



Introduction to Computer Graphics CSC4302



Prerequisites

- Linear algebra
- Familiarity with:
 - Vectors (dot products, cross products...)
 - Matrices
 - C++ or Java
 - Object oriented programming

Topics:

- ❖ A survey of computer graphics
- ❖ Overview of graphics systems
 - Video display devices: raster-scan & random scan
 - Input devices
- ❖ Output primitives (Graphics Algorithm)
 - Pointes and lines operations
 - Line algorithms
 - Circle generation algorithms
 - Bresenham's line algorithm
- ❖ Fundamental of two & three dimensional viewing
 - Coordinate transformations
 - Two-dimensional viewing functions
 - Clipping operations: line, point, polygon, and text
 - Scan-Conversion

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Topics Con'd...

- ❖ Camera modeling
- ❖ Computer-Human Interface
 - Animation
 - Visual realism

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What is Computer Graphics?

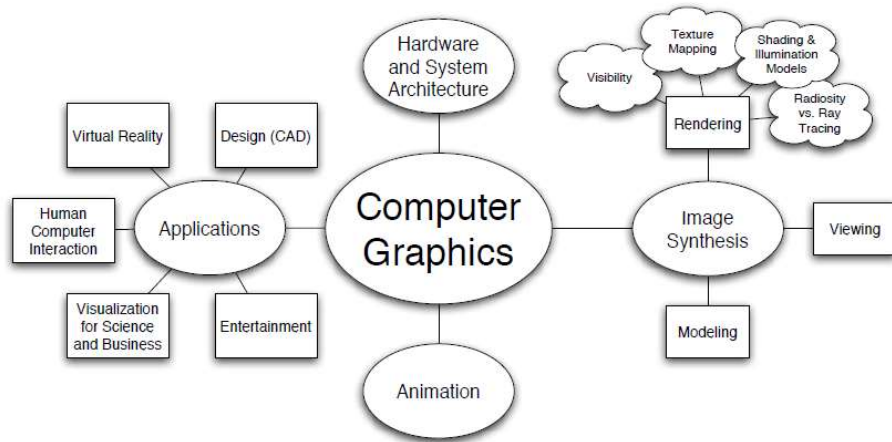
- Creation, Manipulation, and Storage of geometric objects (modeling) and their images (rendering)
- Display those images on screens or hardcopy devices
- Image processing
- Others: GUI, Haptics, Displays (VR)
- CG is technology to apply different mathematics tricks to manipulate some change(s) in image or picture's properties like shape, size, motion etc. through the help of computer...

What Is Computer Graphics?

- Using a computer as a rendering tool for the generation (from models) and manipulation of images is called *computer graphics*
- More precisely: *image synthesis*



What Is Computer Graphics?



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Intro. Cont..

- ❖ Computer graphics is concerned with producing images and animations (or sequences of images) using a computer.
- ❖ This includes the hardware and software systems used to make these images.
- ❖ The task of producing photo-realistic images is an extremely complex one, but this is a field that is in great demand
 - ❑ because of the nearly limitless variety of applications

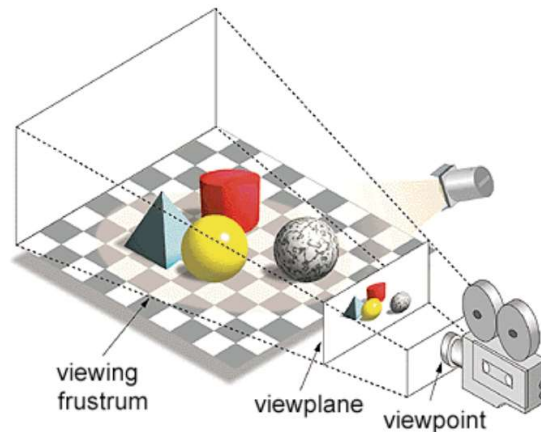
Our focus in this course will not be on how to use these systems to produce these images

- understanding how these systems are constructed, and
- the underlying mathematics, physics, algorithms, and data structures needed in the construction of these systems

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Goals of Computer Graphics

- Generate synthetic images
- Do it in a practical way and scientifically sound.
- In real time?
- And make it look easy...



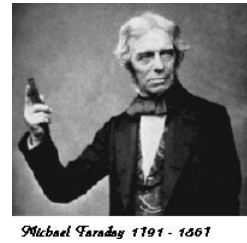
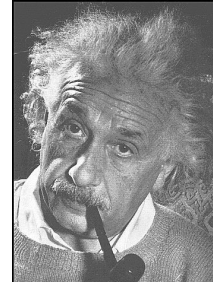
Why Computer graphics?

- **Graphics is cool**
 - I like to see what I'm doing
 - I like to show people what I'm doing
- **Graphics is interesting**
 - Involves *simulation, algorithms, architecture...*
- **Almost no area in which graphical displays cannot be used**

Why should we study Graphics?

- Many of the leading scientists through the ages have been 'visual thinkers'...

