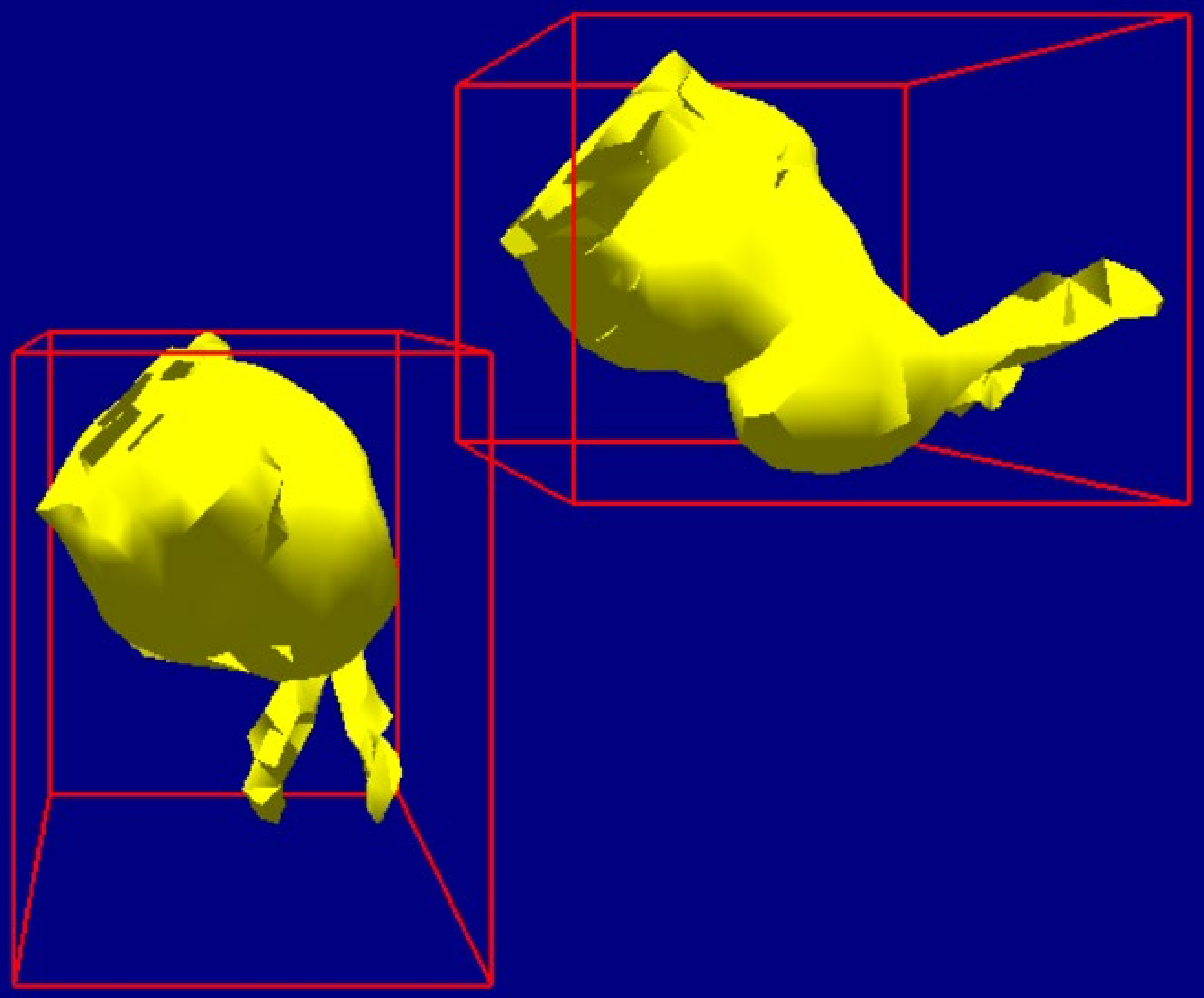


# INTERACTIVE COMPUTER GRAPHICS

HAMZAH ASYRANI SULAIMAN

Based on Angel and Shreiner Lecture Slide

# Computer Graphics

Hardware

Software

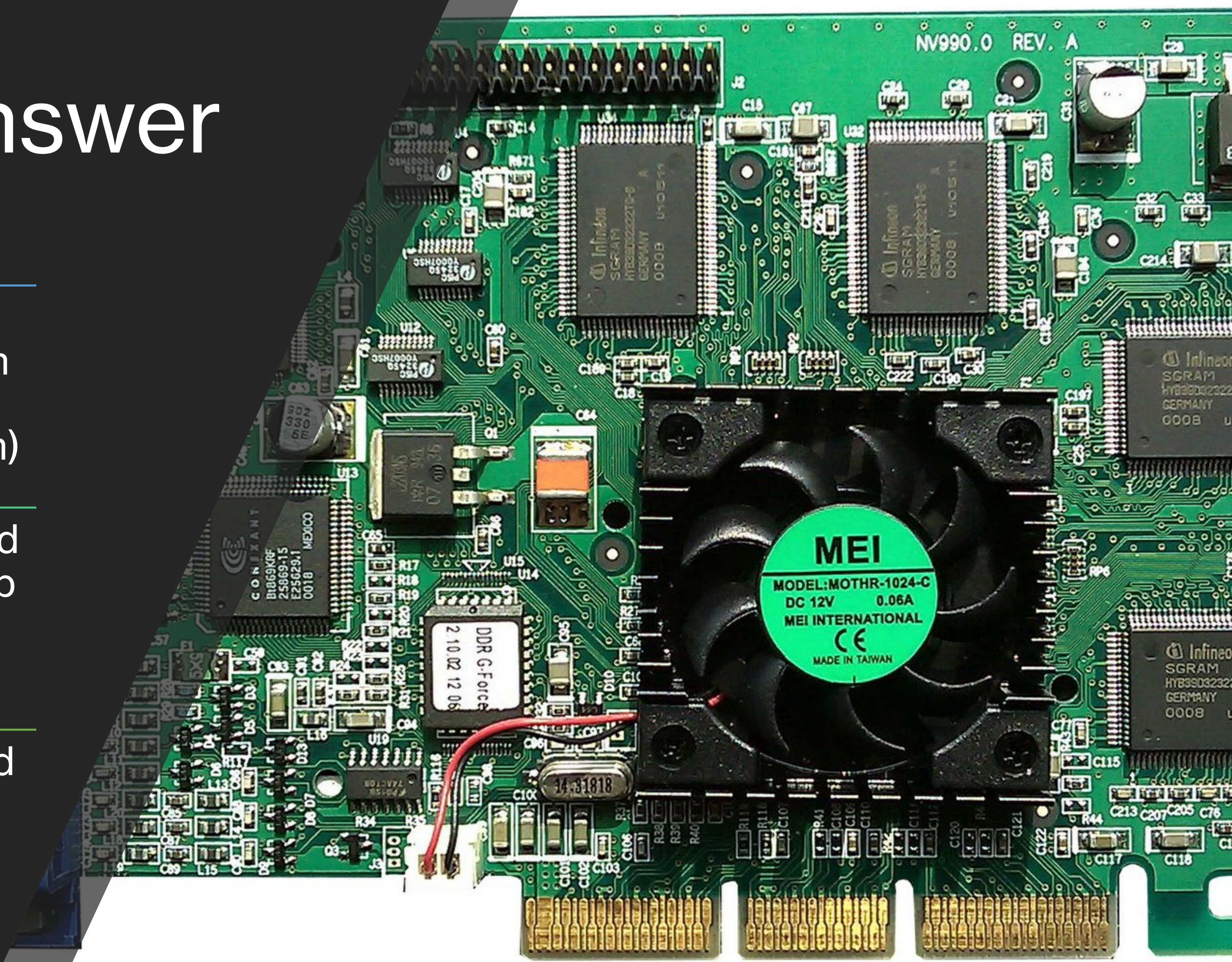
Applications

