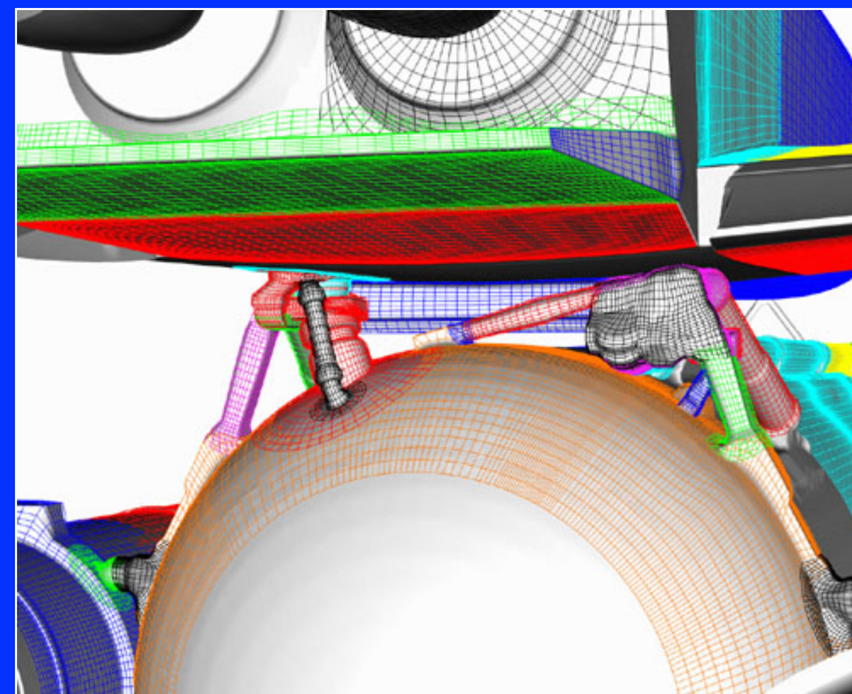


CT Volume Rendering
Image courtesy: GE CRD Labs



Computational Simulations





Flow Fields for Space Shuttle Launch Vehicle

Image Courtesy: Fred Martin *et al.*, NASA Johnson Space Center

What this class is about: Topics

- Geometry
  - Geometric primitives for modeling
  - Motion
  - Perspective
  - Visibility – intersecting lines and surfaces.
- Light
  - How it travels, and is reflected from surfaces.
  - Shadows, radiosity, shading, ray tracing
- Image Processing
  - Blurring, sharpening, image resizing
  - Going between the continuous and the discrete
    - Building continuous objects from discrete input.
    - Movies from discrete input (morphing).
    - Digital images from continuous fields of light.

What class is about: Fundamentals (math) and algorithms

- Inner product – distance in a direction
  - Containment, creating coordinate systems, visibility
- Projection
  - Turning 3D into 2D
- Interpolation
  - Representing lines, z-buffers, morphing, shading, curves, key-frame animation, Perlin noise, image-based rendering
- Sampling – Fourier transform and aliasing
  - Turning light into pixels, image resizing, texture mapping
- Optics
  - Specularities, refraction, shadows, BRDFs, color spaces

Other principles we won’t have much to say about

- Physics
  - Gravity constrains how things move.
  - Simulation of materials (hair, clothing).
- Aesthetics
  - Does it *look* real.
  - Non-realistic may look better.

What we’ll learn

- Fundamental principles/math
- Algorithms
- Programming – OpenGL

Text

- Recommended:
  - Computer Graphics with OpenGL by Hearn
  - Interactive Computer Graphics by Angel
  - OpenGL Superbible by Sellers

Course Requirements

- Prerequisites
  - Linear Algebra
  - CMSC 420 (programming experience)
- Assignments
  - Problem Sets (7)
    - Programming in OpenGL
    - Pencil and paper problems.
    - Challenge problems
  - Quiz, Midterm, Final
  - Presentation for final problem set.

Syllabus

Logistics

- Teacher–David Jacobs djacobs@cs.umd.edu
  - Office hours, Tue: 3-4, Wed. 4-5 (or email for an appt. or stop by).
- TA – Zheng Xu
  - Office hours Wed. 10-12
- Assignments
  - Handing in – Email with paper copies
  - Late policy - Homework due start of class. Due Thursday, late penalty of 10% if 24 hours late. 30% penalty if 11am next Monday. Not accepted later. Due Tuesday, late penalty 10% for 24 hours, 20% for 48 hours, no later.
- Piazza