Introduction to Computer Graphics

1. Graphics Systems

I-Chen Lin

National Yang Ming Chiao Tung University

Textbook: E.Angel, D. Shreiner Interactive Computer Graphics, 6th Ed., Pearson

Ref: D.D. Hearn, M. P. Baker, W. Carithers, Computer Graphics with OpenGL, 4th Ed., Pearson

Intended Learning Outcomes

- On completion of this chapter, a student will be able to:
  - Outline the preliminary concept of a **graphics system**.
  - List the key **breakthroughs** in the development of graphics systems.
  - Describe the concept of **3D projection**.
  - Recognize images produced by **perspective projection**.

Computer Graphics

- Computer graphics deals with all aspects of creating images with a computer.
  - Hardware
  - Software
  - Applications

Example

- Where did this image come from?

- What hardware/software did we need to produce it?

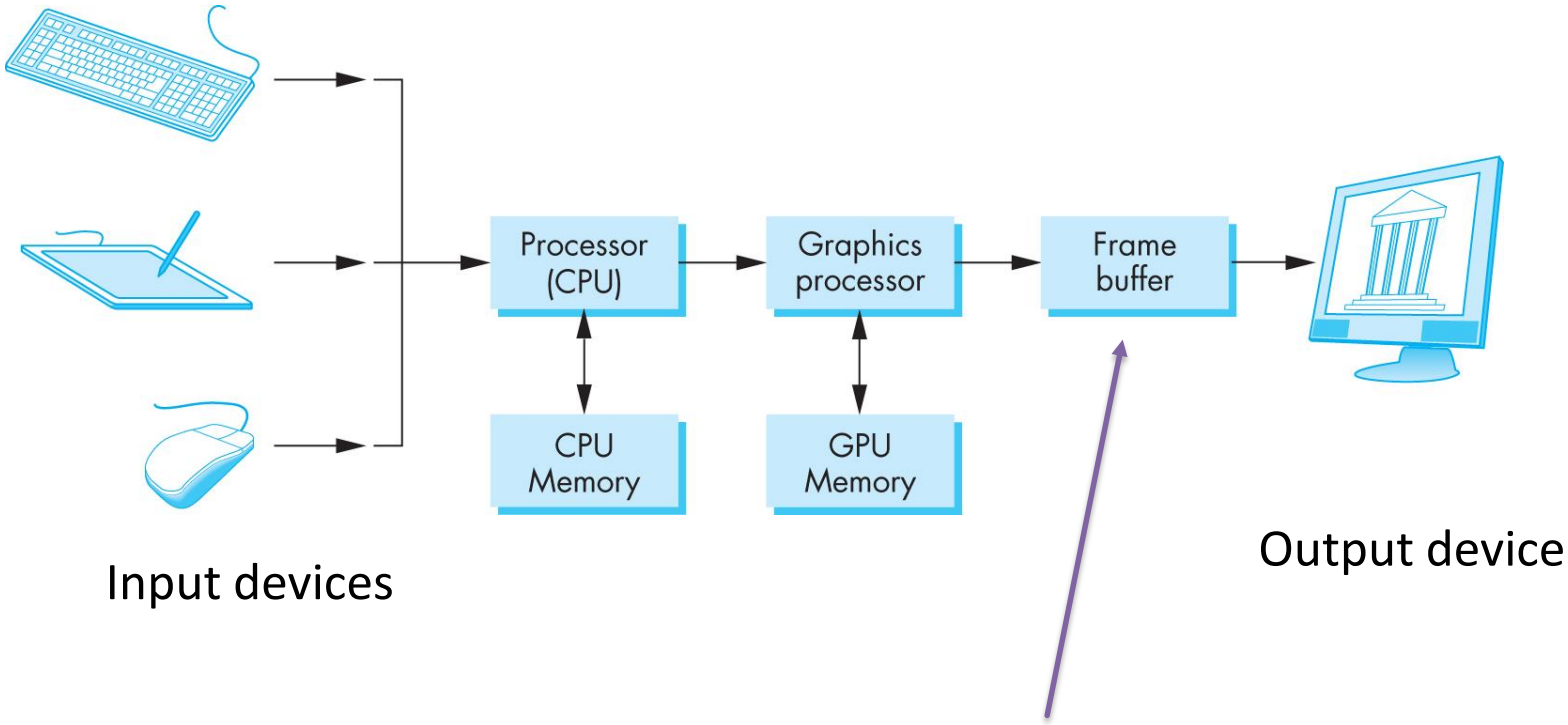
Preliminary Answers

- **Application**: The spherical object is an artist's rendition for an animation to be shown in a domed environment (planetarium)

- **Software**: Maya for modeling and rendering but Maya is built on top of Graphics API.

- **Hardware**: PC with graphics cards for modeling and rendering

Basic Graphics System

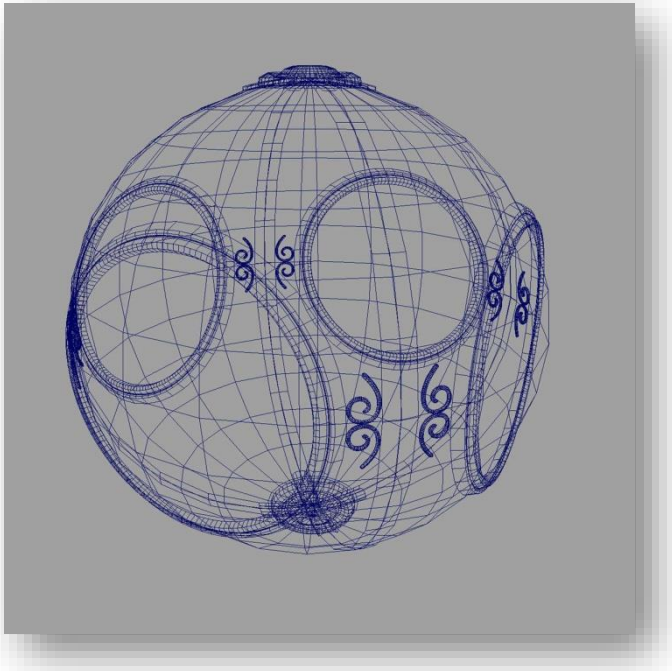


Computer Graphics: 1950-1960

- Computer graphics goes back to the earliest days of computing
  - Strip charts
  - Pen plotters
  - Simple displays using A/D converters to go from computer to calligraphic CRT
- Cost of refresh for CRT is high
  - Computers slow, expensive, unreliable

Computer Graphics: 1960-1970

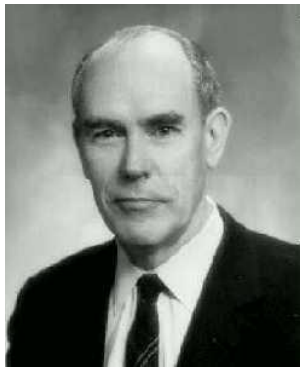
- *Wireframe* graphics
  - Draw only lines
- Sketchpad
- Display Processors
- Storage tube



wireframe representation of the spherical object

Sketchpad

- **Ivan Sutherland**'s PhD thesis at MIT
  - Recognized the potential of man-machine interaction.
  - Sutherland also created many of the now common algorithms for computer graphics



