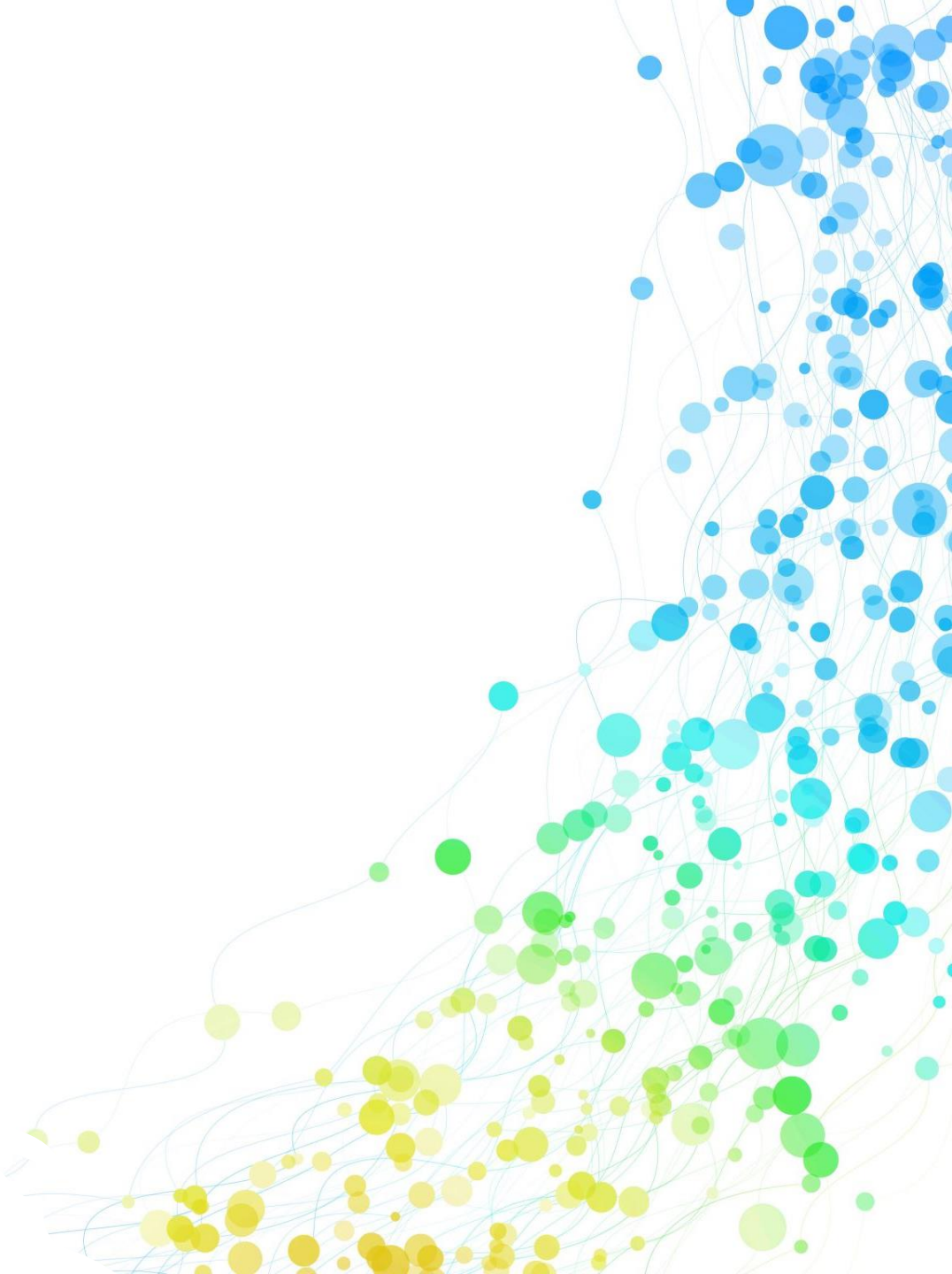
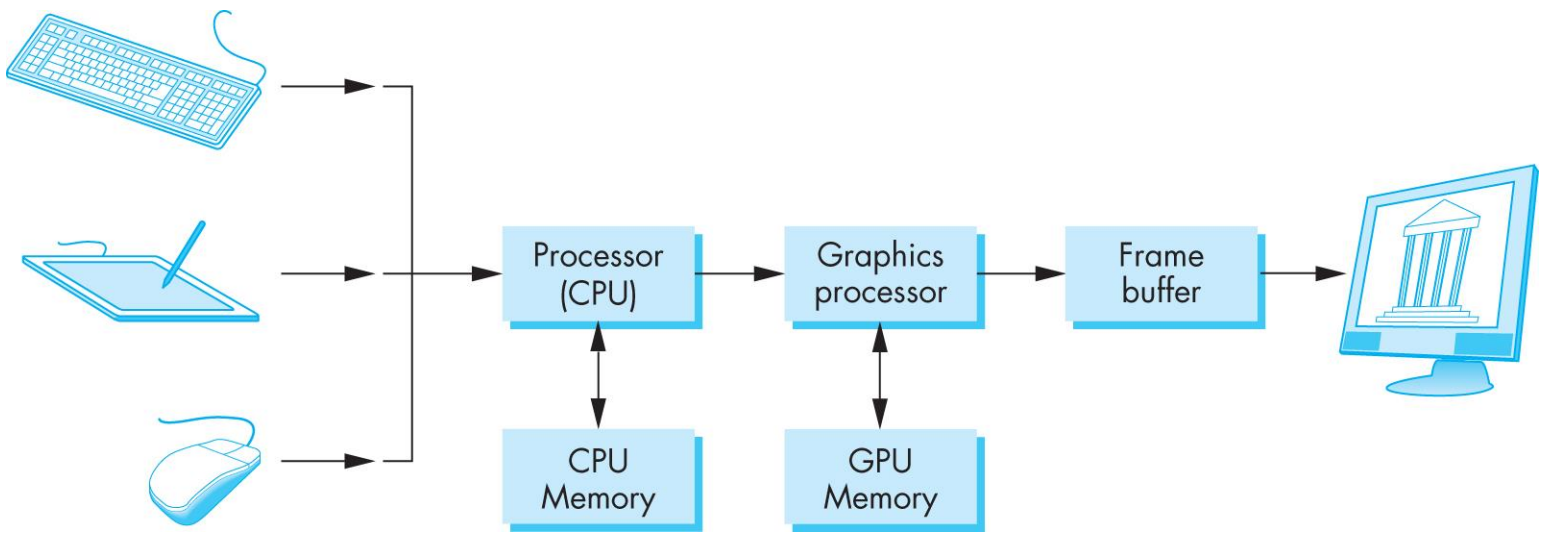
Graphics Systems and Models