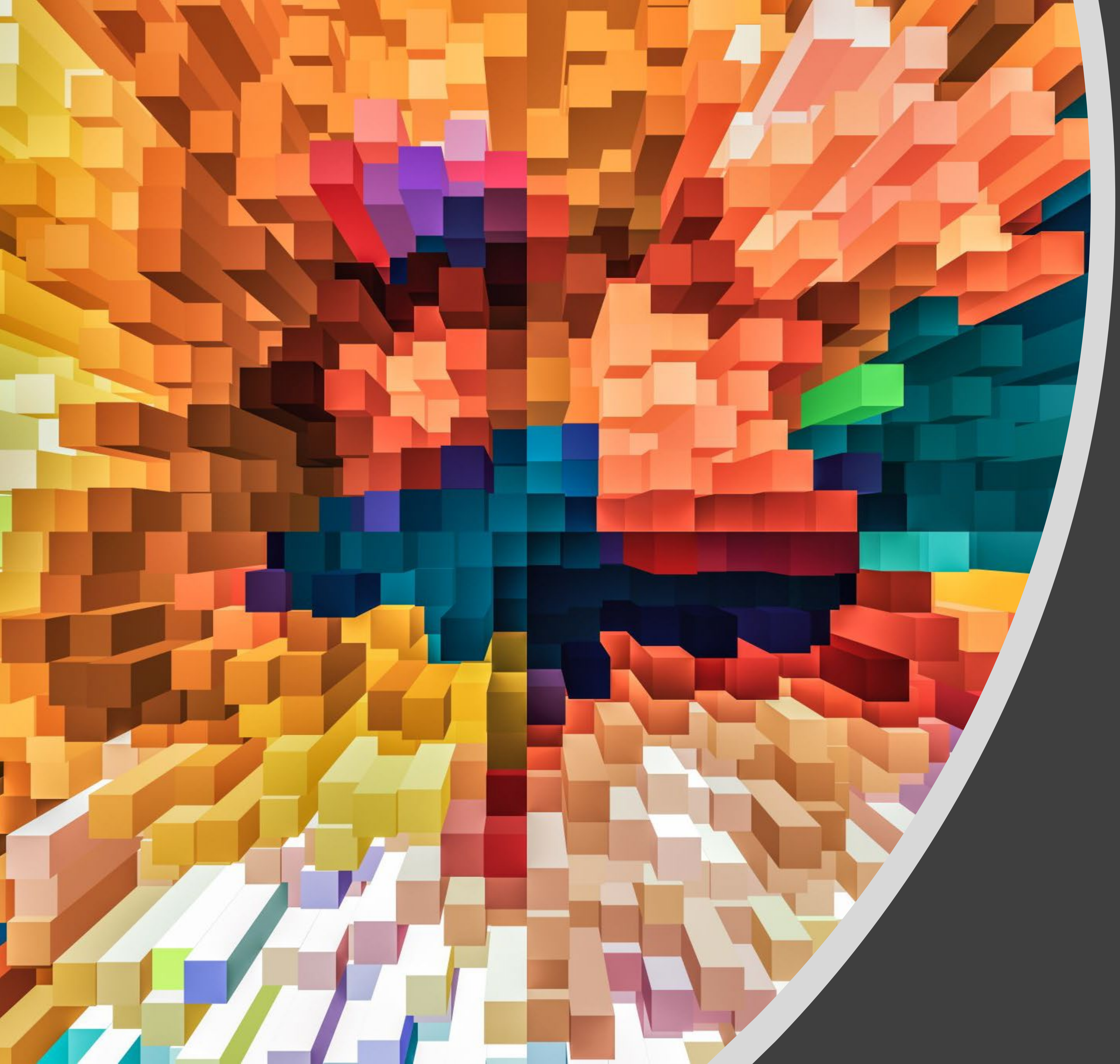
# Preliminary Answer

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

**Software**: Maya for modeling and rendering but Maya is built on top of OpenGL

**Hardware**: PC with graphics