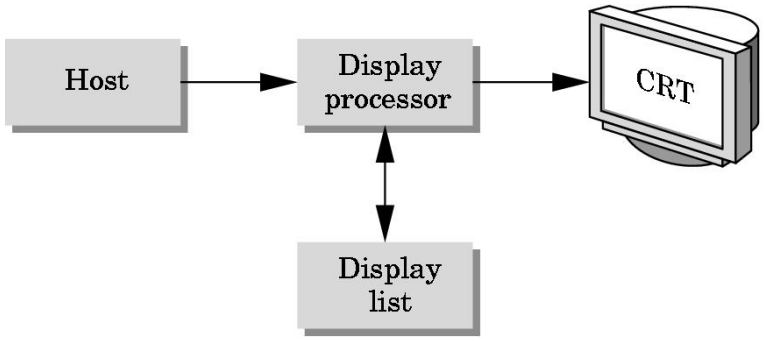
Ivan Sutherland,

Turing Award winner, 1988

The console of the TX-2, Sketchpad Project

Display Processor

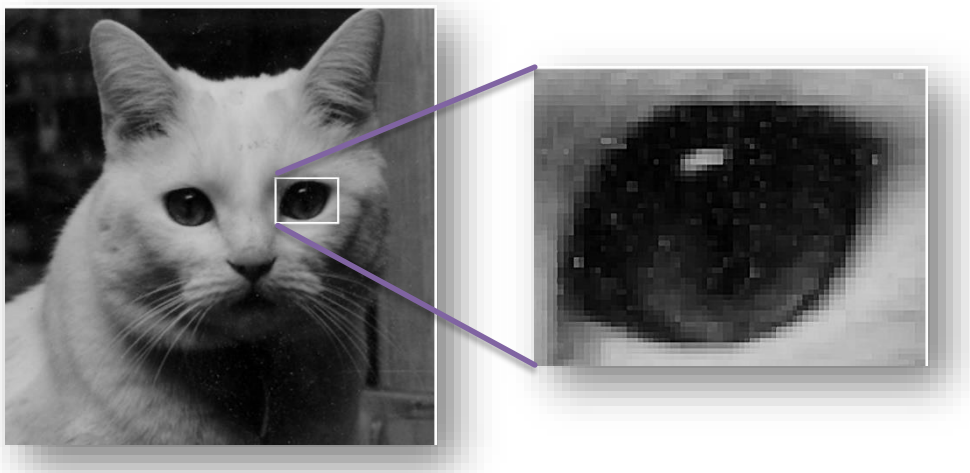
- Rather than have the host computer try to refresh display, use a special purpose computer called a *display processor* (DPU)

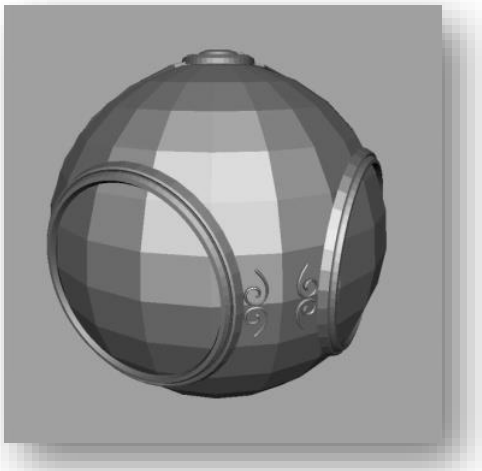


- Graphics stored in display list (display file) on display processor
- Host *compiles* display list and sends to DPU

Computer Graphics: 1970-1980

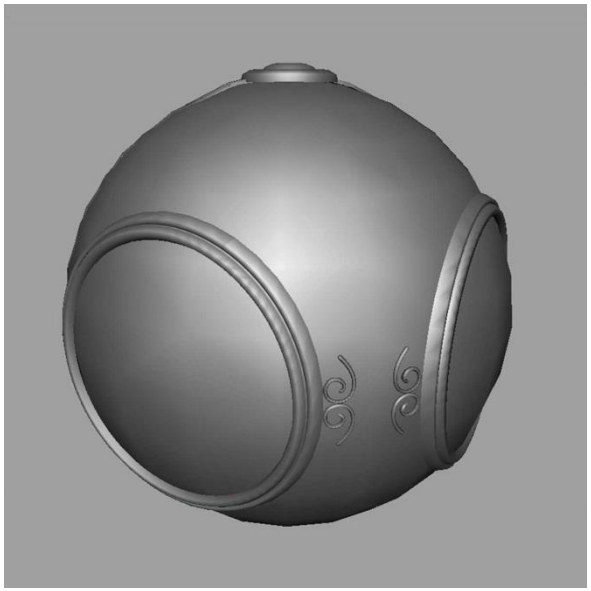
- Raster Graphics
  - Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*
  - Allows us to go from lines and wire frame images to filled polygons





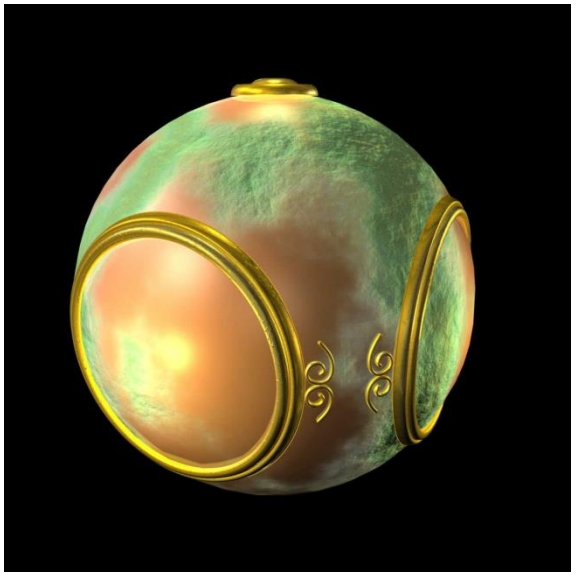
Computer Graphics: 1980-1990

- Realism comes to computer graphics



smooth shading

environment mapping



bump mapping

Note: Gouraud shading published in 1971

Computer Graphics: 1980-1990

- Special purpose hardware
  - Silicon Graphics geometry engine
    - VLSI implementation of graphics pipeline
- Industry-based standards
  - PHIGS
    - Programmer's Hierarchical Interactive Graphics System
  - RenderMan
- Networked graphics: X Window System
- Human-Computer Interface (HCI)

Computer Graphics: 1990-2000

- OpenGL API
- Completely computer-generated feature-length movies (e.g. Toy Story) are successful.
- New hardware capabilities
  - Texture mapping
  - Blending
  - Stencil buffers, …