2ND WEEK, 2021



Graphics System

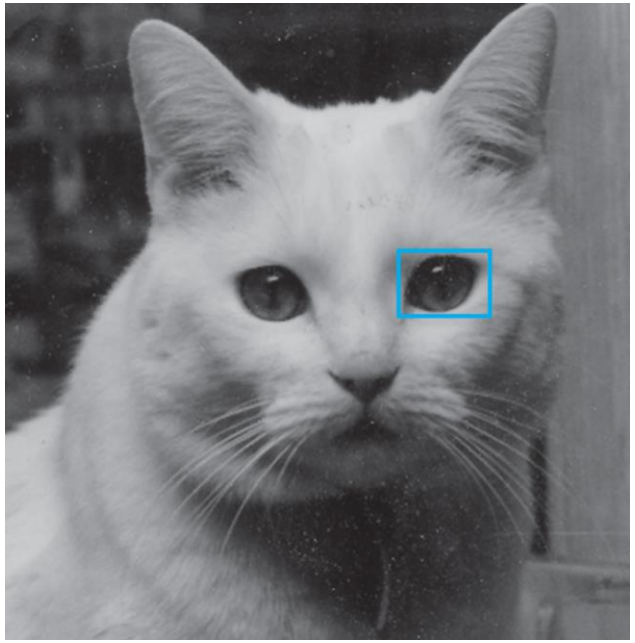
- Six major elements:
  - Input devices
  - Central processing unit
  - Graphics processing unit
  - Memory
  - Frame buffer
  - Output devices

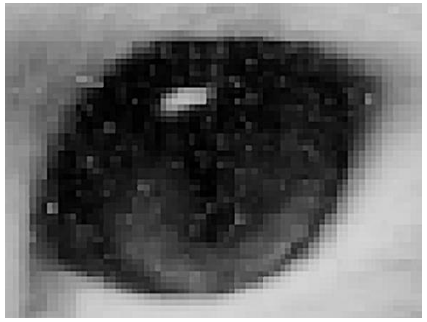


A Graphics System

Pixels and Frame Buffers (1)

- Raster graphics
  - Image produced as an array (the raster) of picture elements (pixels) in the frame buffer (a part of memory where the pixels are stored)





Pixels

Pixels and Frame Buffers (2)

- Resolution
  - The number of pixels in the frame buffer
  - To determine the detail that you can see in the image

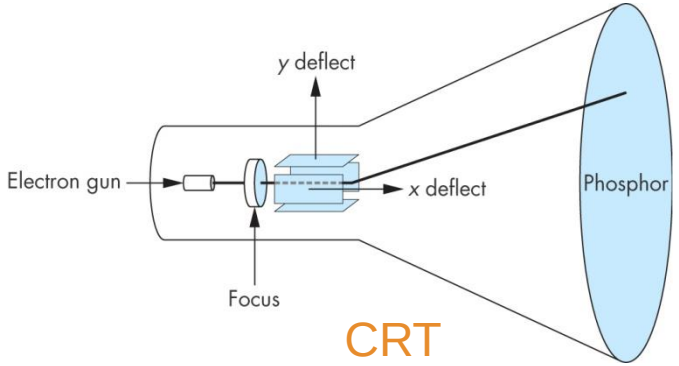
- Depth or precision of the frame buffer
  - The number of bits that are used for each pixel
  - To determine how many colors can be represented
    - Ex) 8 bits per pixel: 2^8=256 colors 24 bits (true-color system), 12 or more bits (HDR – High dynamic range)