card for modeling and rendering

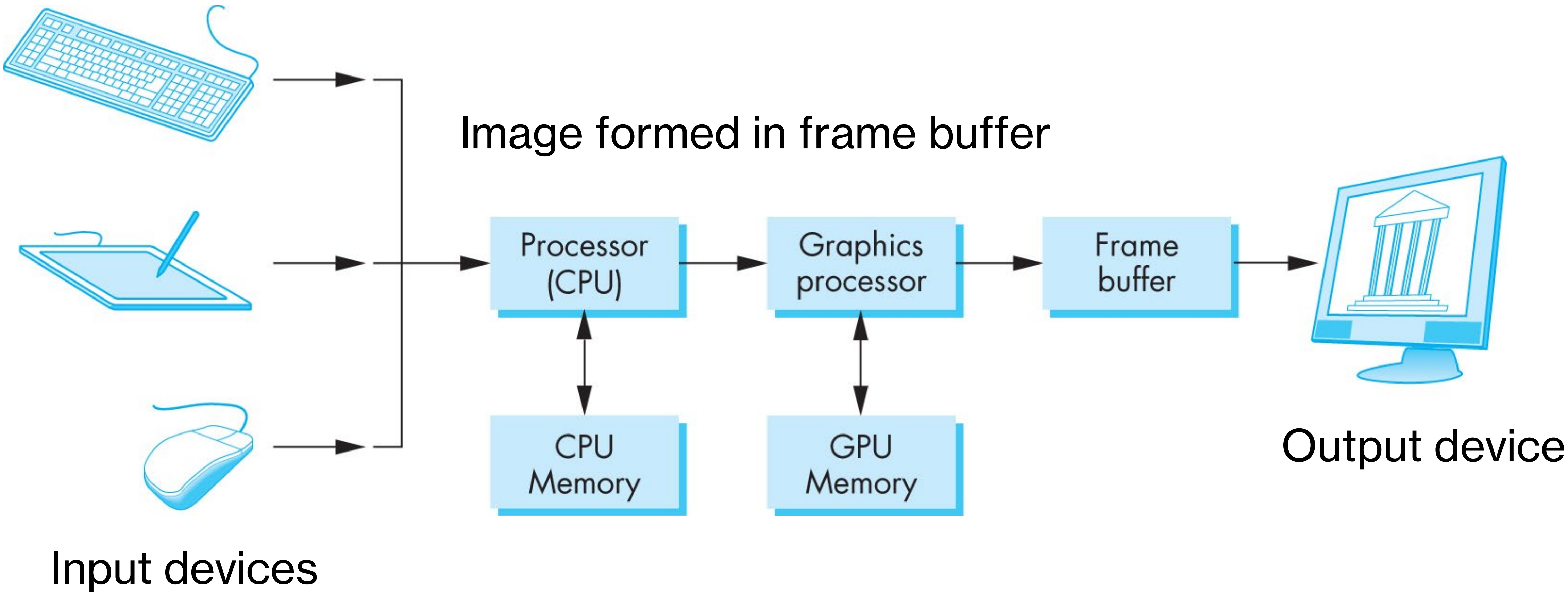




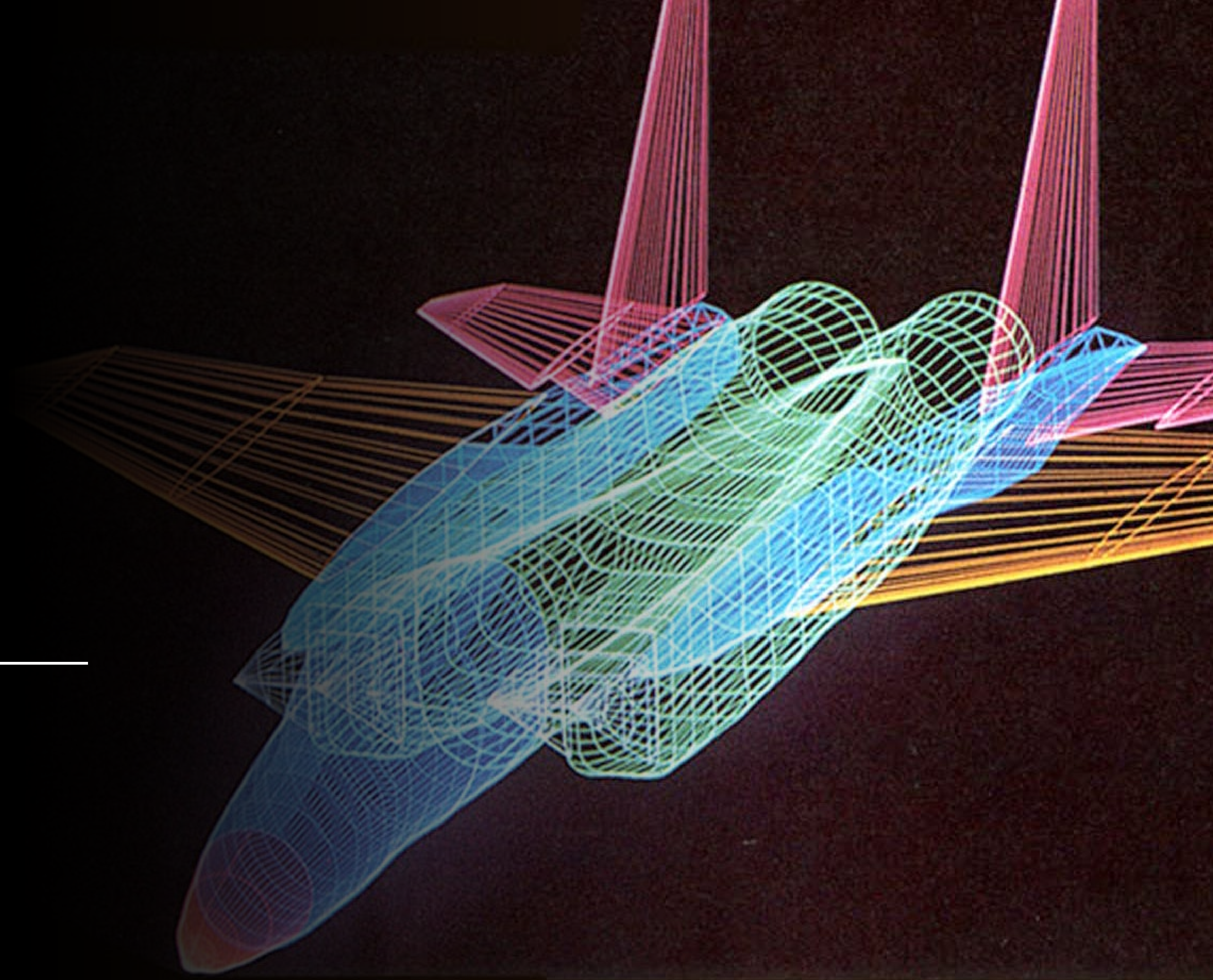
# Business of Generating Images

Images are made up of pixels

# Basic Graphics System



# Computer Graphics