Computer Graphics: 2000-

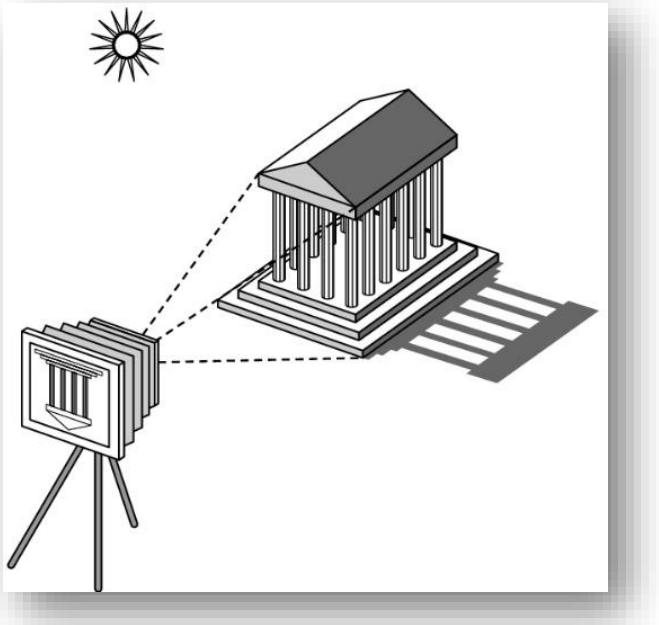
- Photorealism
- Graphics cards for PCs dominate the market
  - Nvidia, ATI (-> AMD)
  - GPU (Graphics processing unit)
- Game boxes and game players determine directions of the market
- Computer graphics routine in movie industry: Maya, Lightwave.
- *Programmable pipelines*

Image Formation

- Fundamental imaging notions
- Physical basis for image formation
  - Light
  - Color
  - Perception
- Synthetic camera model
- Other models

Elements of Image Formation

- Objects
- Viewer
- Light source(s)

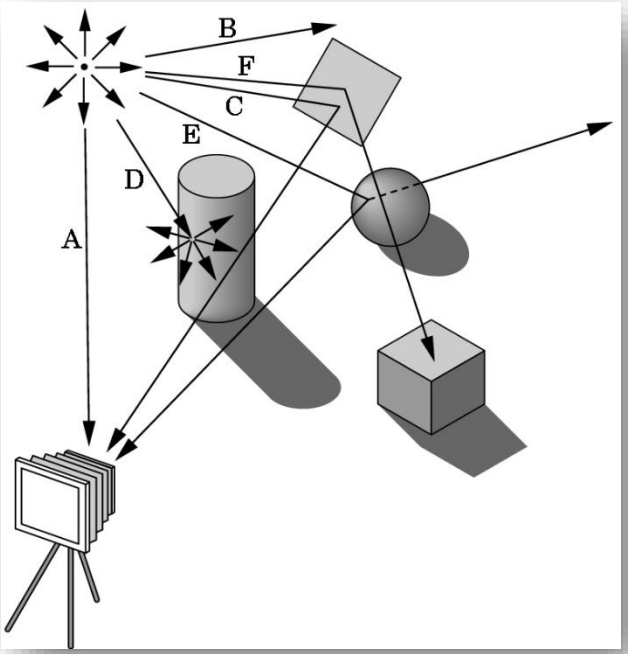


- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, the viewer, and the light source(s)

Ray Tracing and Geometric Optics

- One way to form an image is to follow rays of light from a point source finding which rays enter the lens of the camera.

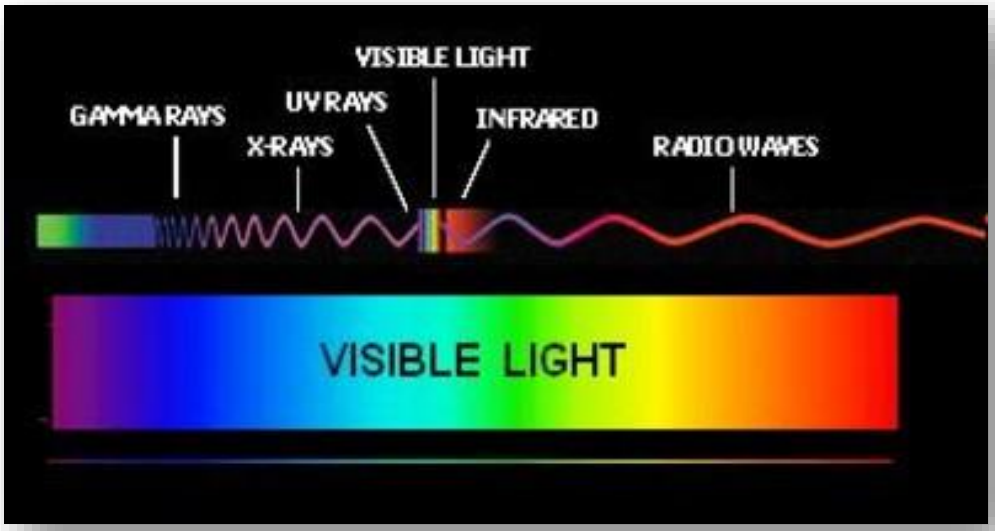
- However, each ray of light may have multiple interactions with objects before being absorbed or going to infinity.



Light

- *Light* is the part of the electromagnetic spectrum that causes a reaction in our visual systems

- Generally these are wavelengths in the range of about 350-750 nm (nanometers)



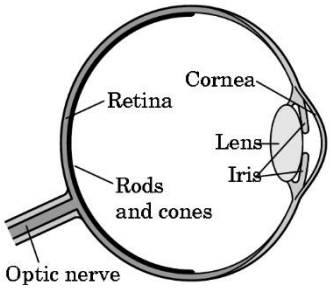
Luminance and Color Images

- Luminance Image
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television

- Color Image
  - Has perceptional attributes of hue, saturation, and lightness
  - Do we have to match every frequency in visible spectrum?

Three-Color Theory

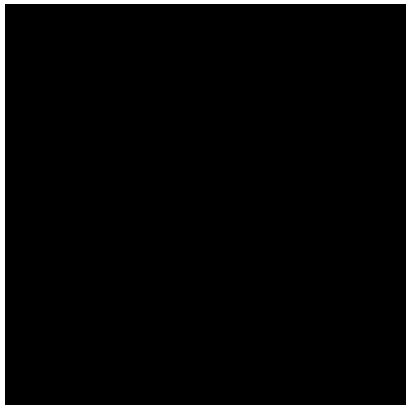
- Human visual system has two types of sensors
  - Rods: monochromatic, night vision
  - Cones
    - Color sensitive
    - Three types of cones
    - Only three values (the *tristimulus* values) are sent to the brain



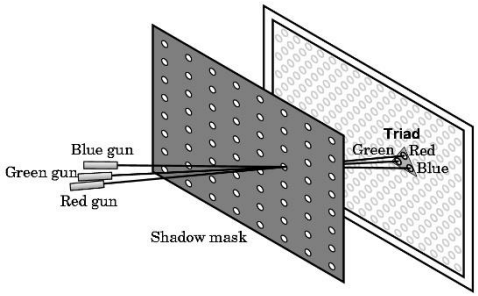
- Need only match these three values
  - Need only three *primary* colors

Additive and Subtractive Color

- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, LCD, projection systems, positive film
  - Primaries: Red (R), Green (G), Blue (B)