The CPU and GPU

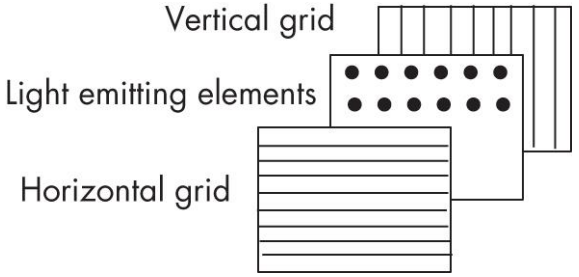
- Central processing unit (CPU)
  - Doing both the normal processing and the graphics processing
  - Rasterization or scan conversion
    - Conversion of geometric entities (such as lines, circles, and polygons) to pixel colors and locations in the frame buffer
- Graphics processing unit (GPU)
  - Custom-tailored to carry out specific graphics functions
  - High degree of parallelism

Output Devices

- Cathode-ray tube (CRT)



CRT



Generic Flat-Panel Display

- Flat-panel monitors
  - Light-emitting diodes (LEDs), liquid-crystal displays (LCDs), and plasma panels
- Projection systems
  - Digital light projection (DLP)
- Hard-copy devices

Input Devices

- Most graphics systems provide a keyboard and at least one other input device
  - Pointing devices

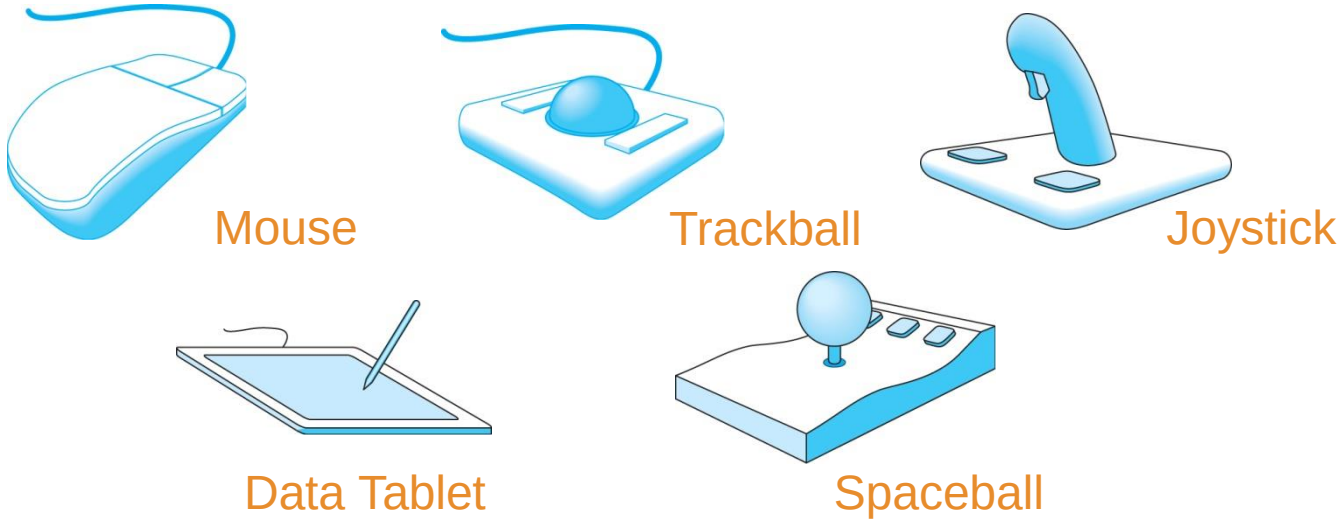
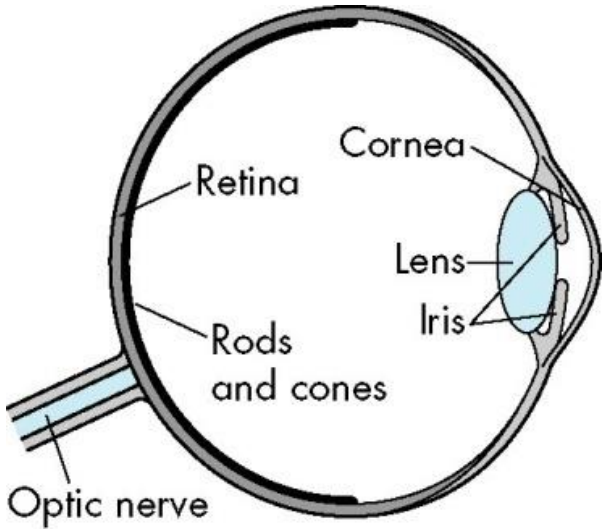


Image Formation (1)