- Leonardo da Vinci
- Einstein
- Clerk Maxwell



Michael Faraday 1791 - 1867

Applications

- Movie, TV special effects
- Video games
- Scientific visualization
- GIS (Geographic Information Systems)
- Medical visualization
- Industrial design
- Simulation
- Communication
- Etc.

What drives computer graphics?

- **Movie Industry**
 - Leaders in quality and artistry
 - Not slaves to conceptual purity
 - Big budgets and tight schedules
 - Reminder that there is more to CG than technology
 - Hey, How'd they do that?
 - Defines our expectations



Who uses computer graphics?

Movies

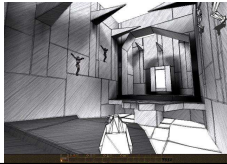


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What drives computer graphics?

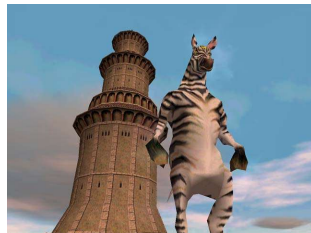
Games are very important in Computer Graphics

- **Game Industry**
 - The newest driving force in CG
 - Why? Volume and Profit
 - This is why we have commodity GPUs
 - Focus on interactivity
 - Cost effective solutions
 - Avoiding computing and other tricks
 - Games drive the baseline



Who uses computer graphics?

Games

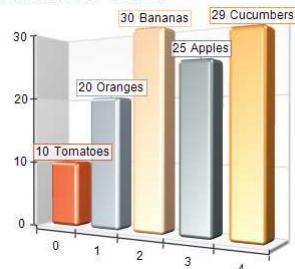


Presentation Graphics

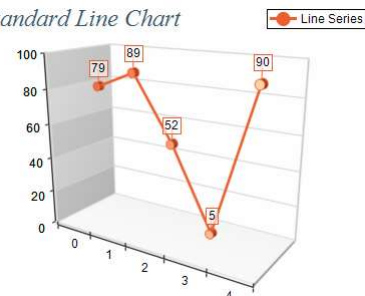
- Used to produce illustrations for reports or generate slides for use with projectors
- Commonly used to summarize financial, statistical, mathematical, scientific, economic data for research reports, managerial reports & customer information bulletins
- Examples : Bar charts, line graphs, pie charts, surface graphs, time chart

Examples of presentation graphics

Standard Bar Chart

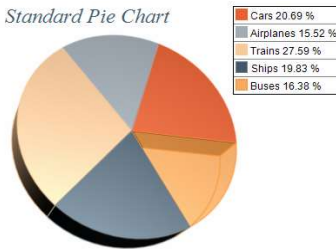


Standard Line Chart

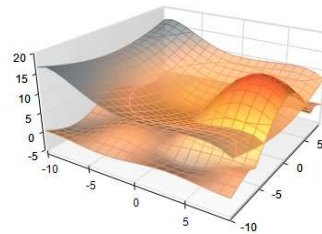


Examples of presentation graphics

Standard Pie Chart



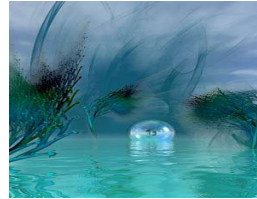
Intersected Surfaces



Computer Art

- **Used in fine art & commercial art**
 - Includes artist's paintbrush programs, paint packages, CAD packages and animation packages
 - These packages provides facilities for designing object shapes & specifying object motions.
 - Examples : Cartoon drawing, paintings, product advertisements, logo design

Examples :



Computer Art

- **Electronic painting**
 - Picture painted electronically on a graphics tablet (digitizer) using a stylus
 - Cordless, pressure sensitive stylus
- **Morphing**
 - A graphics method in which one object is transformed into another





What drives computer graphics?

- **Medical Imaging and Scientific Visualization**
 - Tools for teaching and diagnosis
 - No cheating or tricks allowed
 - New data representations and modalities
 - Drive issues of precision and correctness
 - Focus on presentation and interpretation of data
 - Construction of models from acquired data



Who uses computer graphics?

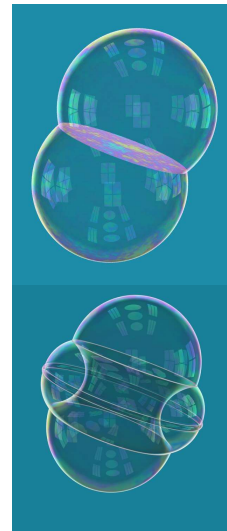
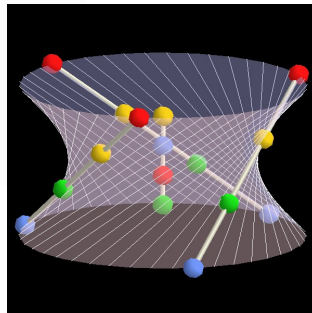
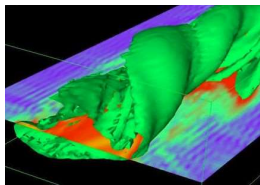
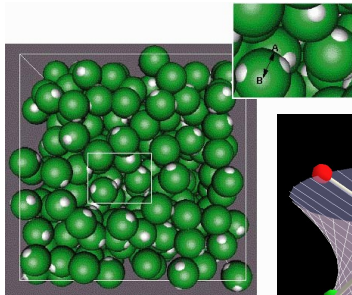
Doctors



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Who uses computer graphics?