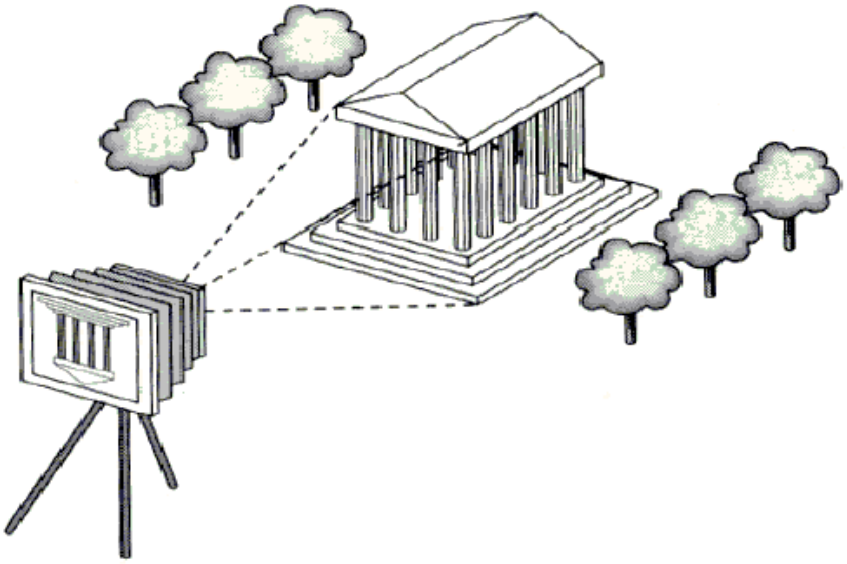


Shadow Mask CRT



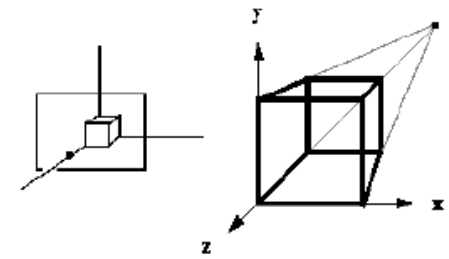
  - Subtractive color
  - Form a color by filtering white light with:
    - Cyan (C), Magenta (M), and Yellow (Y) filters
    - Printing, Negative film

Basic 3D Graphics

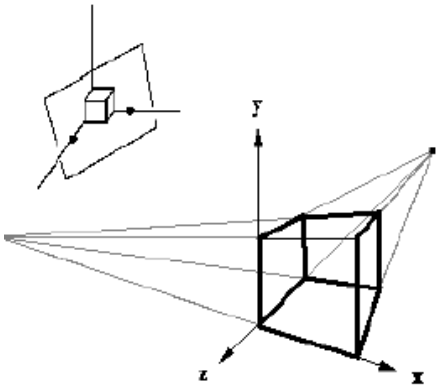


Which one is more realistic in geometry?

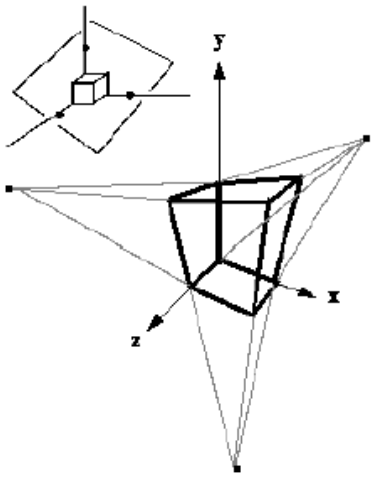
Vanishing points



One Point Perspective
(z-axis vanishing point)



Two Point Perspective
z, and x-axis vanishing points

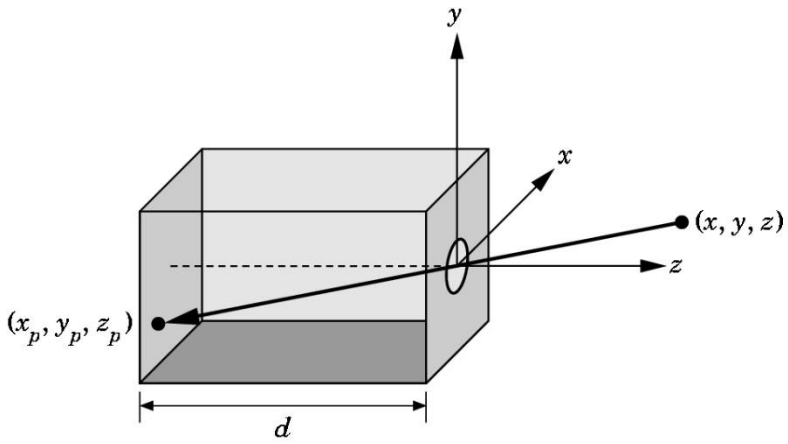


Three Point Perspective
(z, x, and y-axis
vanishing points)

Camera obscura

- Camera Obscura, Reinerus Gemma-Frisius, 1544
  - (L. dark chamber), an aid to painting, consists of a darkened box and a small aperture where light passes.

Pinhole Camera



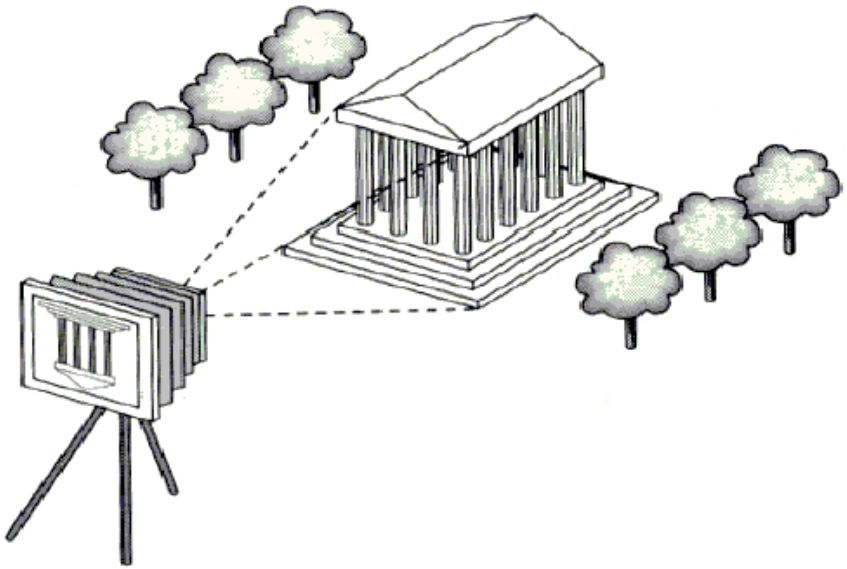
Use trigonometry to find projection of point at (x,y,z)

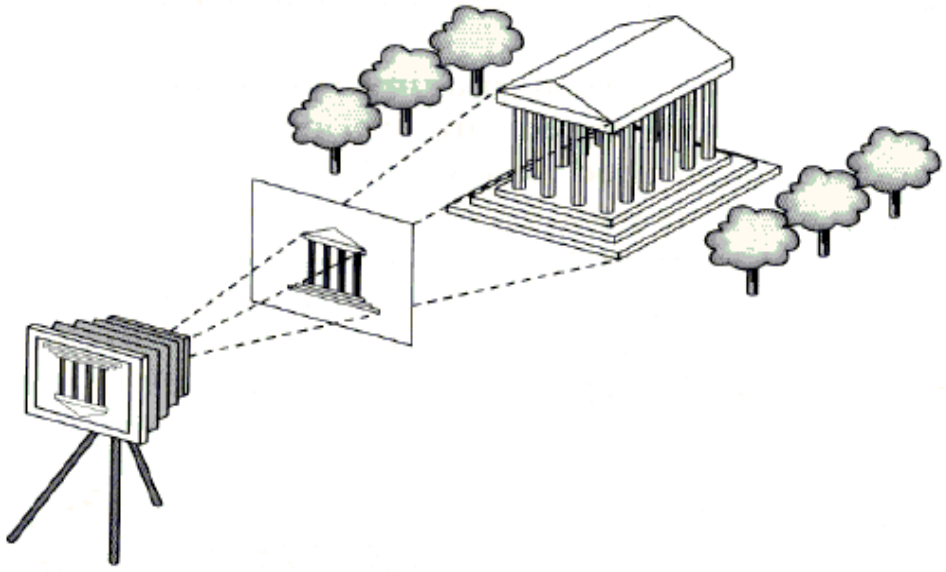
$$x_p = -x/(z/d) \qquad y_p = -y/(z/d) \qquad z_p = d$$