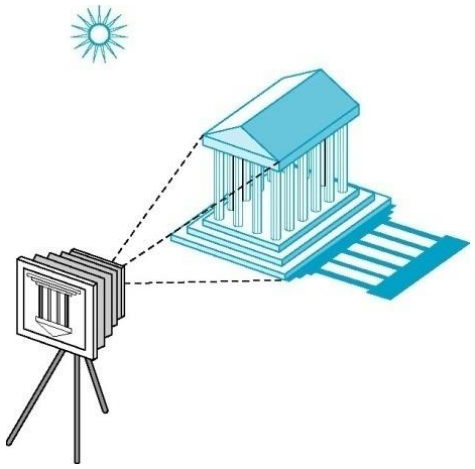
- There always has been analogous process how image are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system
    - Rods and cones are light sensors
    - Rods – monochromatic, night vision
    - Cones – color sensitive
      - Three types of cones
      - Only three values (the tristimulus values) are sent to the brain



The Human Visual System

Image Formation (2)

- Elements of image formation
  - Objects
    - Independent of any viewer and of any image-formation process
  - Viewer (Camera)
    - To form the image of objects
  - Light sources



Camera System

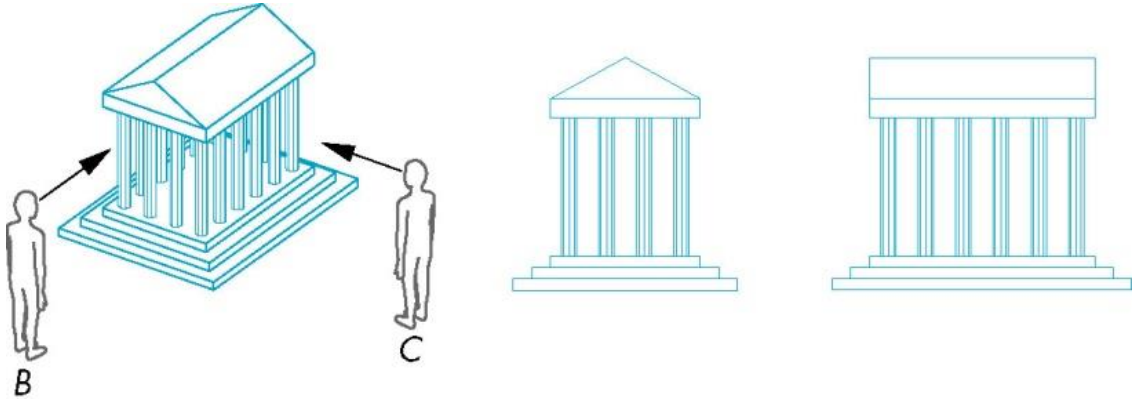
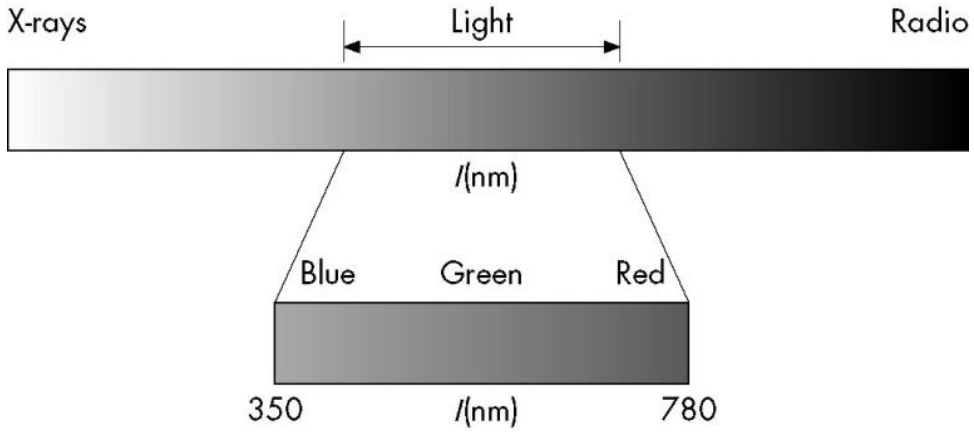