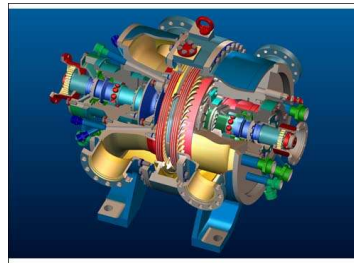
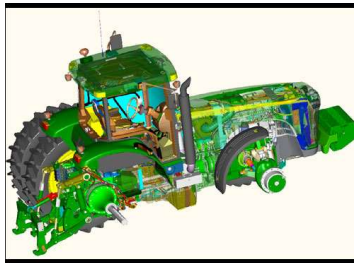
Scientists



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What drives computer graphics?

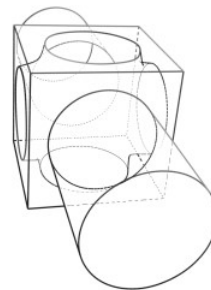
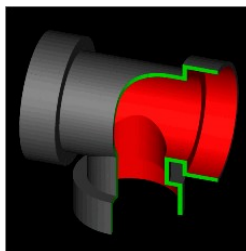
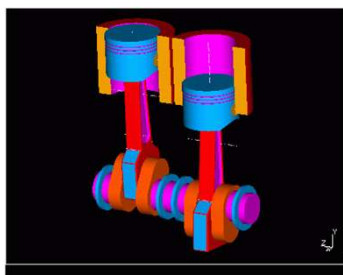
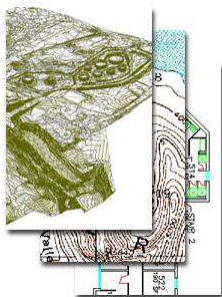
- **Computer Aided Design**
 - Mechanical, Electronic, Architecture,...
 - Drives the high end of the hardware market
 - Integration of computing and display resources
 - Reduced design cycles == faster systems, sooner



ProEngineer, www.ptc.com

Who uses computer graphics?

Engineers



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Education & Training

- Computer generated models of physical, financial and economic systems are used as educational aids.
- Models of physical systems, physiological systems, population trends, or equipment such as color-coded diagram help trainees understand the operation of the system

- **Specialized systems used for training applications**
 - simulators for practice sessions or training of ship captains
 - aircraft pilots
 - heavy equipment operators
 - air traffic-control personnel



Training

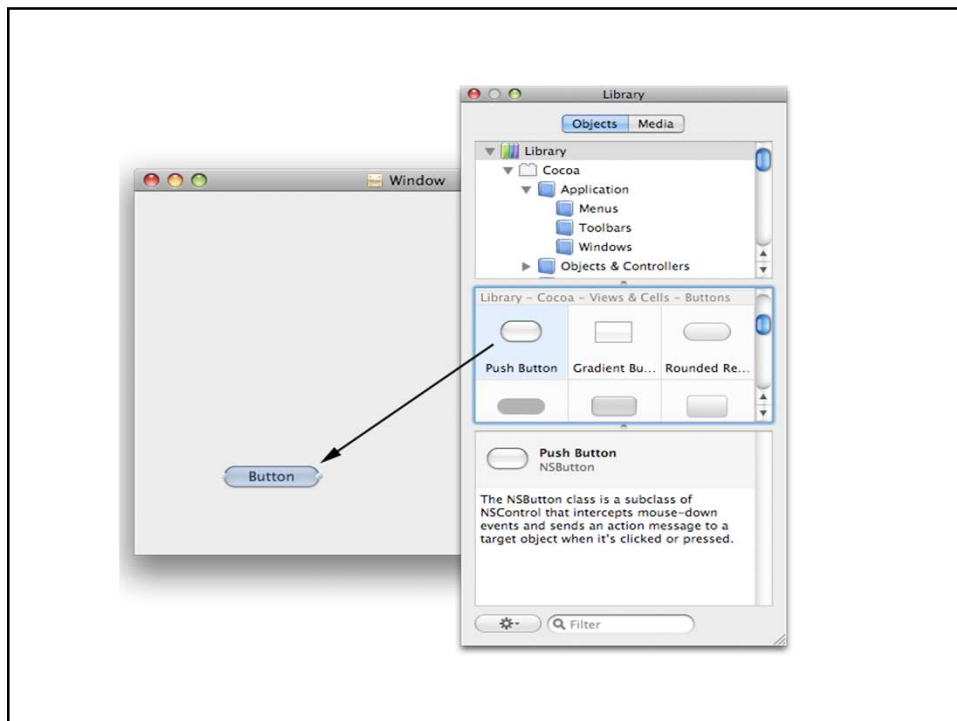


What drives computer graphics?

