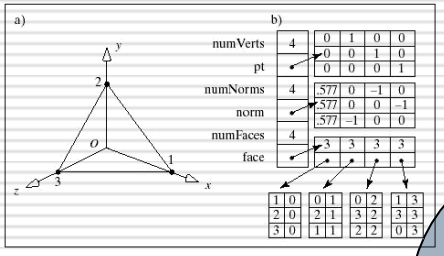
Computer Graphics

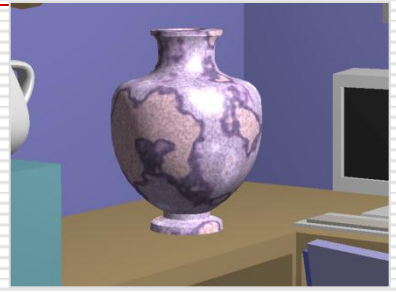
Bing-Yu Chen
National Taiwan University
The University of Tokyo

Introduction

- The Graphics Process
- Color Models
- Triangle Meshes
- The Rendering Pipeline

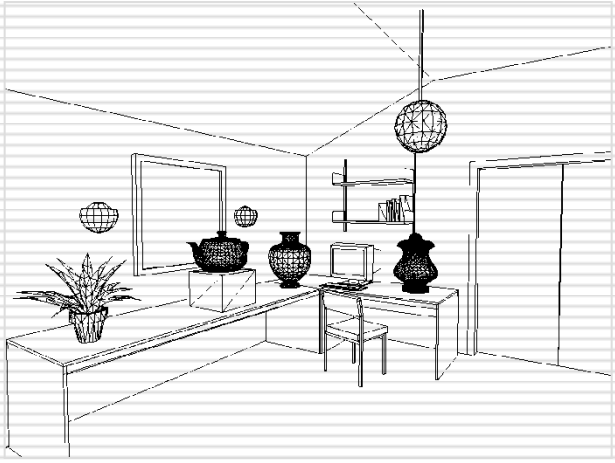
What is Computer Graphics ?