Image Seen by Three Different Viewers

Light and Images

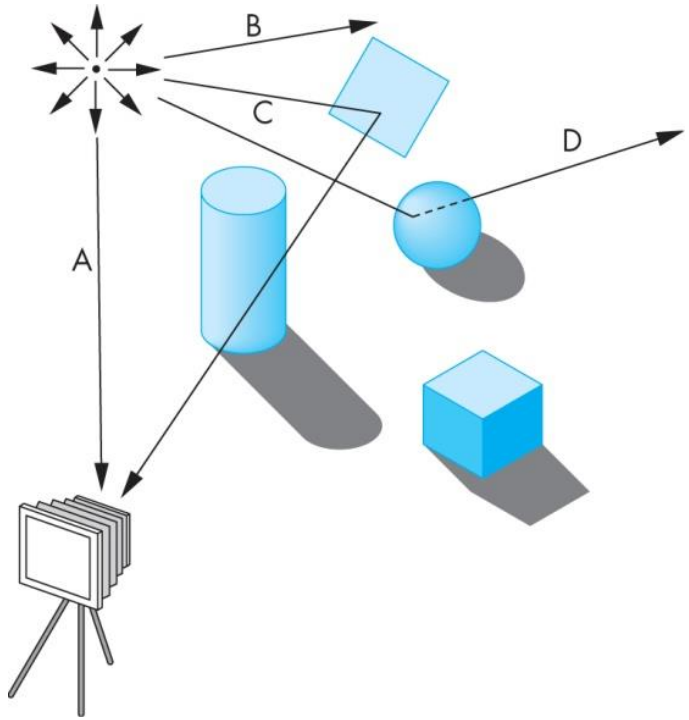
- Interaction between light and the surfaces of the objects
  ➔ How much light enters the camera
- Visual Spectrum = visible light
  - Wavelengths in the range 350~780nm
    - Long wavelengths: reds
    - Short wavelengths: blues



The Electromagnetic Spectrum

Imaging Models

- Ray tracing
  - Image formation techniques
  - Following rays of light from a point source finding which rays enter the lens of the camera
- Radiosity
  - Based on conservation of energy



Ray Interactions

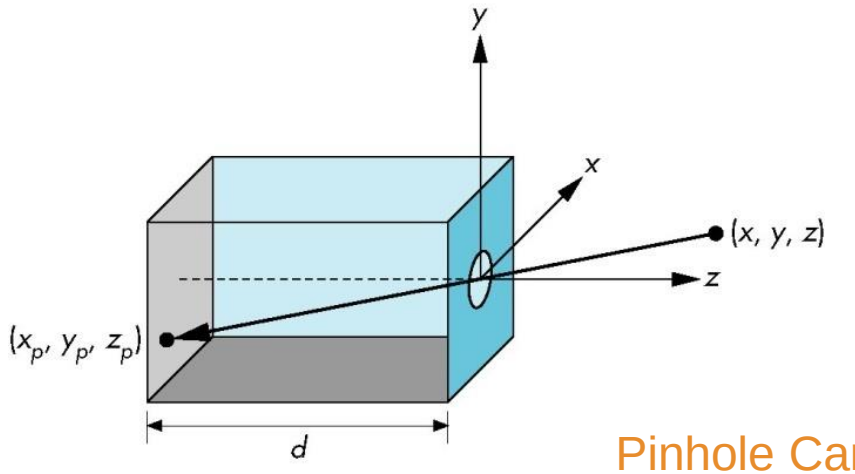
Imaging Systems

- Pinhole Camera
  - Projection of point (x, y, z)

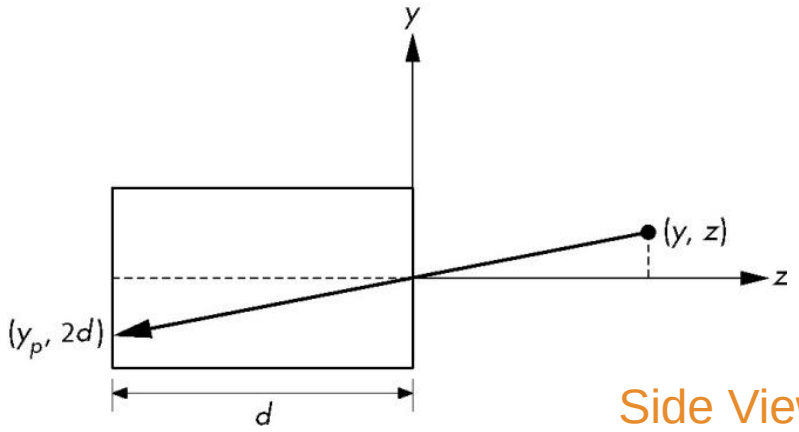
$$x_p = -\frac{x}{z/d} \quad y_p = -\frac{y}{z/d} \quad z_p = -d$$

  - Field of view (angle of view)