- **Graphic User Interfaces (GUI)**

Graphical User Interfaces

- Major component – Window manager (multiple-window areas)
- To make a particular window active, click in that window (using an interactive pointing device)
- Interfaces display – menus & icons
- Icons – graphical symbol designed to look like the processing option it represents
- Advantages of icons – less screen space, easily understood
- Menus contain lists of textual descriptions & icons



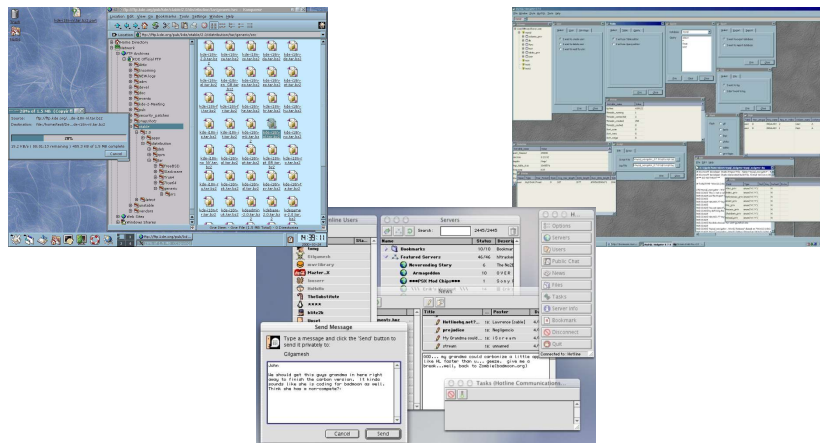
Who uses computer graphics?

You

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Who uses computer graphics?

You



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What is Computer Graphics?

- **Look at 5 areas**
 - **Rendering**
 - **Interaction**
 - **Modeling**
 - **Scientific Visualization**
 - **Hardware**

What is computer graphics about?

Computer graphics, as we will focus on it in this course, is about taking a computer **model** and producing an **image** of that model.

What is computer graphics about?

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Is that it? Yes, no, maybe ...

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What is computer graphics about?

Computer graphics, as we will focus on it in this course, is about taking a computer **model** and producing an **image** of that model.

Is that it? Yes, no, maybe ...

Definitely part of the broader area of computer graphics:

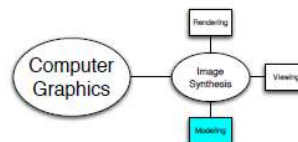
- We often wish to **interact** with that model, creating new images on the fly.
- Sometimes we want to **animate** the model in a predetermined way (like a script) or according to a set of rules.
- Also, there are issues how best to **represent** that model.
- Of course, all this assumes a way to **capture** or **create** the model, then to finally **display** the images.
- We shouldn't forget the actual **computation** required to convert from model to image.

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Modeling

- **Modeling** refers to the techniques involved with creating, scanning, editing, and manipulating 3D geometric data
- Modeling is often done by a human user with an interactive editing program
- More complex objects, such as trees, can be constructed with automatic *procedural modeling* algorithms
- 3D models are also often acquired from real world objects using laser scanning or computer vision techniques
- Modeling also includes the use of curved surfaces and other higher order primitives, which are often converted into triangles using various *tessellation* algorithms
- Another important area of modeling includes mesh reconstruction for surface simplification
- Modeling makes heavy use of *computational geometry*

Modeling



- How to represent real environments
 - Geometry: curves, surfaces, volumes
 - Photometry: light, color, reflectance
- How to build these representations
 - Interactive: sculpt it
 - Algorithmic: let it grow (fractals, extraction)
 - Scanning: via 3D sensing
- Generate primitives
 - Lines, triangles, quads, patches
 - Cylinder, spheres
 - Higher-order primitives

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What kinds of things are modeled?

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What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

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What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

Position

Where is it?

45

What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

Position

Where is it?

Orientation

Which way is it facing?

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What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

Position

Where is it?

Orientation

Which way is it **facing**?

Surface properties

What **color** is it? Is it **shinny**? Is it **smooth**?

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What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

Position

Where is it?

Orientation

Which way is it facing?

Surface properties

What color is it? Is it shinny? Is it smooth?

Volumetric properties

Is it dense? How does it scatter light?

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What kinds of things are modeled?

Shape

What is it? Can we approximate it with simpler shapes?

Position

Where is it?

Orientation

Which way is it facing?

Surface properties

What color is it? Is it shiny? Is it smooth?

Volumetric properties

Is it dense? How does it scatter light?

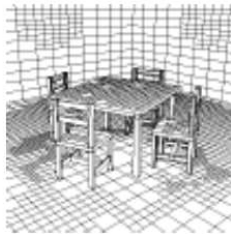
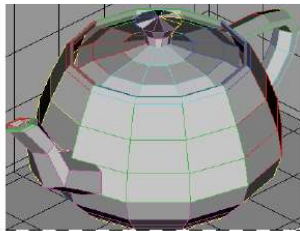
Lights

How bright? What color? Where? Is it directional?