modeling → rendering

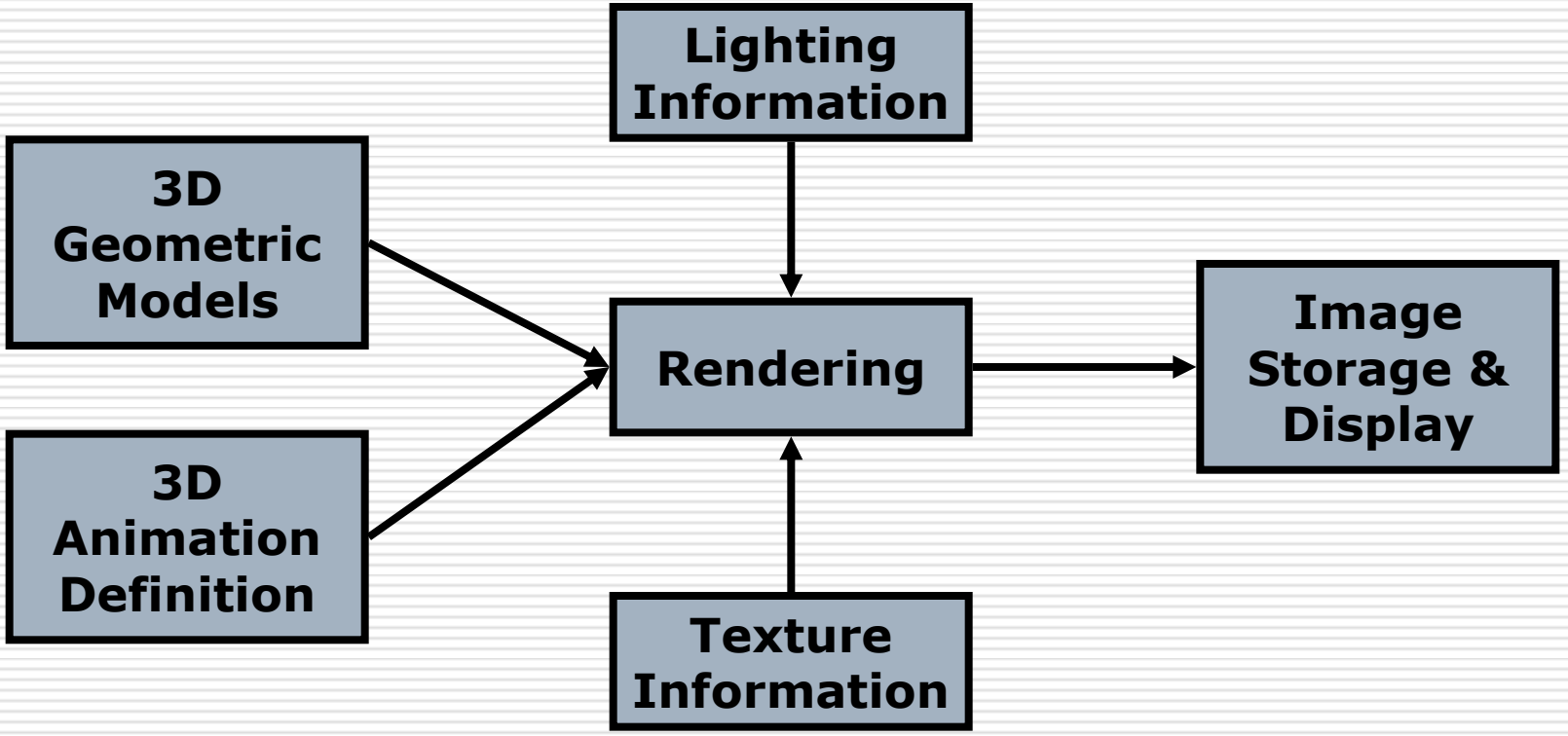
modeling → animation → rendering



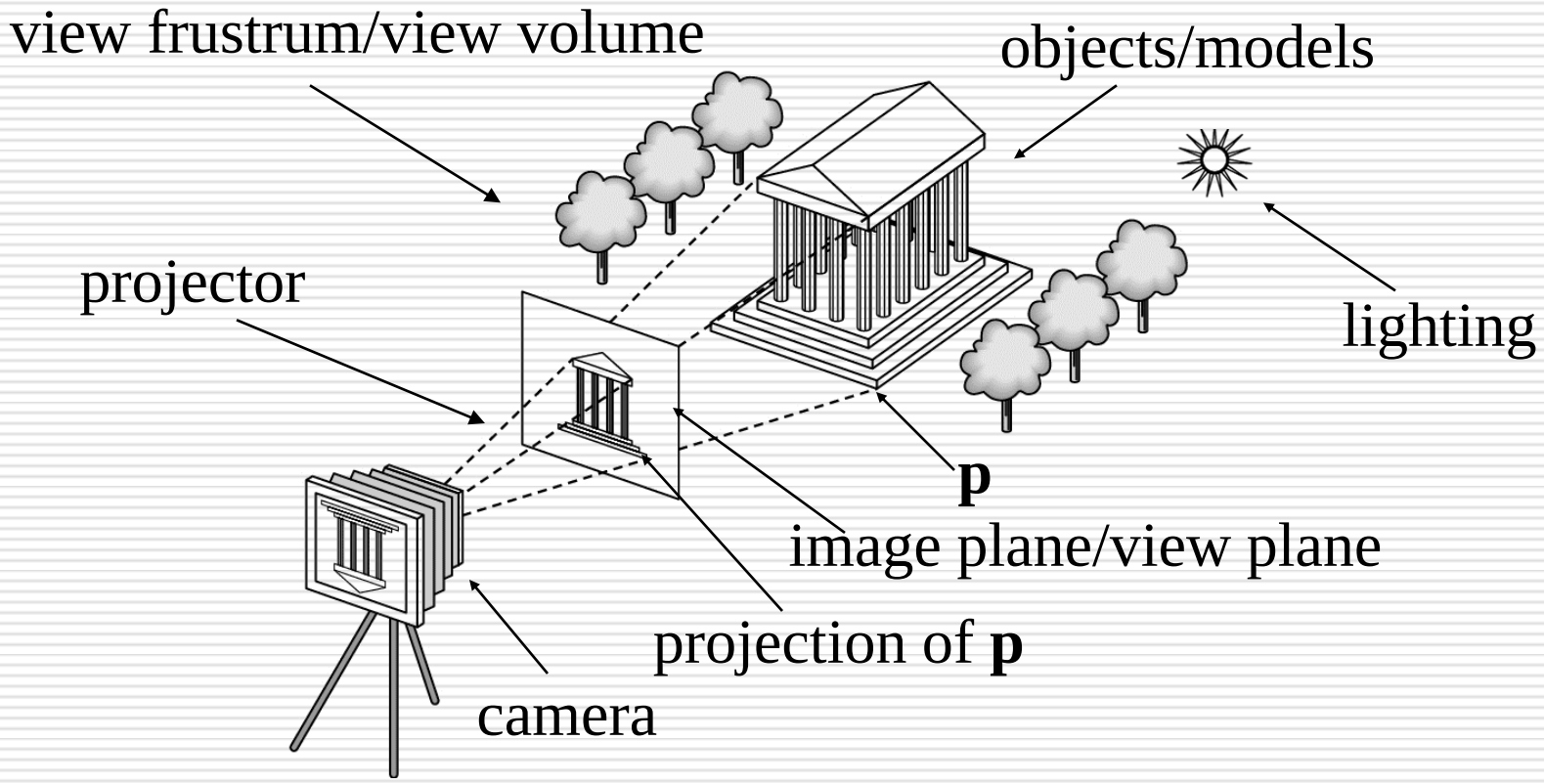
Applications

- Movies
- Interactive entertainment
- Industrial design
- Architecture
- Culture heritage