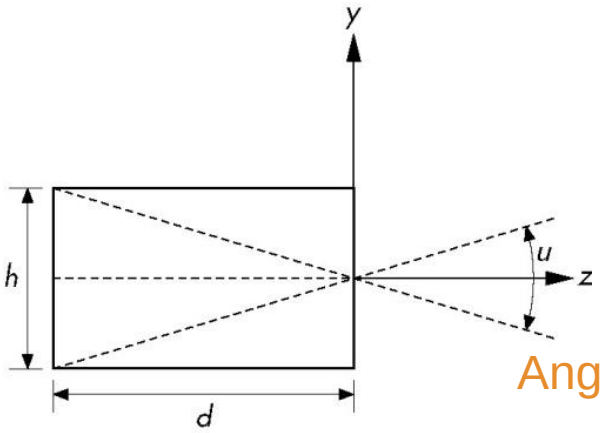
$$\theta = 2\tan^{-2}\frac{h}{2d}$$



Pinhole Camera



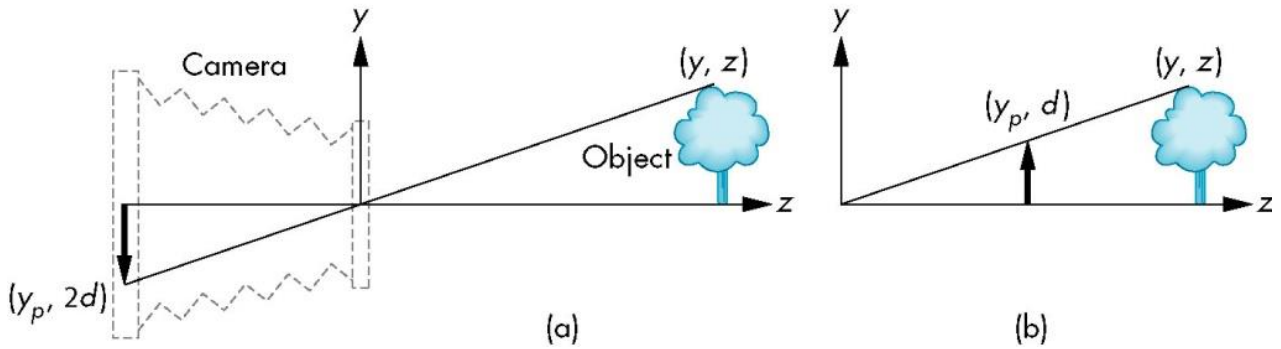
Side View



Angle of View

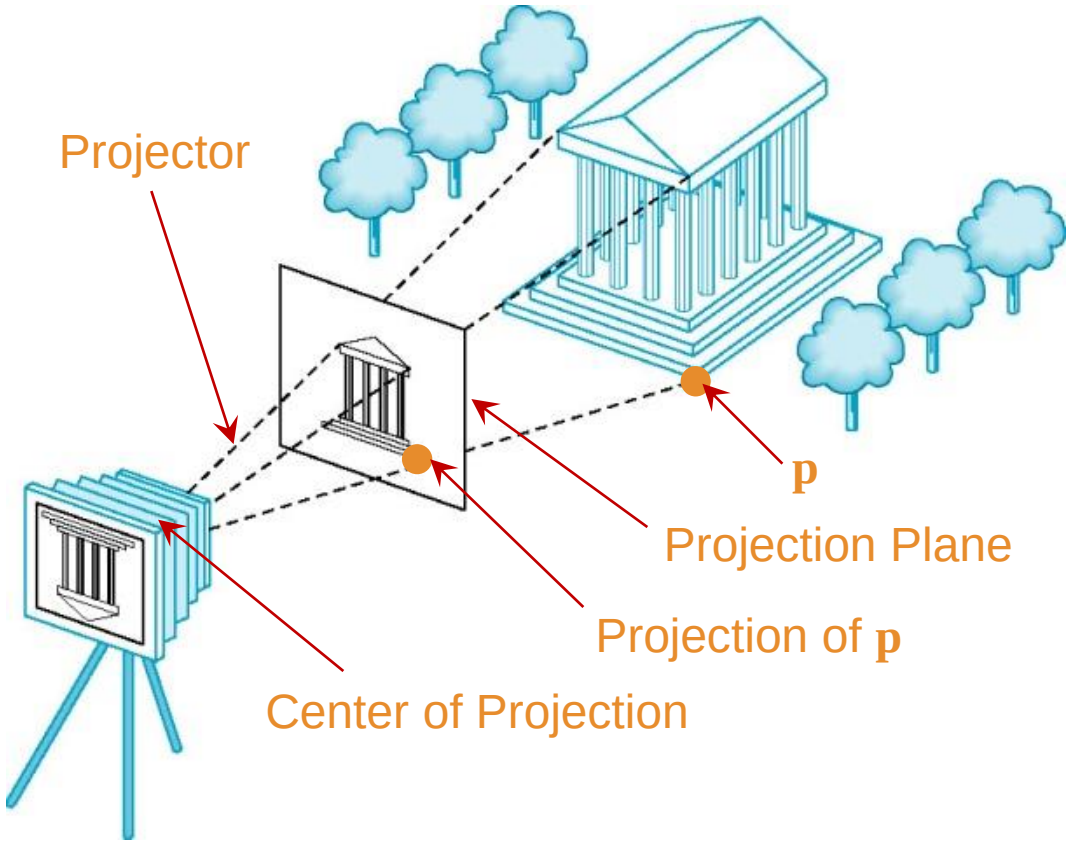
Synthetic-Camera Model (1)

- Conceptual foundation for three-dimensional computer graphics
  - Projector
    - Line from the center of lens to a point on the object
  - COP (center of projection)
    - The center of the lens
  - Projection plane
    - Virtual image plane that are moved in front of the lens