History



# Timeline

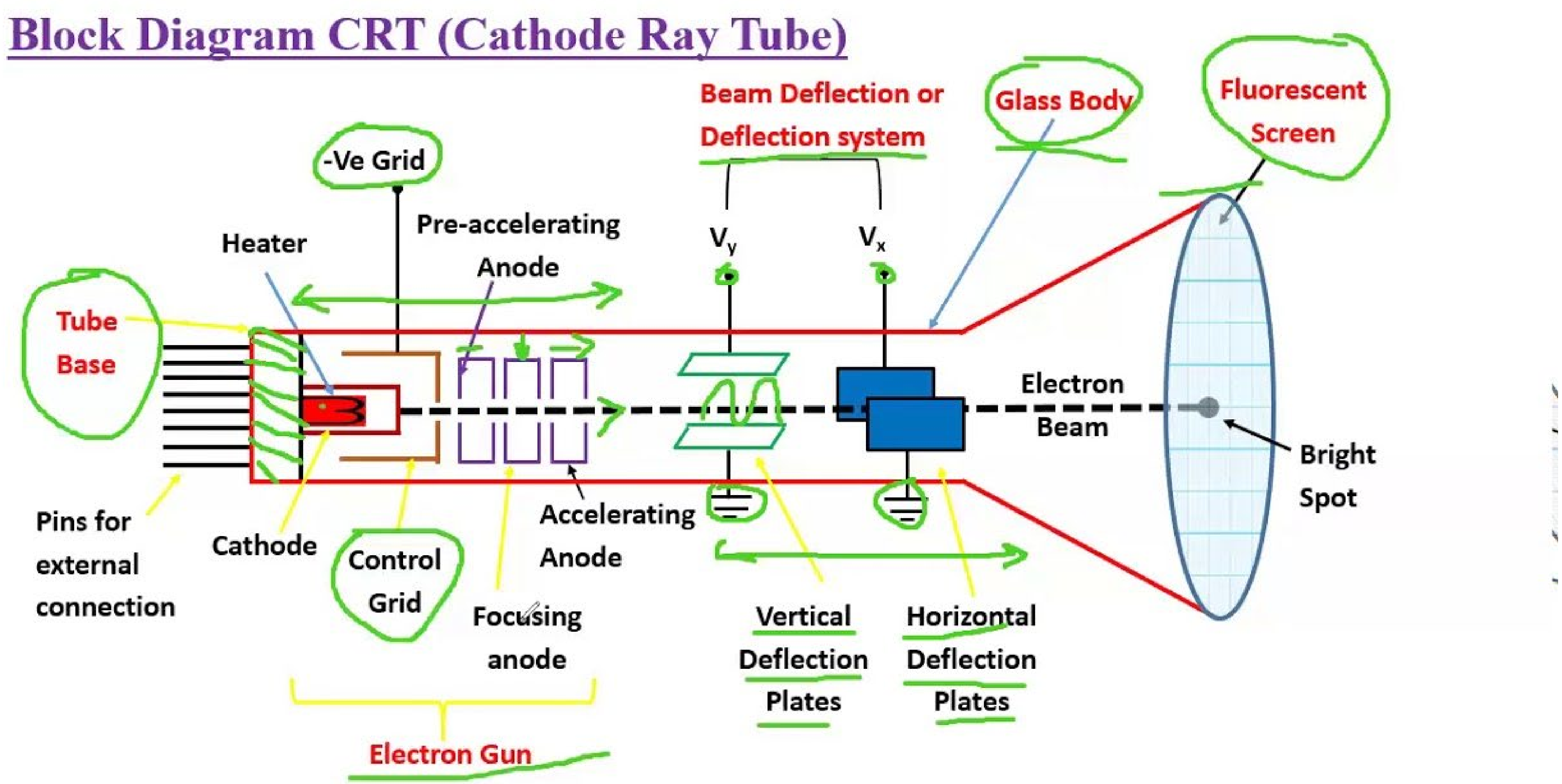
Late 1950s into the 1980s

- SAGE air-defense system (mid 50s) used command & control CRT
- It used CRT display consoles on which operators identified targets with light pens