These are equations of simple perspective

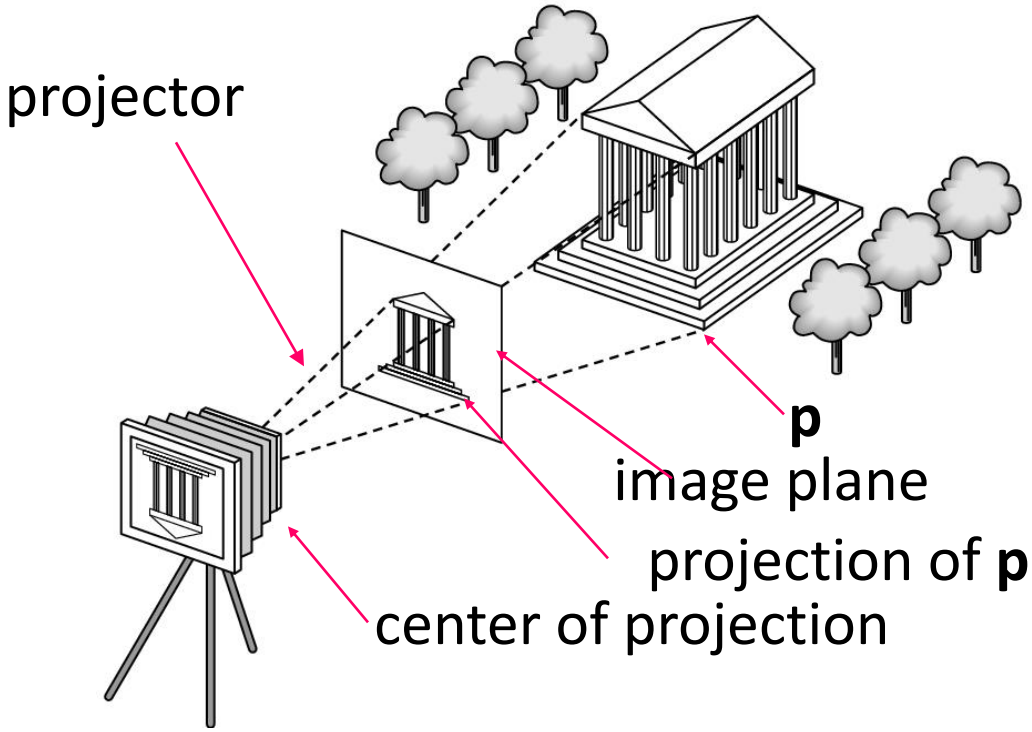
Perspective projection

- Taking photographing as an example.



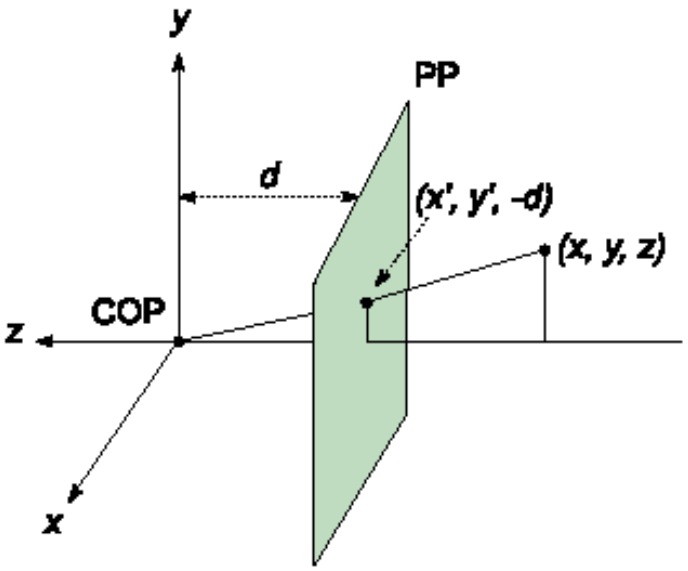


Synthetic Camera Model

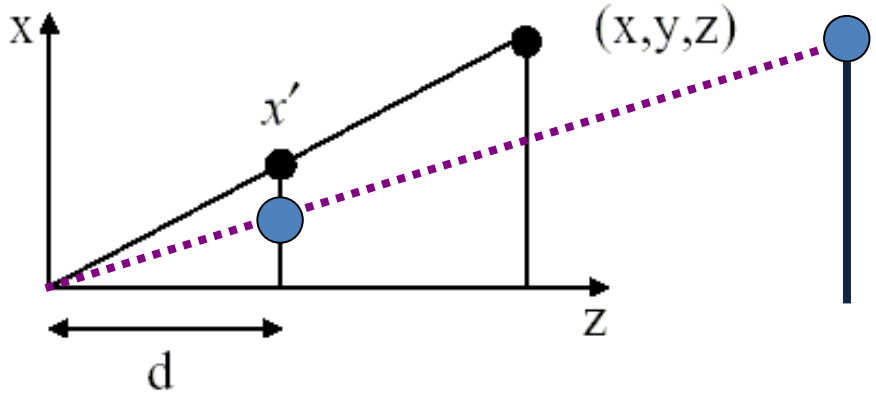


Perspective projection (cont.)