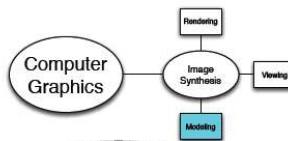
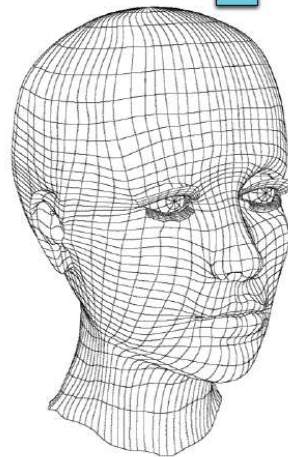
And More ...

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Modeling: Interactive

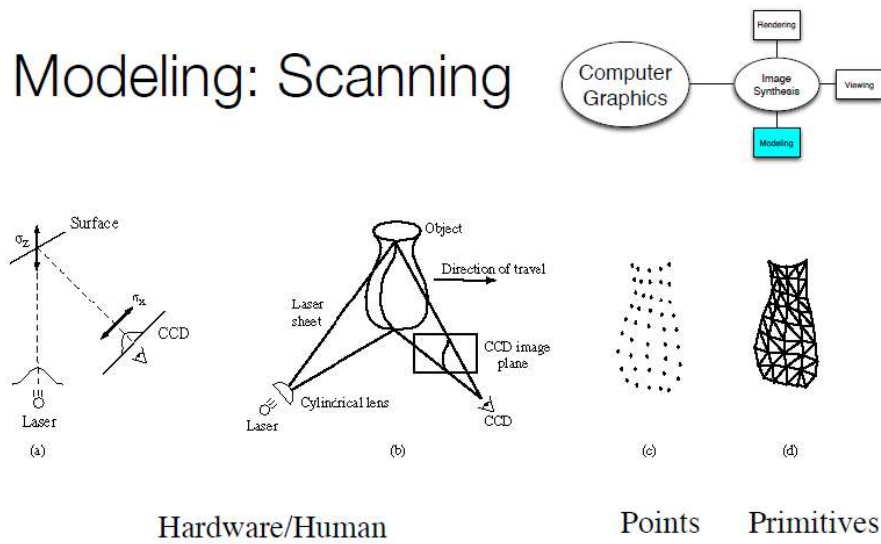


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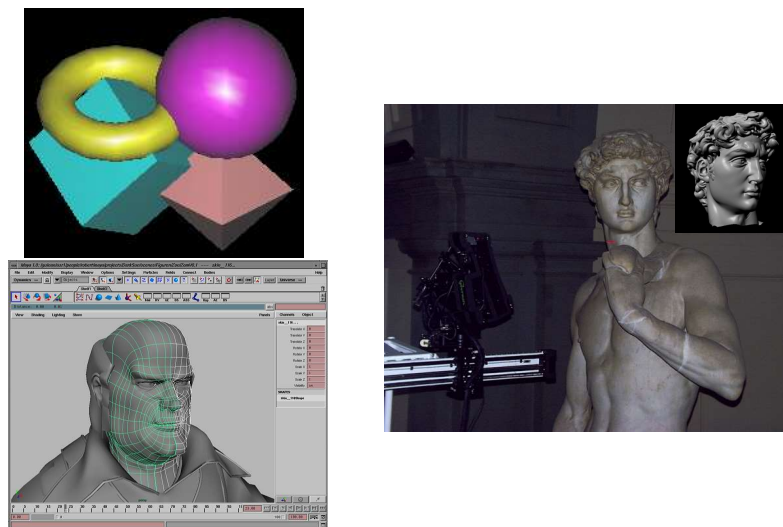
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Modeling: Scanning



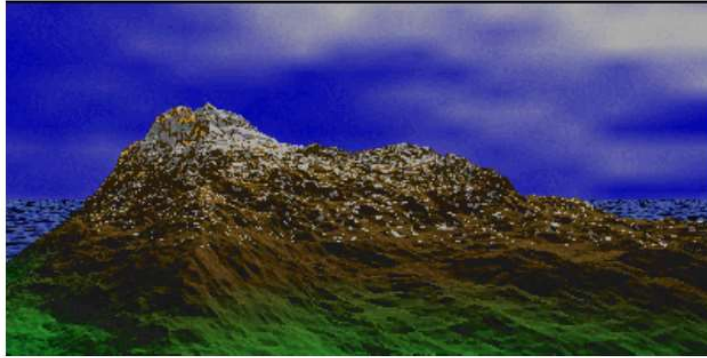
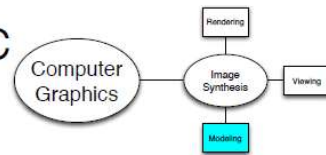
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Where do we get the models?