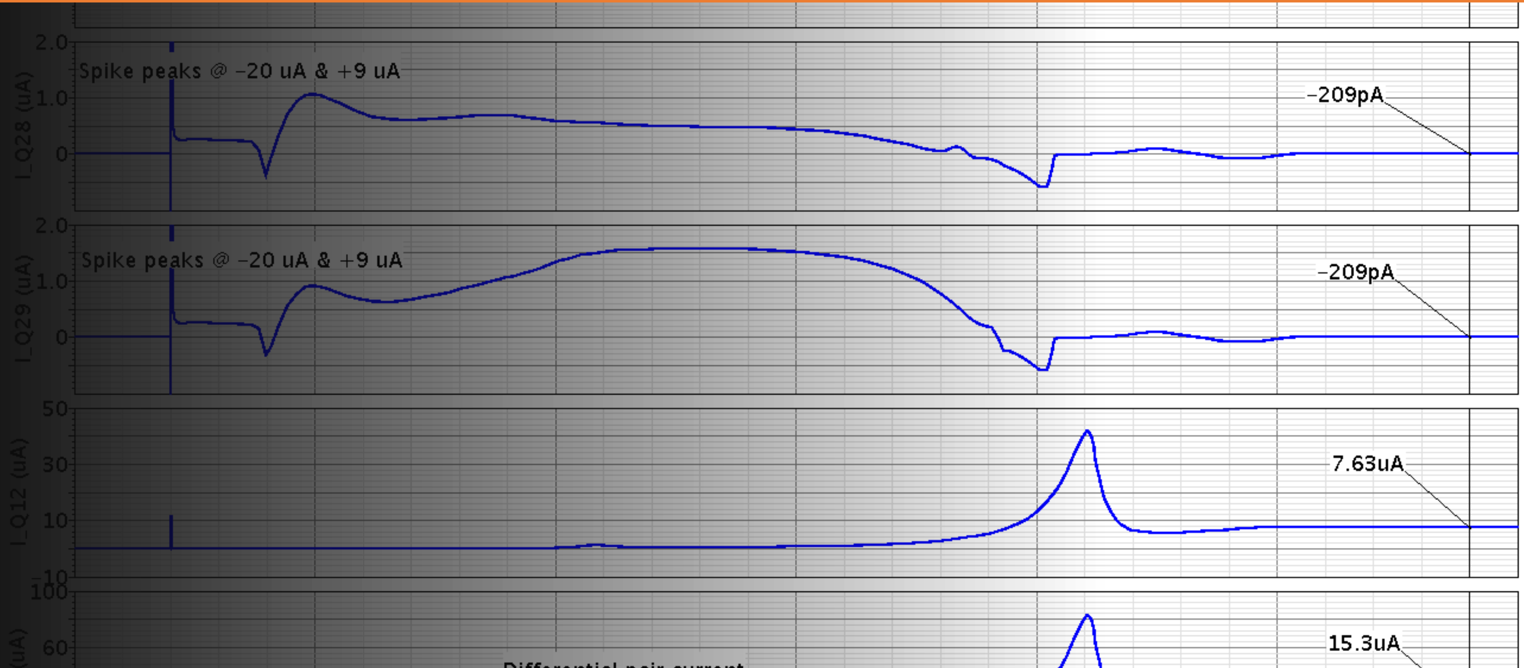

Explore new ways to think, express and create with Windows 11
Like what you see?
Windows 11 brings you closer to the people and things you love.
3:40
Saturday, 11 December