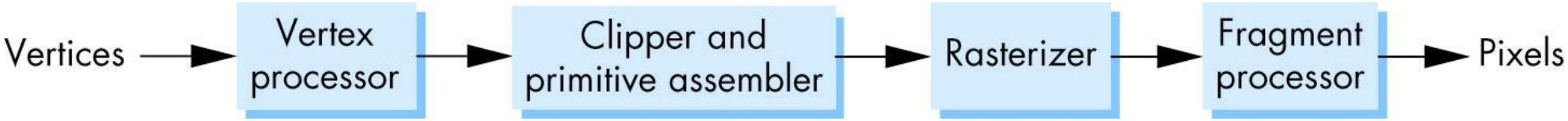
Equivalent views of image formation

Synthetic-Camera Model (2)



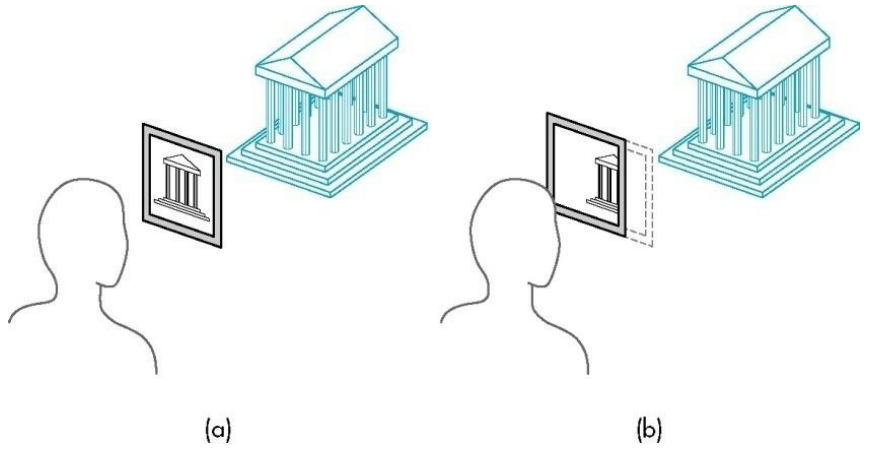
Graphics Architecture

- Graphics pipeline
  - Geometry – collection of primitive types and vertices



Geometric pipeline

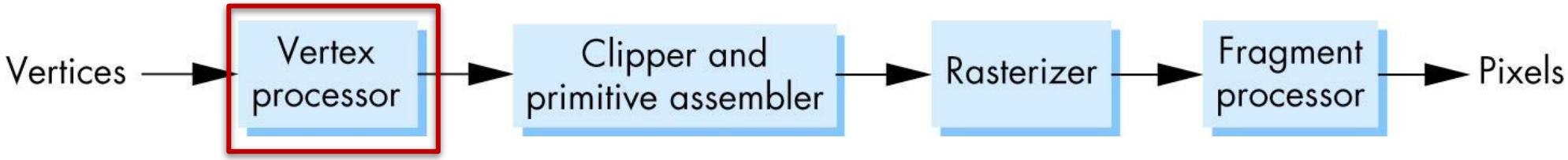
  - Vertex processing
    - World and view transformation
    - Projection
    - Lighting
  - Clipping and primitive assembly
  - Rasterization
  - Fragment processing



Clipping

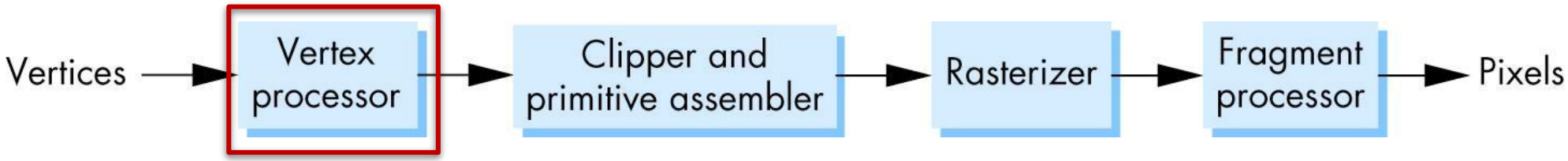
Vertex Processing (1)

- Much of the work in the pipeline is in converting object representations from one coordinate system to another
  - Object coordinates
  - Camera (eye) coordinates
  - Screen coordinates
- Every change of coordinates is equivalent to a matrix transformation
- Vertex processor also computes vertex colors



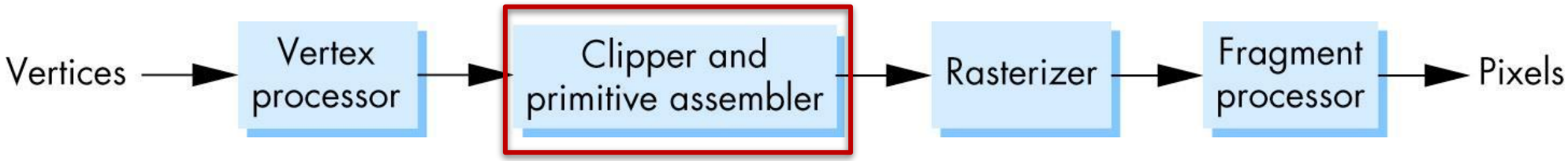
Vertex Processing (2)