The Graphics Process

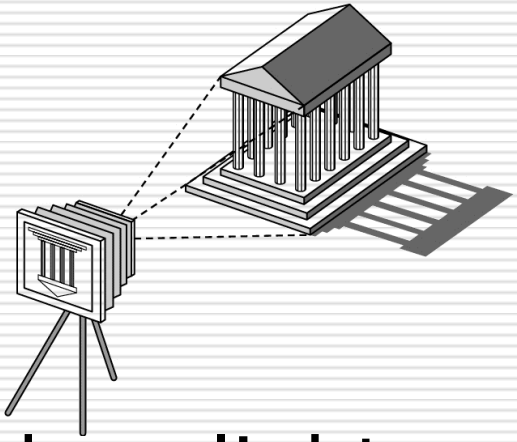


Synthetic Camera Model



Elements of Image Formation

- Objects
- Viewer
- Light source(s)



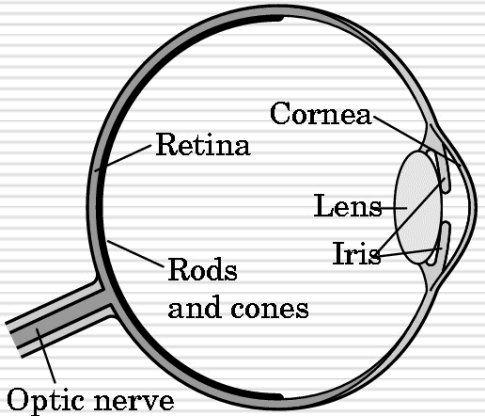
- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, viewer, and light source(s)

Luminance and Color Images

- Luminance
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television
- Color
  - Has perceptional attributes of hue, saturation, and lightness
  - Do we have to match every frequency in visible spectrum? No!

Three-Color Theory

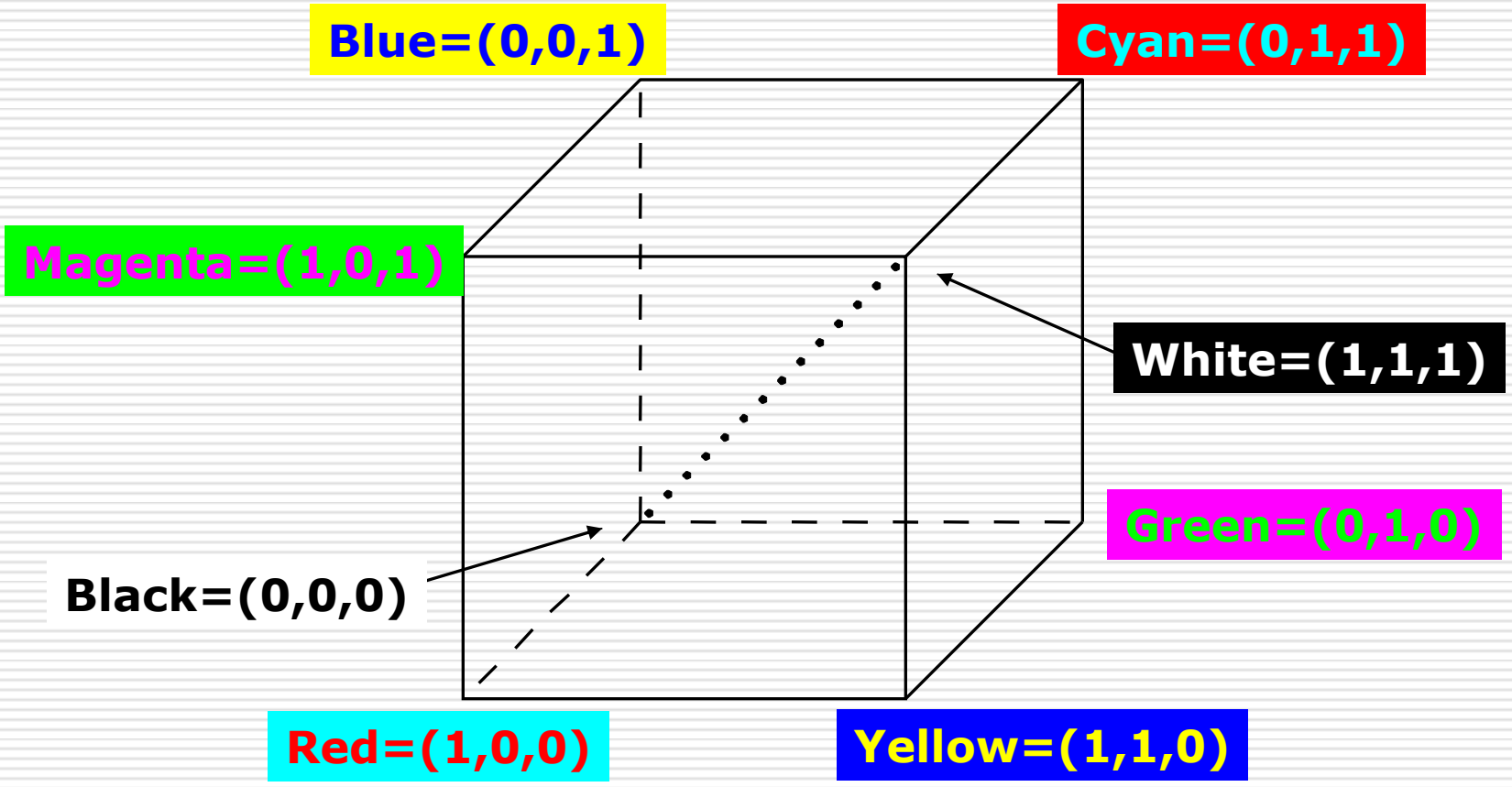
- Human visual system has two types of sensors
  - Rods: monochromatic, night vision
  - Cones
    - Color sensitive
    - Three types of cone
    - Only three values (the *tristimulus* values) are sent to the brain
- Need only match these three values
  - Need only three *primary* colors