# CRT

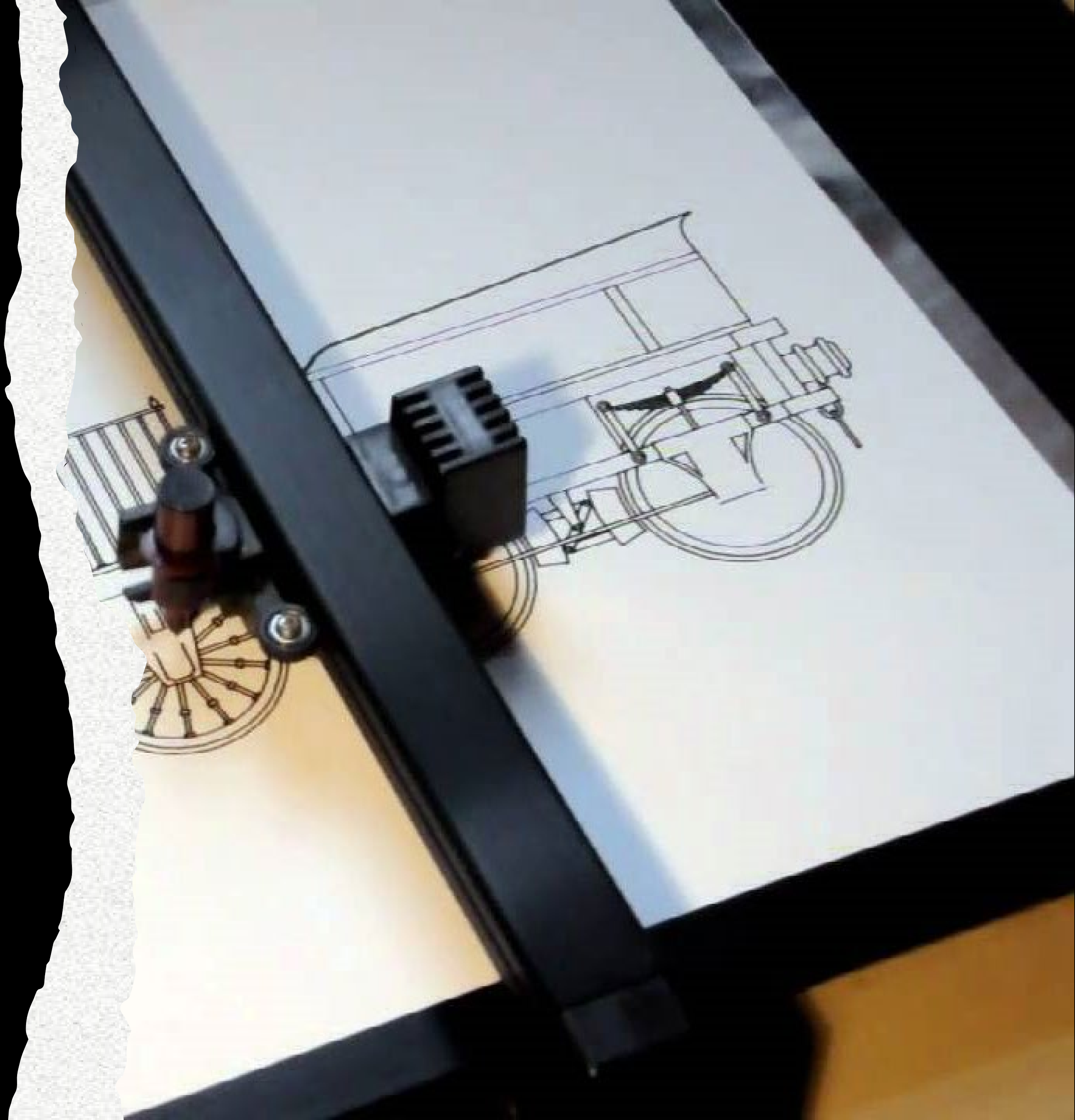
Can be used either as a line-drawing device (calligraphic) or to display contents of frame buffer (raster mode)



# CG 1950-1960 STRIP CHART



# CG 1950-1960 PLOTTERS



# CG 1960 - 1970

- Archive film showing possibly the first example of digital rendering, made by Pixar co-founders Ed Catmull and Fred Parke in 1972, was stumbled upon by the son of Robert B Ingebretsen, who also set up the world-famous U.S. studio.

Read more: http://www.dailymail.co.uk/sciencetech/article-2034003/How-Pixar-founders-worlds-3D-graphics.html#ixzz4VnwA6bmM
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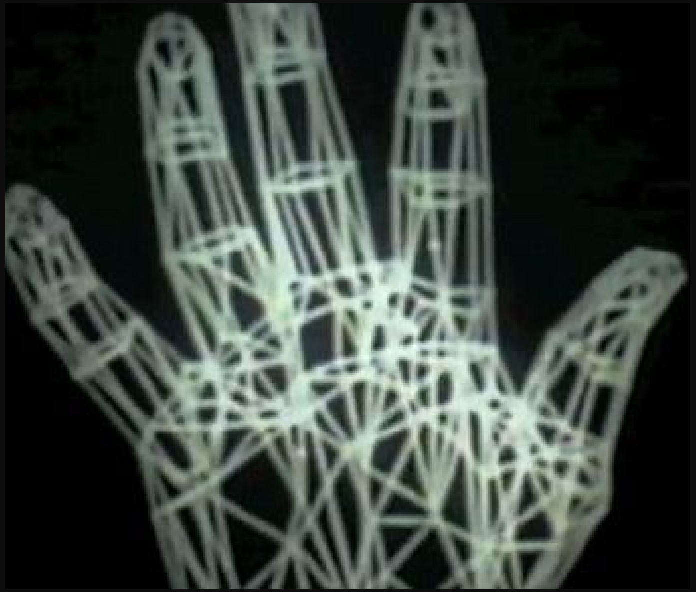
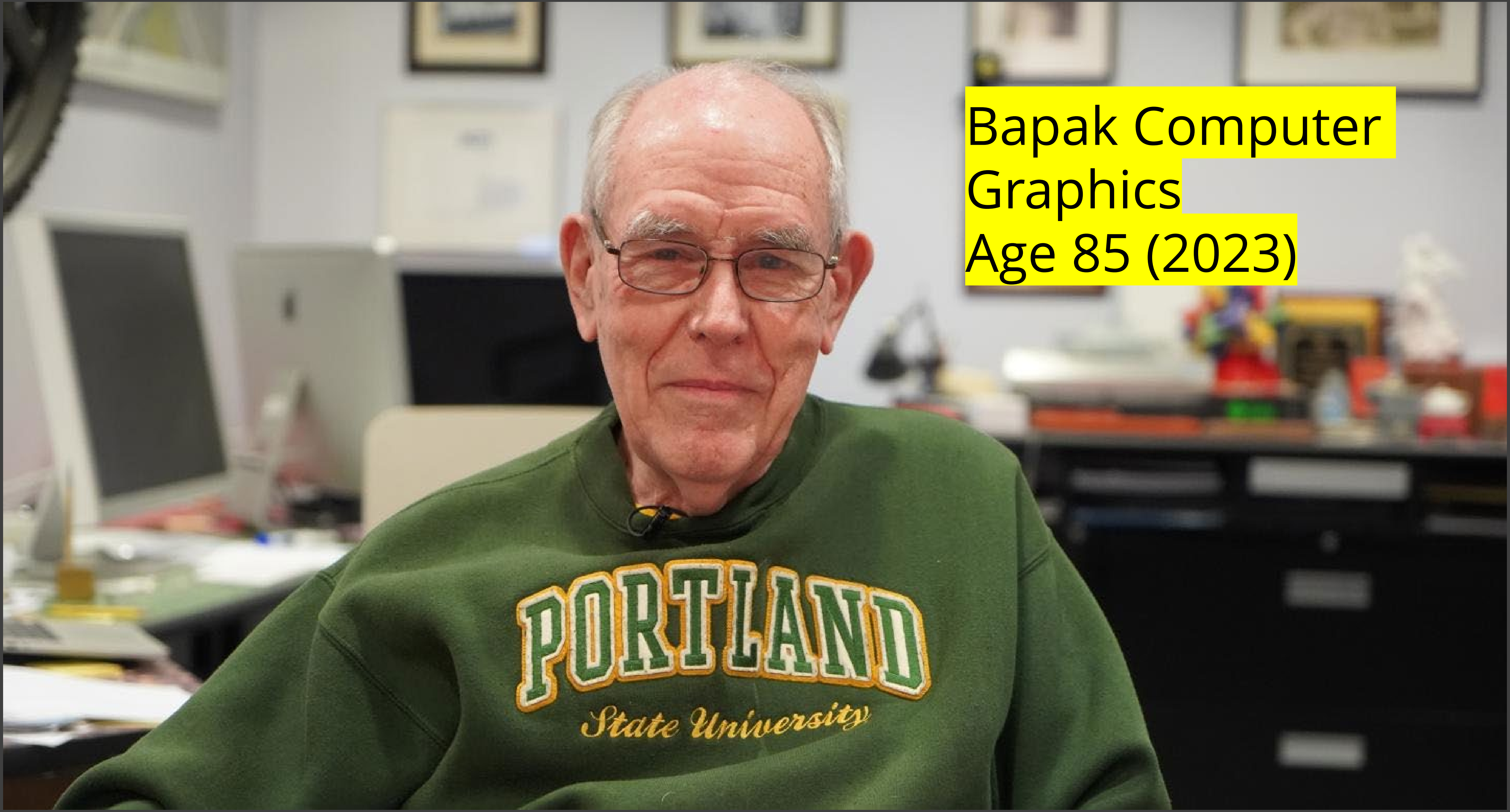