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Modeling: Algorithmic and Procedural

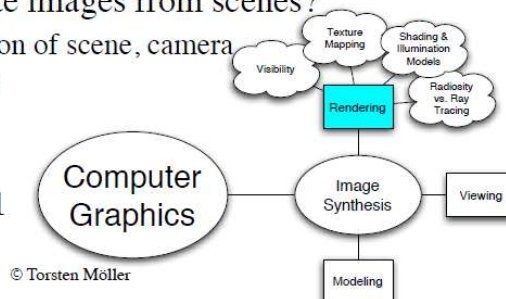


Out of nowhere - fractals

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Rendering

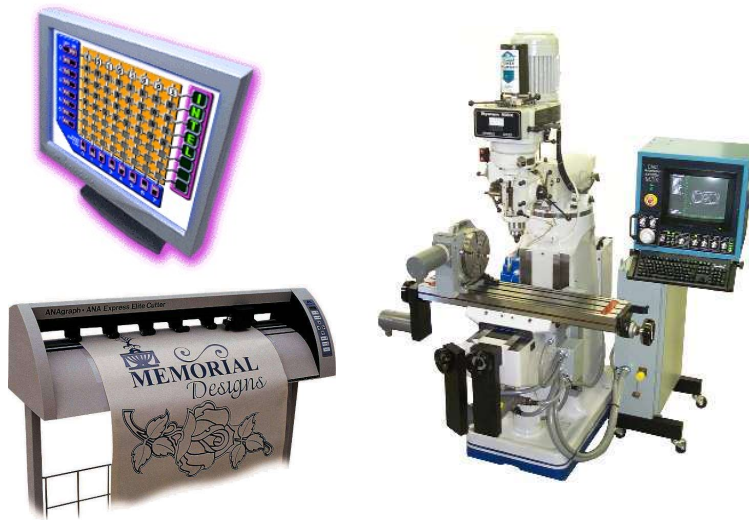
- What is an image?
 - Distribution of light energy on 2D “film”
- How do we represent and store images?
 - Sampled array of “pixels”: $p[x,y]$
- How do we generate images from scenes?
 - Input: 3D description of scene, camera
 - Project to camera’s viewpoint
 - Illumination
- See CMPT 461/761



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How do we display images?



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What is our model isn't like the real world?



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3D Scene Capture

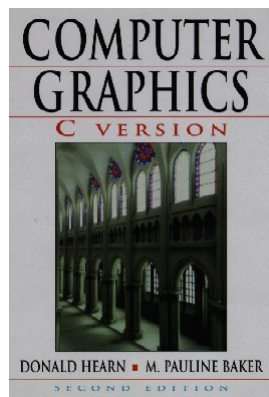


Fuchs et.al., UNC



UNC and UVA

What's in between modeling and display?



Computer Imaging

- Computer imaging deals with storing, manipulating, and transforming images with a computer.
- Images need first to have been input by some means, such as a scanner, a video camera, a digital camera, etc.
- More generally, computer imaging deals with all aspects of processing images with a computer, and encompasses image synthesis and analysis.

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Image Processing

- CG- Computer is used to create a picture
- Image Processing – applies techniques to modify or interpret existing pictures such as photographs and TV scans
- Medical applications
 - Picture enhancements
 - Tomography
 - Simulations of operations
 - Ultrasonics & nuclear medicine scanners
- 2 applications of image processing
 - Improving picture quality
 - Machine perception of visual information (Robotics)

- To apply image processing methods
 - Digitize a photograph (or picture) into an image file
 - Apply digital methods to rearrange picture parts to
 - enhance color separations
 - Improve quality of shading
 - Tomography – technique of X-ray photography that allows cross-sectional views of physiological systems to be displayed
 - Computed X-ray tomography (CT) and position emission tomography (PET) use projection methods to reconstruct cross sections from digital data
 - Computer-Aided Surgery is a medical application technique to model and study physical functions to design artificial limbs and to plan & practice surgery

Image Processing

☐ Manipulating images to:

- Improve quality
- Detect lines/curves
- Detect corners
- Sharpen/blur
- Segment

– ...

☐ Often used to facilitate computer vision

Image Processing

- Some computer graphics operations involve manipulating 2D images (bitmaps)
- *Image processing* applies directly to the pixel grid and includes operations such as color correction, scaling, blurring, sharpening, etc.
- Common examples include digital photo processing and digital 'painting' programs (Adobe Photoshop...)

Image Synthesis

- *Image synthesis* or *image generation* refers more to the construction of images from scratch, rather than processing of existing images
- Synthesis of a 2D image from a 3D scene description is more commonly called *rendering*

Photoreal Rendering

- ***Photoreal rendering*** refers to rendering a 3D scene in a realistic way
- Modern photoreal rendering algorithms are essentially a physically based simulation of light propagation and scattering throughout a 3D environment
- In a sense, this means that there is a 'correct' image that should be generated, given an input data set. This allows the subject of photoreal rendering to have a strong theoretical basis (namely, the science of optics)
- Most modern photoreal rendering algorithms are based on the classic *ray tracing* algorithm, that traces the path of individual light rays starting from the eye and working backwards to the light sources



Rendering/Modeling Hair



QuickTime™ and a
Photo decompressor
are needed to see this picture.