Additive and Subtractive Color

- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, projection systems, positive film
  - Primaries are Red (R), Green (G), Blue (B)
- Subtractive color
  - Form a color by filtering white light with Cyan (C), Magenta (M), and Yellow (Y) filters
    - Light-material interactions
    - Printing
    - Negative film

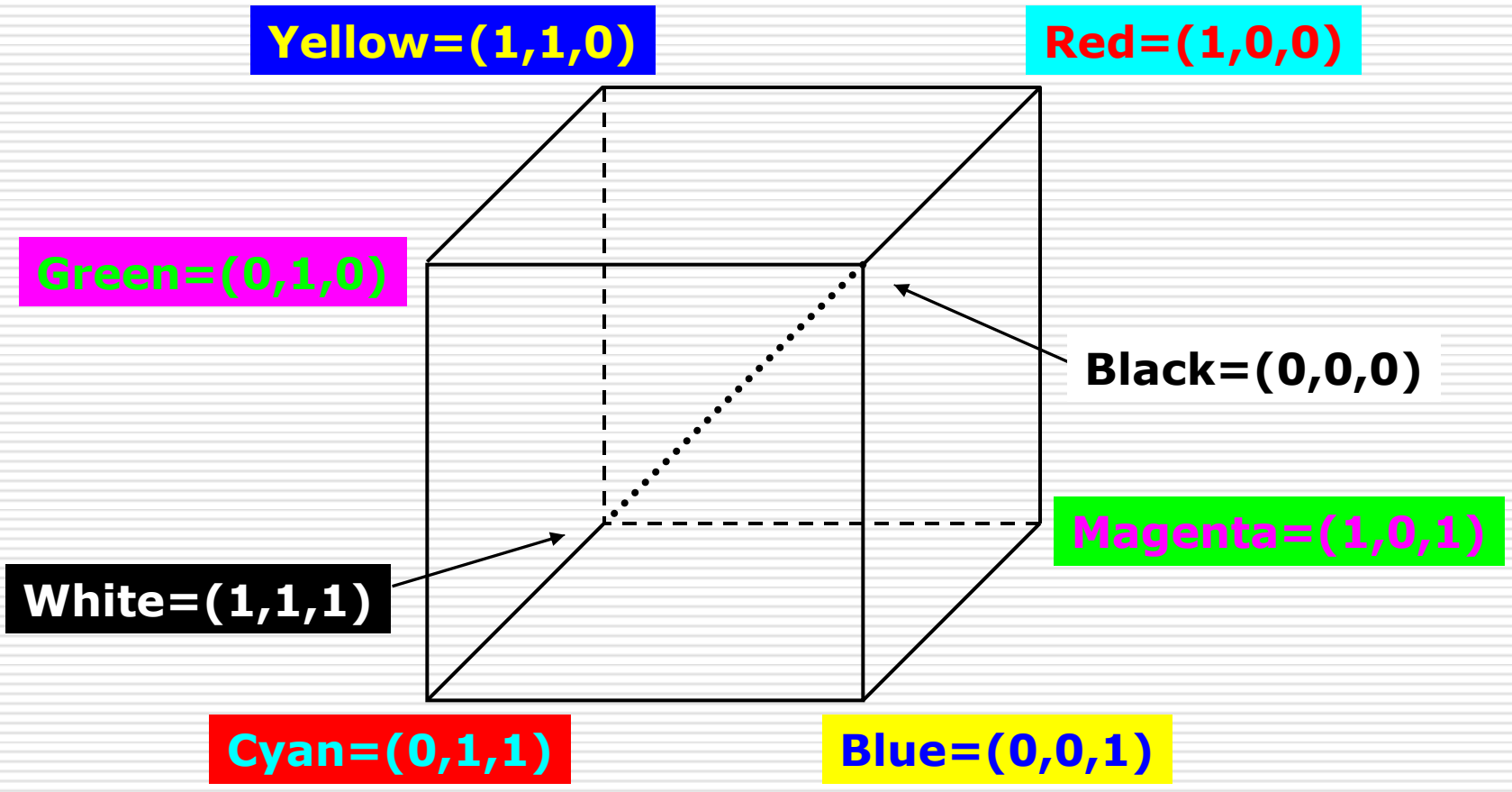
The RGB Color Model – for CRT



Color Depth

- Can choose number of bits for each of *r*, *g* and *b*
  - More bits per component means more colors can be distinguished, but image files will be larger
  - 8 bits (1 byte) per component: *24-bit color*, millions of colors