- Projection

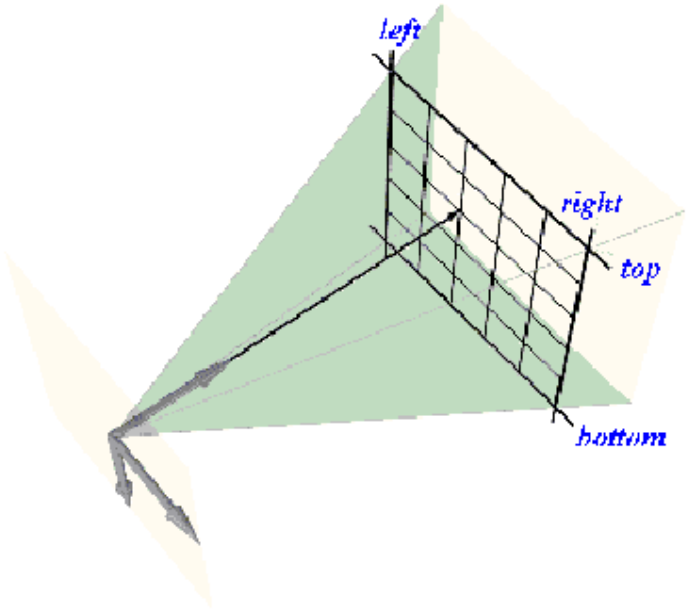


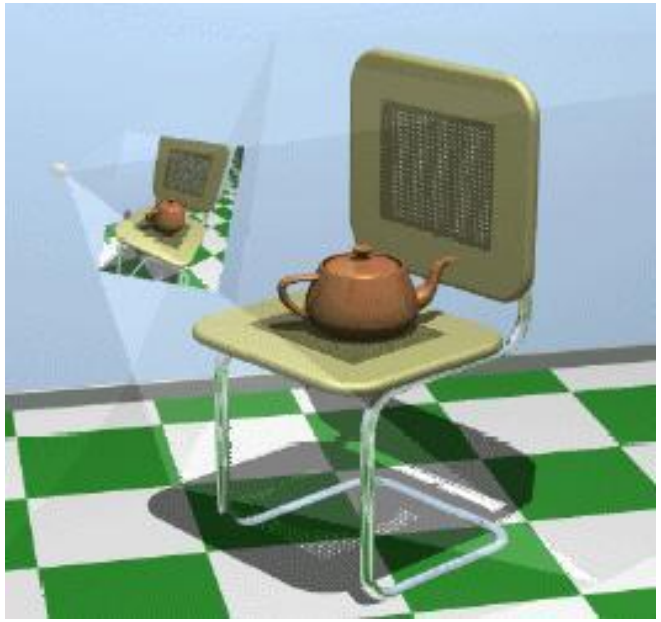
Using similar triangles gives:



Perspective projection (cont.)

- Let pupils as the pinhole and a screen as the film.



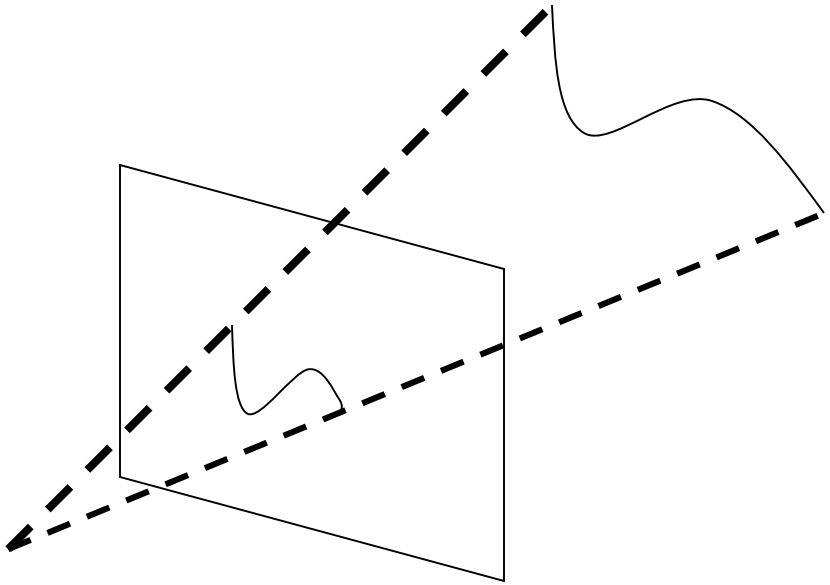


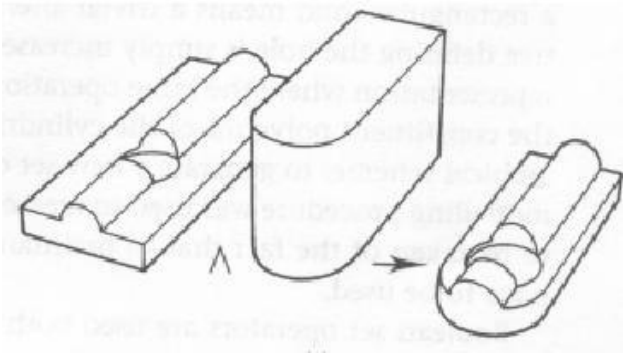
Generating perspective views

- From the continuous world to a digital one.
- Representing by surfaces?

Represented by primitives

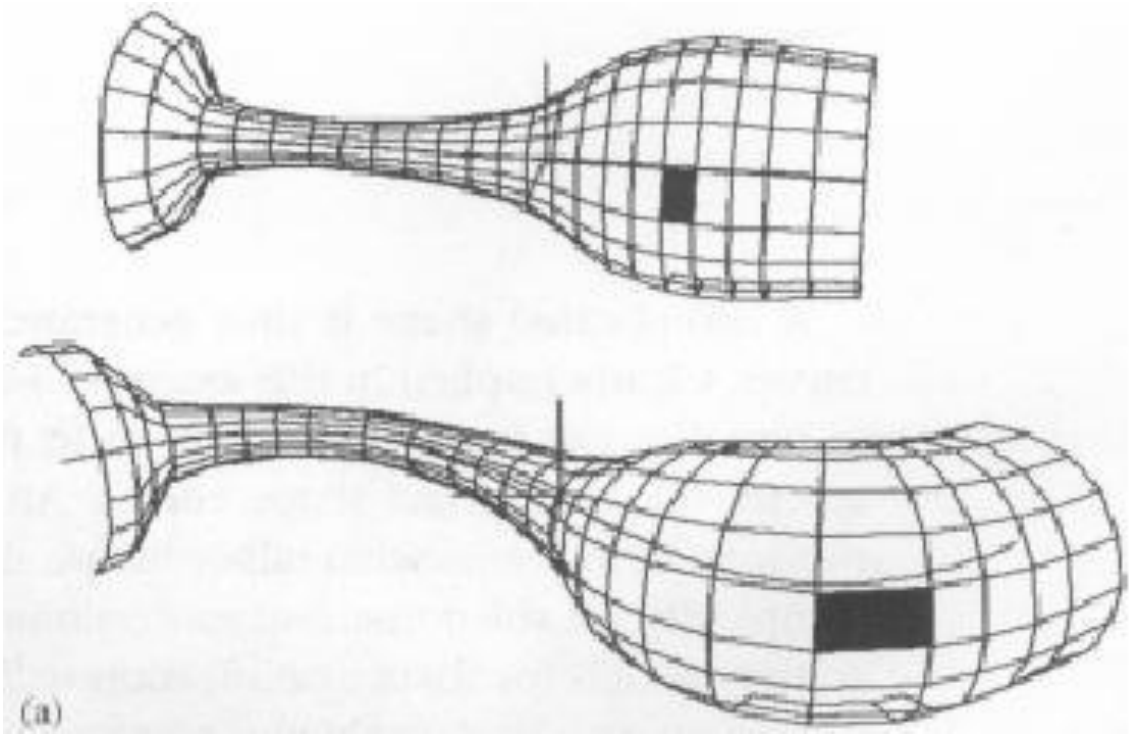
- Curves and surfaces are **inefficient** to render directly.





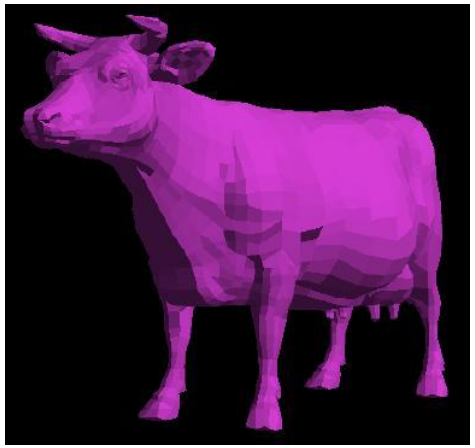
Represented by primitives (cont.)