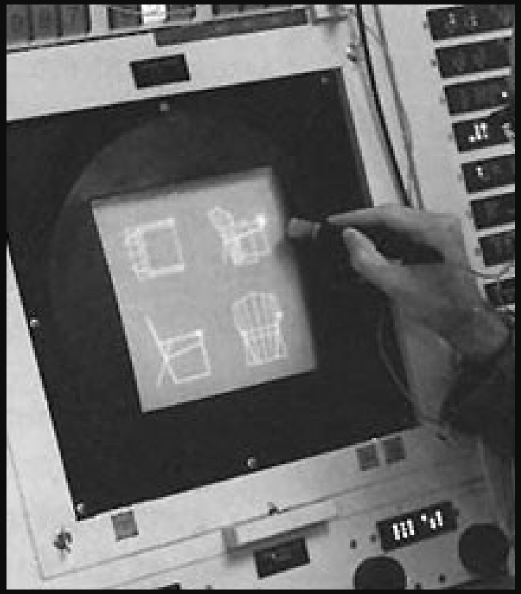
# Computer Graphics History continued

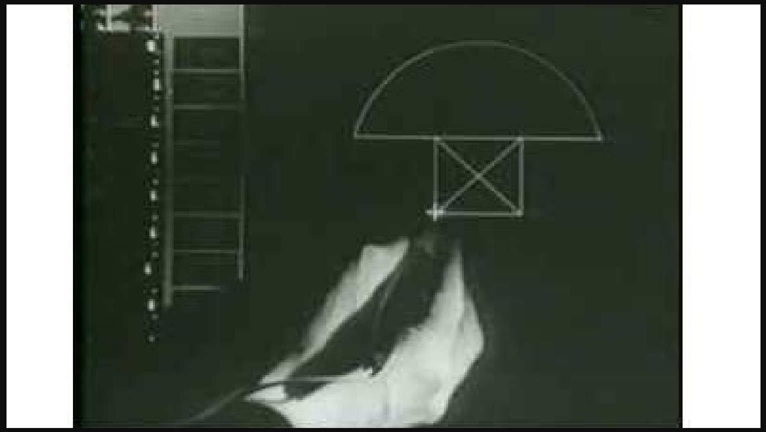
- Beginnings of modern interactive graphics attributed to Ivan Sutherland’s doctoral work at MIT
  - presented work at Spring Joint Computer Conference in 1963 in the form of a movie.
  - He developed the Sketchpad drawing system


Bapak Computer
Graphics
Age 85 (2023)
PORTLAND
State University

# Sketchpad

- Ivan Sutherland's PhD thesis at MIT
  - Recognized the potential of man-machine interaction
  - Loop
    - Display something
    - User moves light pen
    - Computer generates new display
  - Sutherland also created many of the now common algorithms for computer graphics





# Computer Graphics: 1970-1980

- Raster Graphics
- Beginning of graphics standards
  - IFIPS
    - GKS: European effort
      - Becomes ISO 2D standard
    - Core: North American effort
      - 3D but fails to become ISO standard
- Workstations and PCs


Raster graphics are digital images created or captured (for example, by scanning in a photo) as a set of samples of a given space.