- Projection is the process that combines the 3D viewer with the 3D objects to produce the 2D image
  - Perspective projection: all projectors meet at the center of projection
  - Parallel projection: projectors are parallel, center of projection is replaced by a direction of projection



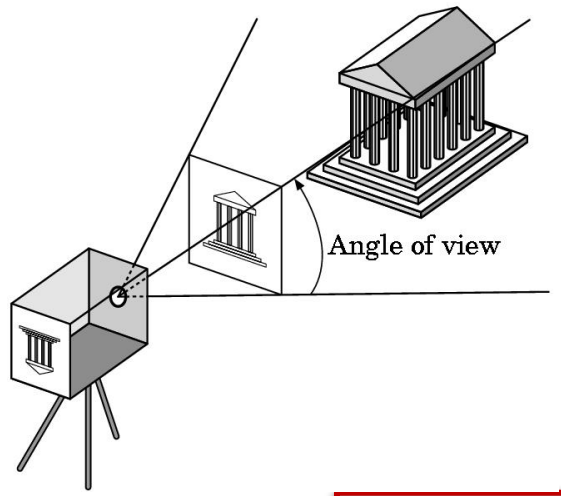
Primitive Assembly

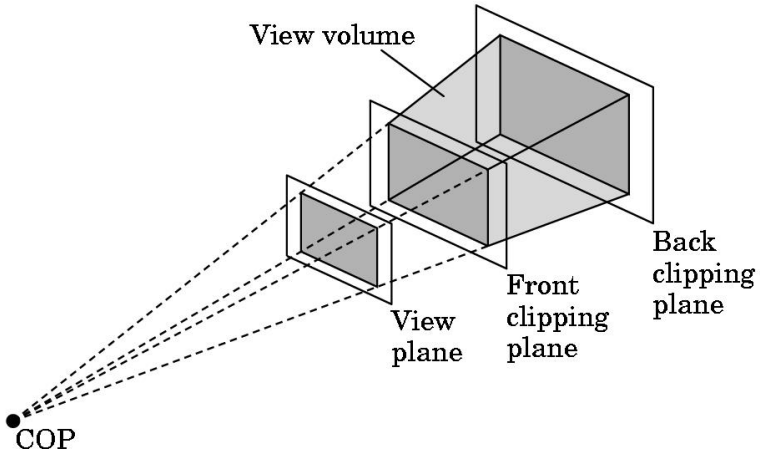
- Vertices must be collected into geometric objects before clipping and rasterization can take place
  - Line segments
  - Polygons
  - Curves and surfaces

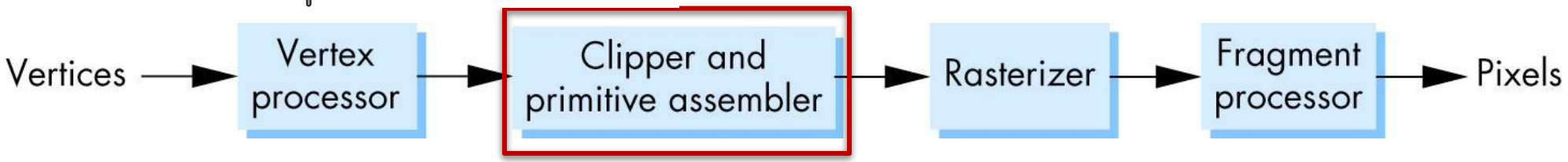


Clipping

- Just as a real camera cannot “see” the whole world, the virtual camera can only see part of the world or object space
  - Objects that are not within this volume are said to be clipped out of the scene

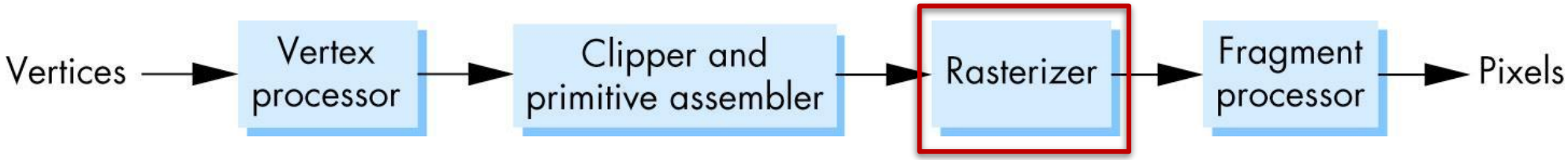






Rasterization

- If an object is not clipped out, the appropriate pixels in the frame buffer must be assigned colors
- Rasterizer produces a set of fragments for each object
- Fragments are "potential pixels"
  - Have a location in frame buffer
  - Color and depth attributes
- Vertex attributes are interpolated over objects by the rasterizer



Fragment Processing

- Fragments are processed to determine the color of the corresponding pixel in the frame buffer
- Colors can be determined by texture mapping or interpolation of vertex colors
- Fragments may be blocked by other fragments closer to the camera
  - Hidden-surface removal