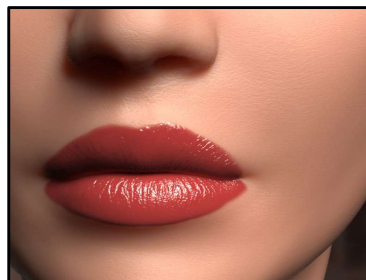
QuickTime™ and a
Video decompressor
are needed to see this picture.

<http://www.rhythm.com/~ivan/hairRender.html>

Humans

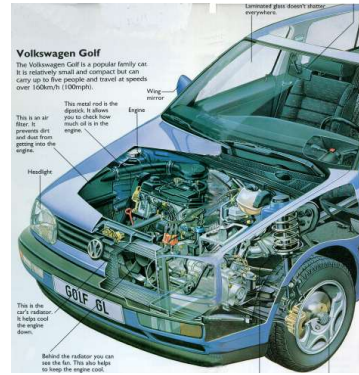


Final Fantasy (Sony)

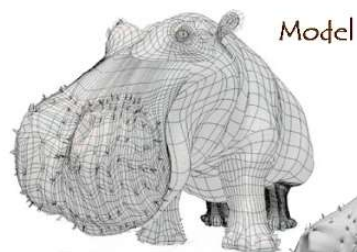


Jensen et al.

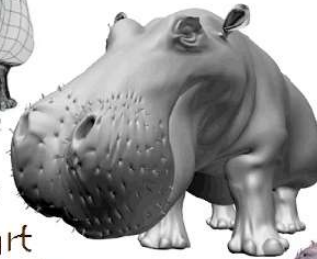
Is Photorealism Everything?



The Quest for Visual Realism



Model + Shading



Model + Shading
+ Textures



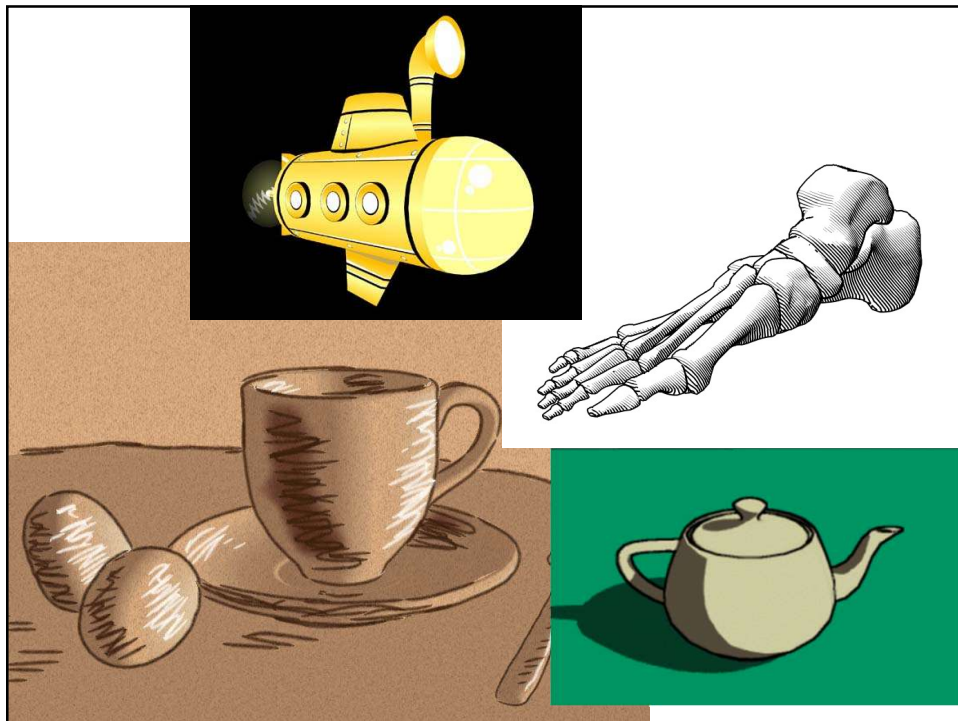
At what point
do things start
looking real?

For more info on the computer artwork of Jeremy Birn
see <http://www.3drender.com/jbirn/productions.html>

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Non-Photoreal Rendering

- *Non-photoreal rendering* (NPR) refers to rendering images in other ways...
- Sometimes, this is done to achieve aesthetic goals such as artificial water colors, pencil sketches, paint brushstrokes...
- Other times, the goal is to maximize the communication of visual information, as in scientific and medical visualization



Computer Vision

- Computer vision is sometimes considered as a separate discipline from computer graphics, although they share many things in common
- A central goal in computer vision is to take a set of 2D images (usually from a video or set of photos) and infer from that a 3D description of what is being viewed
- This is a very different process than rendering, and is more of a form of artificial intelligence