- If $r = g = b$, color is a shade of gray, so grayscale can be represented by a single value
  - 8 bits permits 256 grays

The CMY Color Model – for hardcopy

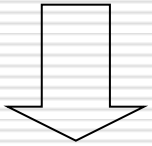


Undercolor Removal: CMYK System

- Real inks do not correspond to ideal subtractive primaries
- Combining three inks for black is undesirable
- Printers use *four process colors*, cyan, magenta, yellow and black
- CMYK gamut is not the same as RGB
  - Implications for using images prepared for print (CMYK) on the Web (RGB)

The CMYK Color Model – for hardcopy

- $C = G+B = W-R$
- $M = R+B = W-G$
- $Y = R+G = W-B$



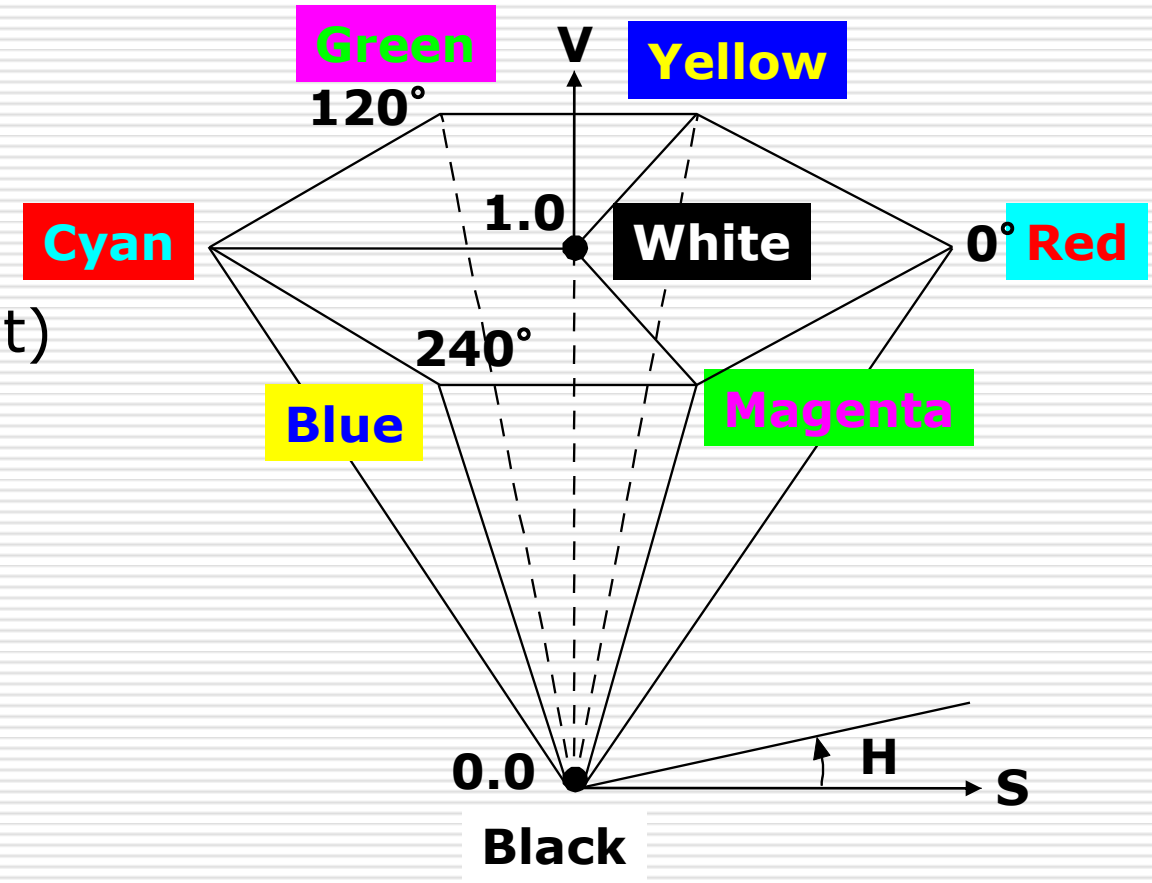
- $K = \min(C,M,Y)$
- $C \leftarrow C-K$
- $M \leftarrow M-K$
- $Y \leftarrow Y-K$