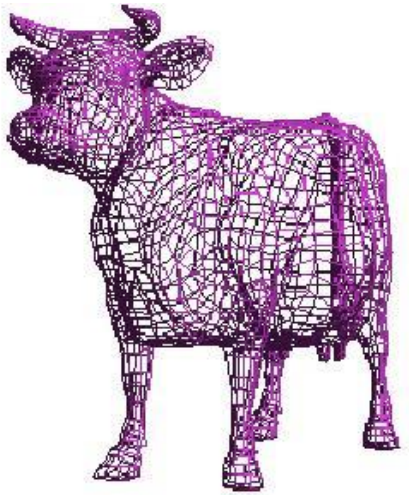
- We use primitives such as polygons instead.

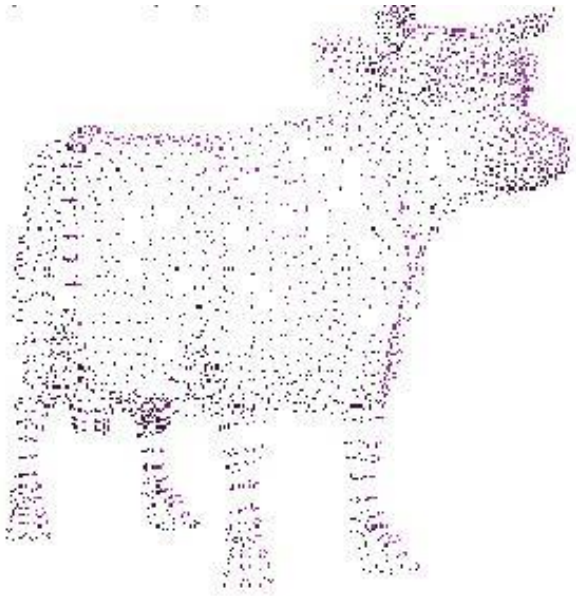


Represented by primitives

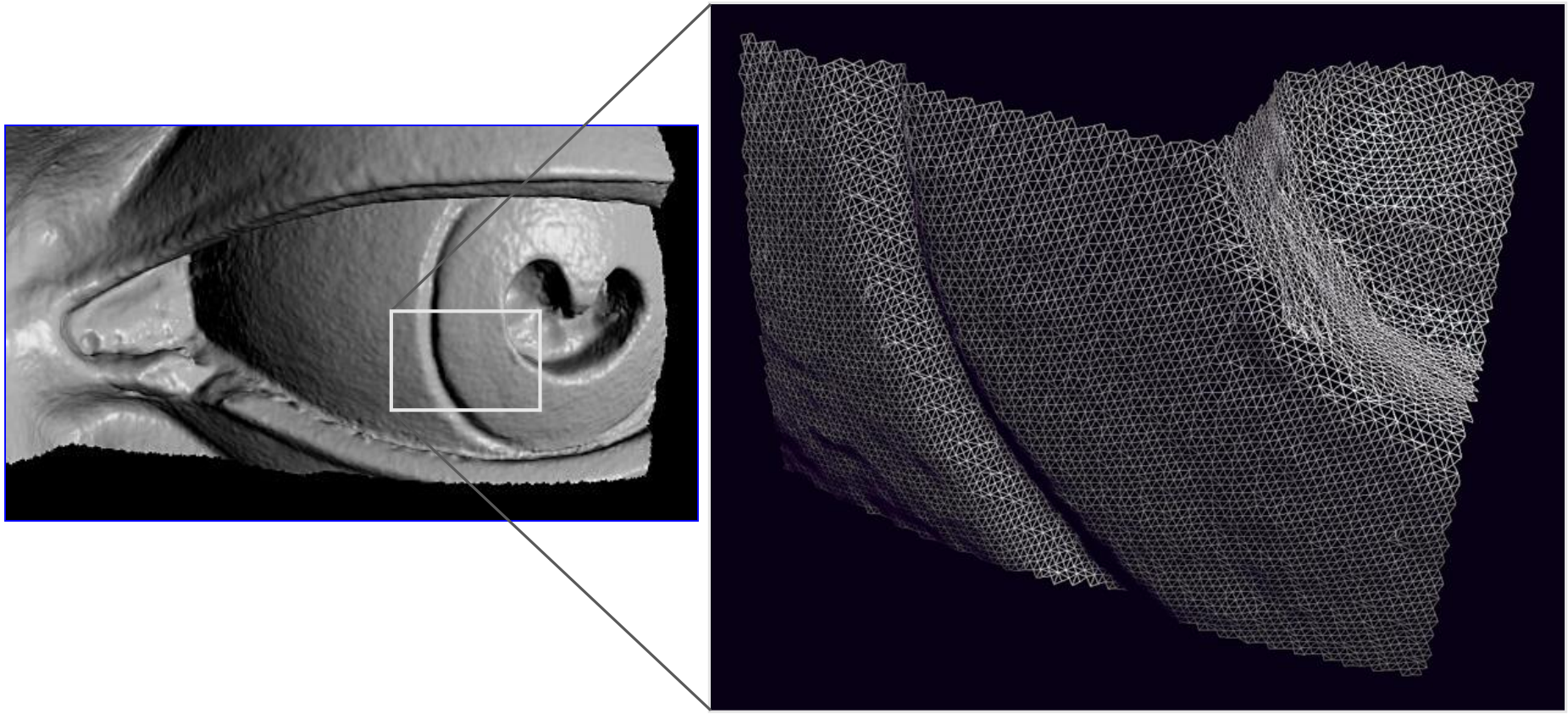
- Polygons







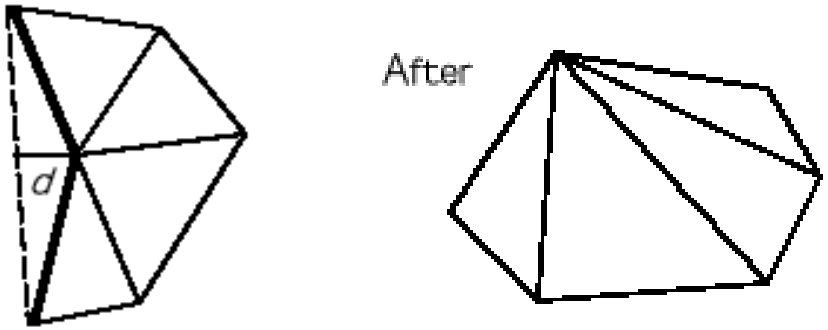
Represented by primitives



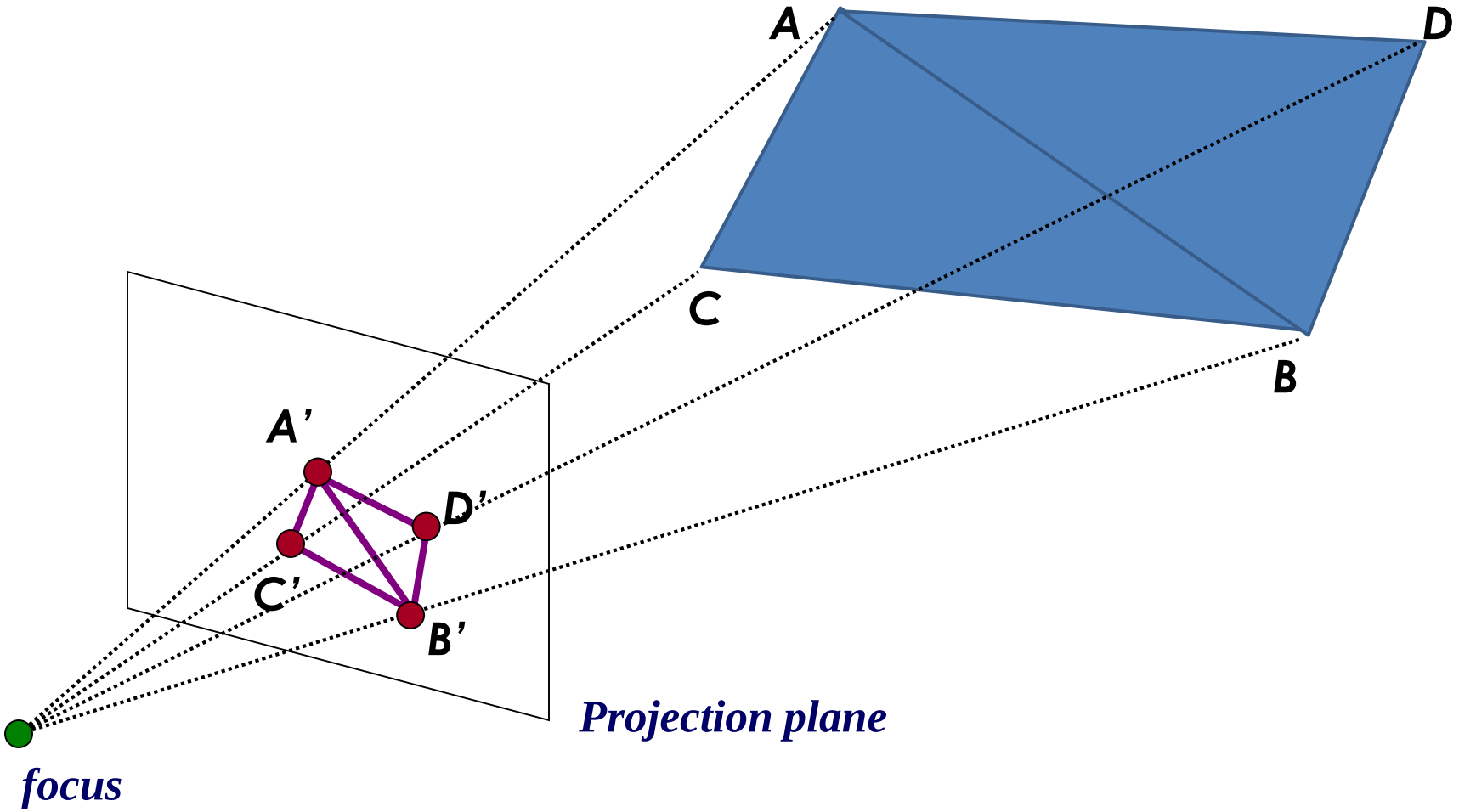
Digital Michelangelo Project, Stanford University

Represented by primitives (cont.)

- A triangle is usually the most basic primitive.
- Polygons -> triangles.

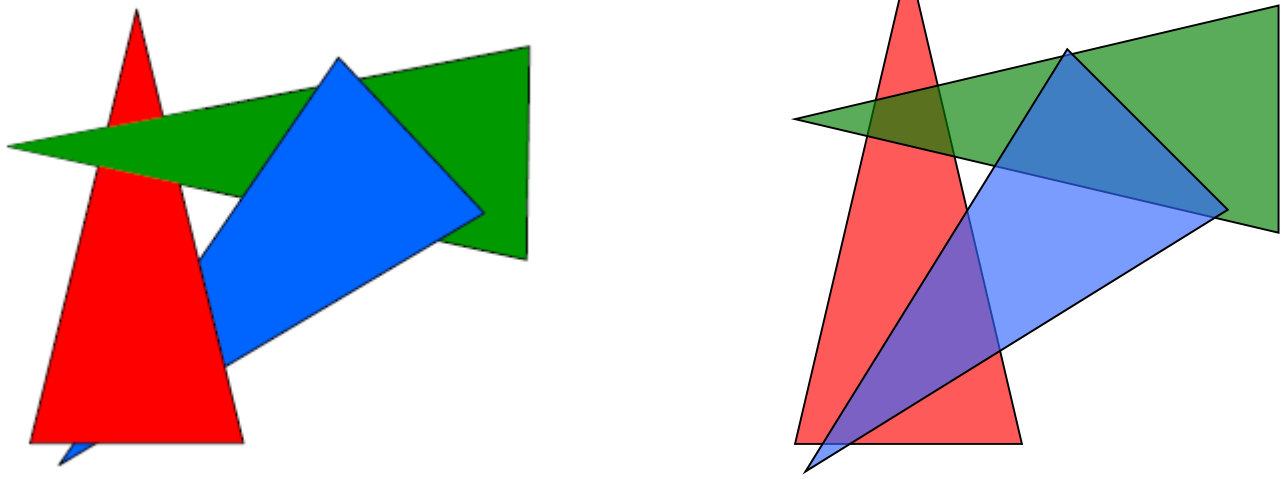


Projection of triangles



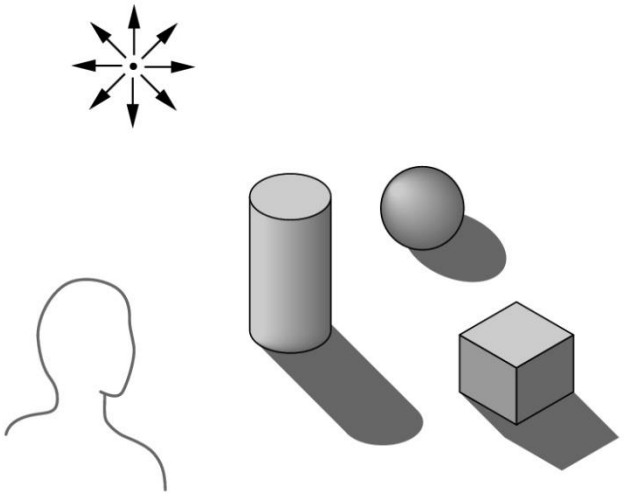
Visibility

- If we draw triangles directly, our screen will be a “mess”.
- Remove hidden surfaces.



Global vs Local Lighting

- Cannot compute color or shade of each object independently
  - Some objects are blocked from light
  - Light can reflect from object to object
  - Some objects might be translucent



A realistic 3D view

- Delicate 3D models.
- Perspective.
- Hidden surface removal.
- Shading (lighting & reflection).
- Shadow.
- Detailed textures and normals

Geri's Game, Pixar corp.

Fig. from B. Martin, U. Utah

slido

Please download and install the Slido app on all computers you use

Which images are produced with/by perspective projection?

ⓘ Start presenting to display the poll results on this slide.

Appendix: What's a so-called "3D" movie?

- "3D movies" or "Stereo movies" often refer to movies that can provide binocular cues.