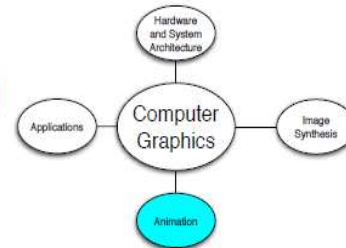
Computer Vision



Animation

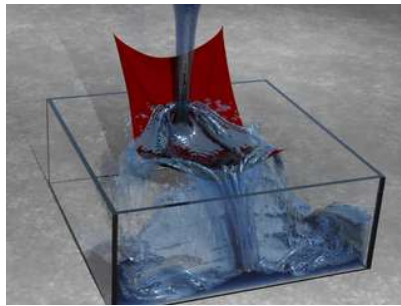
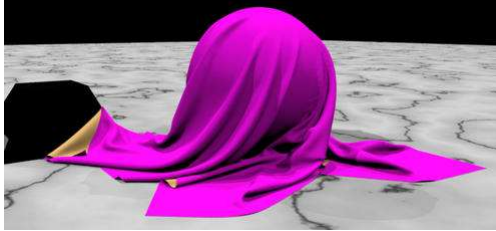
- An animation is just a sequence of individual images
- Basically, the subject of computer animation focuses on how things change over time. Usually, this refers to motion, but can also refer to other properties changing over time.
- Physical simulation is a very powerful tool in computer animation and can be used to generate believable animations of rigid objects, deformable objects, gasses, liquids, fracture, particle effects, and even explosions and fire
- Computer animation also includes a large number of techniques specifically developed to manipulate virtual characters

Animation

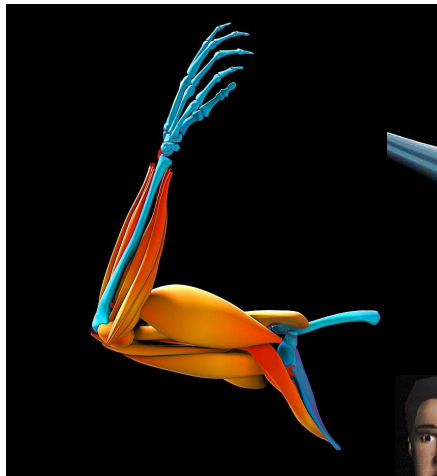
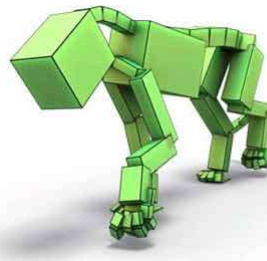


- Model how things move
- Temporal change of
 - Objects (position, orientation, size, shape, color, etc.)
 - Camera (position, direction, angle, focus, etc.)
 - Illumination (position, direction, color, brightness)
- Represent motion
 - Sequence of stills
 - Parameter curves

Physics Simulation



Character Animation

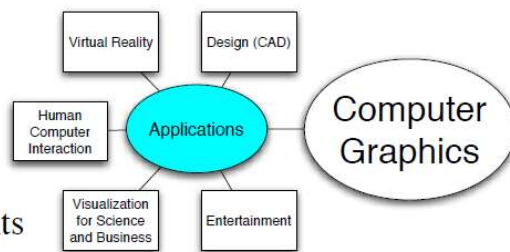


Raster Graphics

- Modern graphics displays are *raster* based
- This just means that they display a grid of pixels, where each pixel color can be set independently
- Individual pixels are usually formed from smaller red, green, and blue subpixels. If you look very closely at a TV screen or computer monitor, you will notice the pattern of subpixels
- Older style *vector* displays didn't display a grid of pixels, but instead drew lines directly with an electron beam
- Raster graphics are also sometimes called *bitmapped graphics*

Uses Of Graphics

- Special effects
- Feature animation
- Computer Games
- Virtual environments
- Visualization
(science, business, cartography, ...)
- Design
- Interaction
- ...



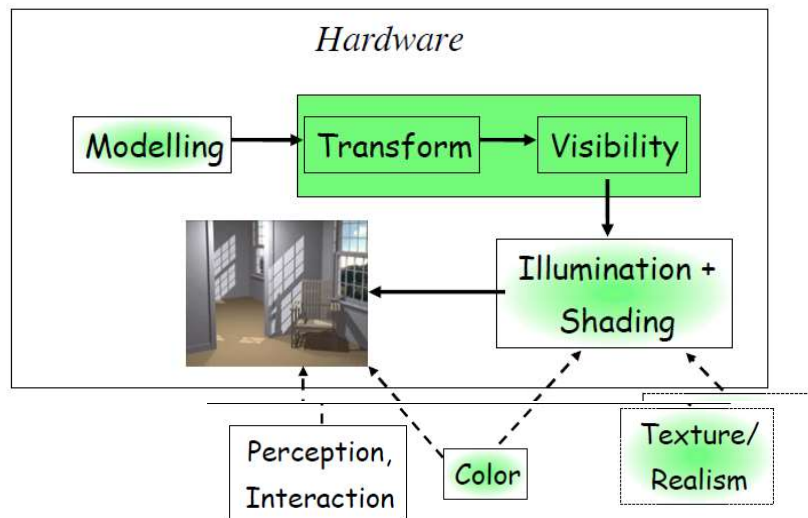
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Interaction



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Graphics Pipeline



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