The HSV Color Model – for user-oriented

- Alternative way of specifying color
- *Hue* (roughly, dominant wavelength)
- *Saturation* (purity)
- *Value* (brightness)
- Model HSV as a cylinder: *H* angle, *S* distance from axis, *V* distance along axis
- Basis of popular style of *color picker*

The HSV Color Model – for user-oriented

- H : hue
- S : saturation
- V : value
  - (or B for blight)

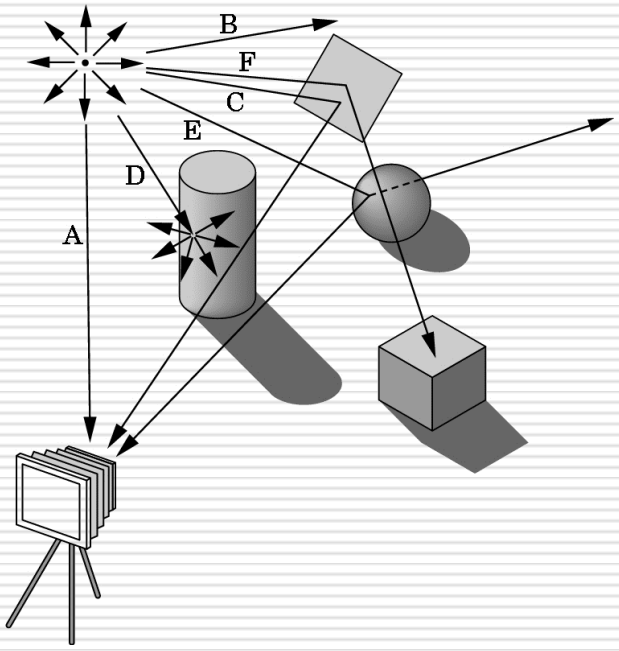


Basics of Rendering

- Pipeline Based Rendering
  - Objects in the scene are rendered in a sequence of steps that form the Rendering Pipeline.
- Ray-Tracing
  - A series of rays are projected thru the view plane and the view plane is colored based on the object that the ray strikes

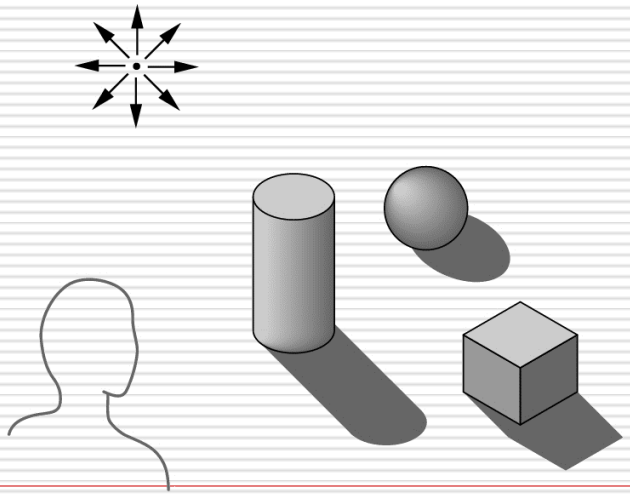
Ray Tracing and Geometric Optics

One way to form an image is to follow rays of light from a point source determine 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.

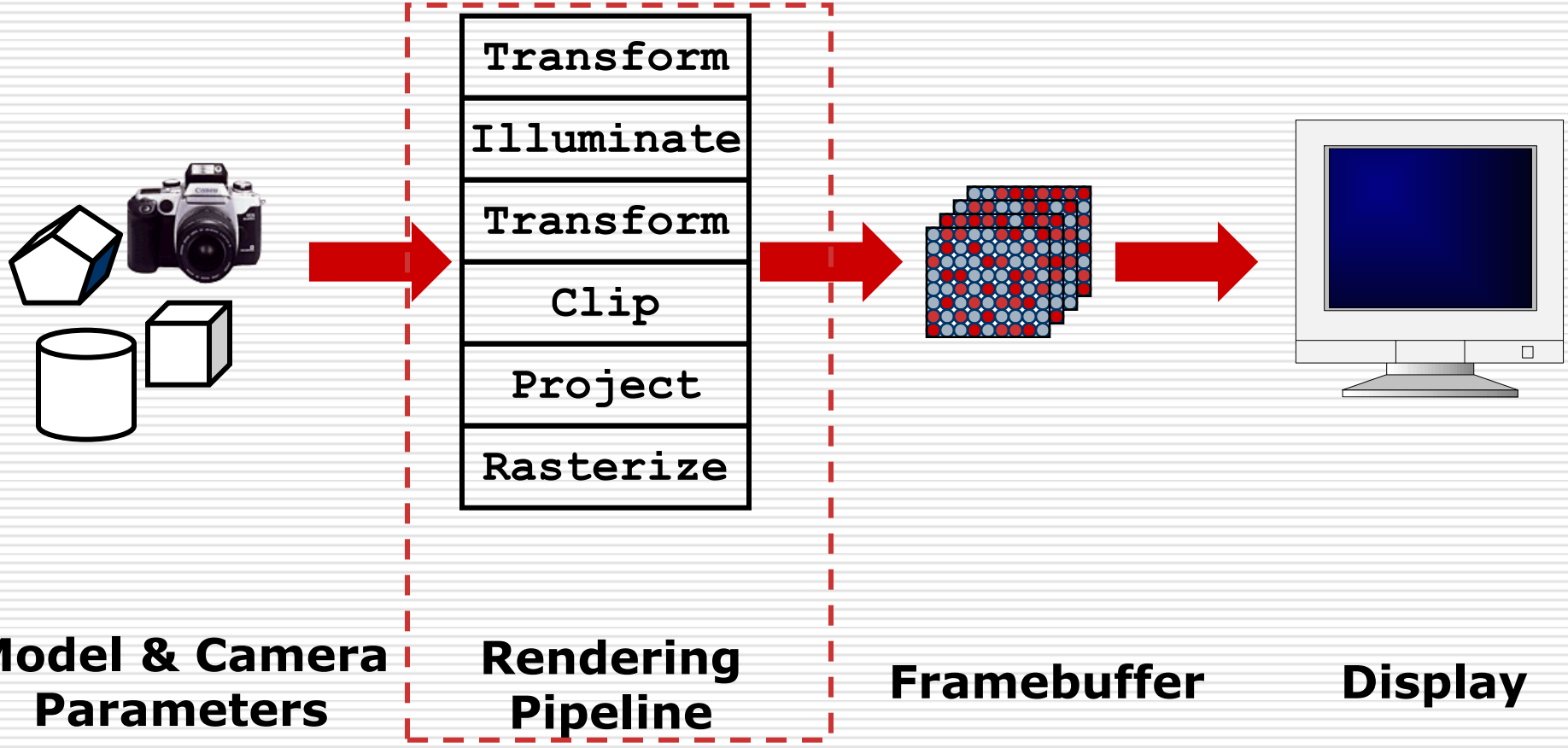


Global vs. Local Lighting

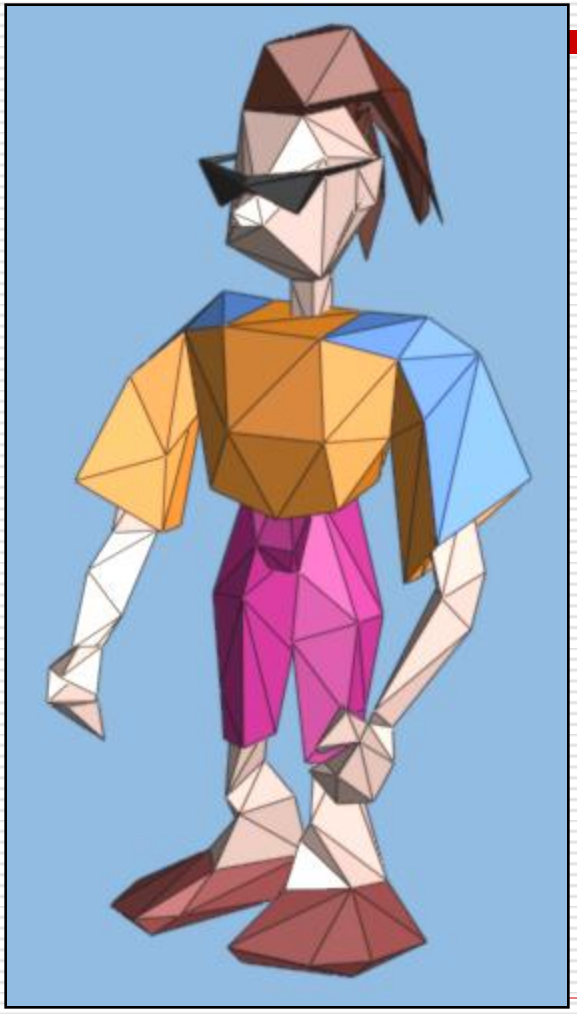
- Cannot compute color or shade of each object independently
  - Some objects are blocked from light
  - Light can reflect from object to object
  - Some objects might be translucent



Pipeline Rendering



Definitions of Triangle Meshes



[Hoppe 99']

$\{f_1\} : \{ v_1 , v_2 , v_3 \}$
$\{f_2\} : \{ v_3 , v_2 , v_4 \}$
…

connectivity

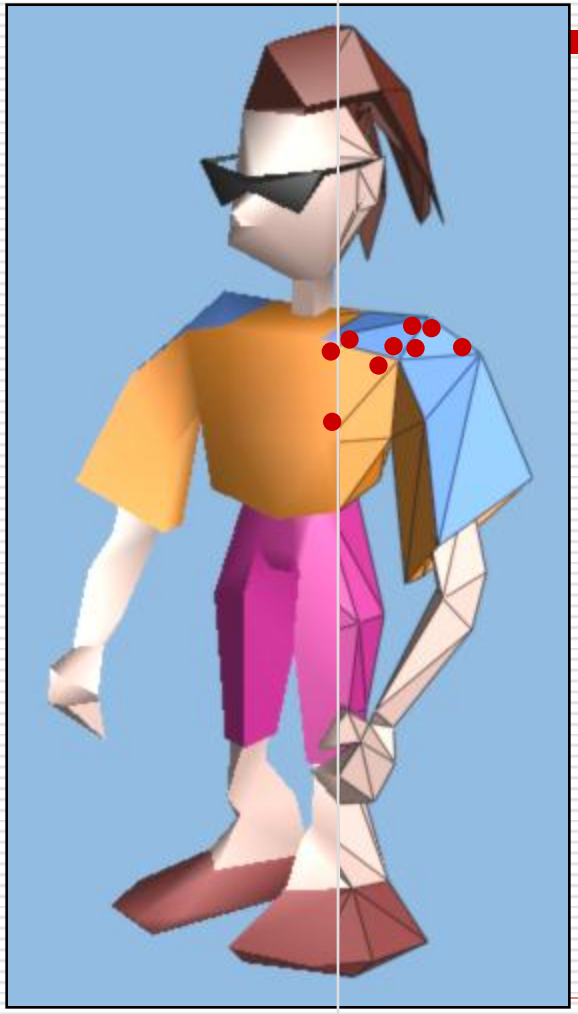
$\{v_1\} : (x,y,z)$
$\{v_2\} : (x,y,z)$
…

geometry

$\{f_1\}$: *"skin material"*
$\{f_2\}$: *"brown hair"*
…

face attributes

Definitions of Triangle Meshes



[Hoppe 99']

$\{f_1\} : \{ v_1 , v_2 , v_3 \}$
$\{f_2\} : \{ v_3 , v_2 , v_4 \}$
…

connectivity

$\{v_1\} : (x,y,z)$
$\{v_2\} : (x,y,z)$
…

geometry

$\{f_1\}$: *"skin material"*
$\{f_2\}$: *"brown hair"*
…

face attributes

$\{v_2,f_1\} : (n_x,n_y,n_z)\ (u,v)$
$\{v_2,f_2\} : (n_x,n_y,n_z)\ (u,v)$
…

corner attributes

Rendering: Transformations

- So far, discussion has been in *screen space*
- But model is stored in *model space* (a.k.a. object space or world space)
- Three sets of geometric transformations:
  - Modeling transforms
  - Viewing transforms
  - Projection transforms

The Rendering Pipeline