WORKSTATION
GAMING PC
ThinkStation
ThinkStation
ThinkPad
msi

# PCs and Workstations

- Although we no longer make the distinction between workstations and PCs, historically they evolved from different roots
  - Early workstations characterized by
    - Networked connection: client-server model
    - High-level of interactivity
  - Early PCs included frame buffer as part of user memory
    - Easy to change contents and create images

ORIGINAL SOURCE
https://pediaa.com/difference-between-workstation-and-desktop/

**WORKSTATION**
**VERSUS**
**DESKTOP**

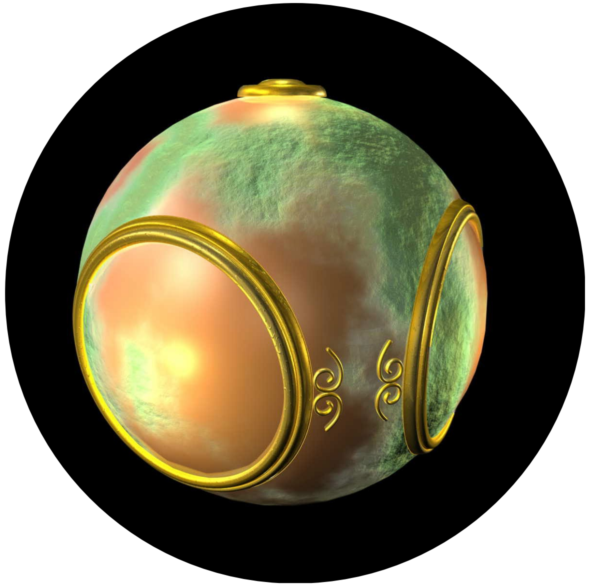
| WORKSTATION | DESKTOP |
| --- | --- |
| A special computer designed for technical or scientific applications | A personal computer designed for regular use at a single location on or near a desk or table due to its size and power requirements |
| Used to solve high-end technical matters such as mechanical designing, animations, engineering simulations, etc. | Used to perform regular tasks such as web browsing, word processing, gaming, etc. |
| Has higher specifications | Has lower specifications |
| Expensive | Less expensive |

Visit www.PEDIAA.com

# Computer Graphics: 1980-1990

https://www.cs.cmu.edu/~ph/nyit/

environment mapping



bump mapping

smooth shading

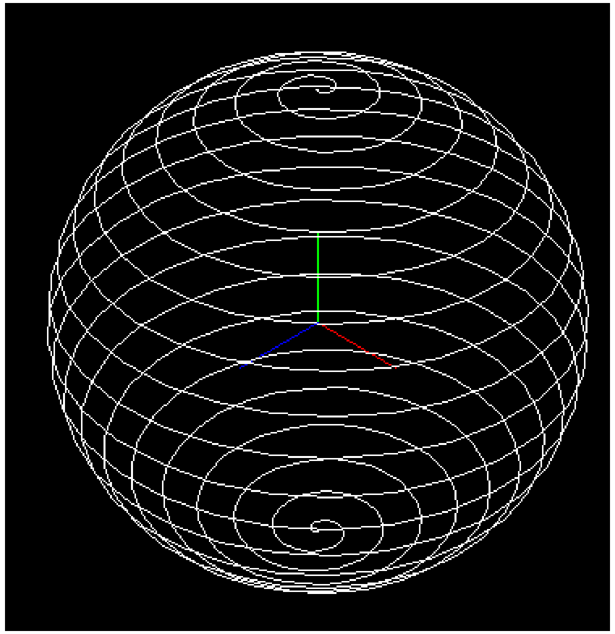
# Computer Graphics: 1980-1990

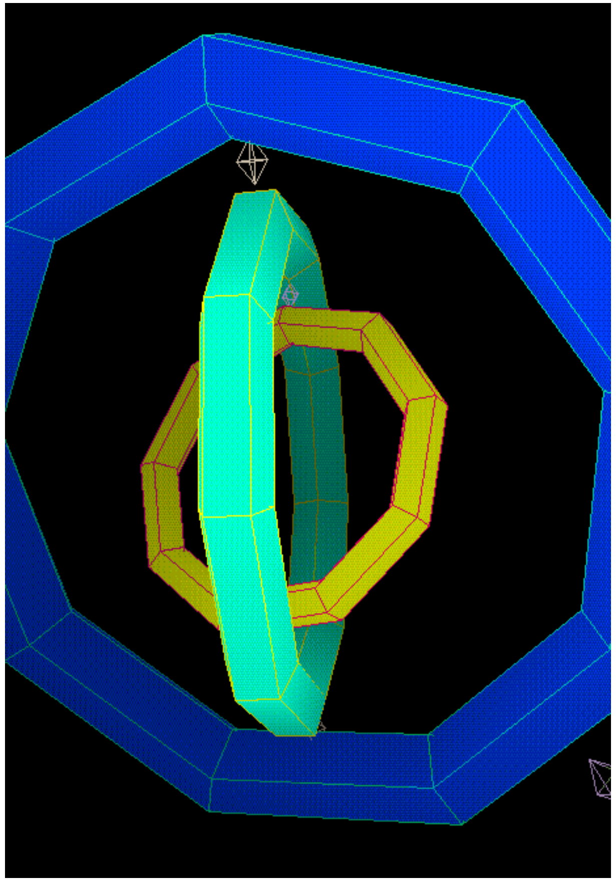
# PHIGS

stands for

## Programmer's Hierarchical Interactive Graphics System

# PHIGS



# Computer Graphics: 1990-2000

OpenGL API

Completely computer-generated feature-length movies (Toy Story) are successful

New hardware capabilities

- Texture mapping
- Blending
- Accumulation, stencil buffers

# 1995

**Toy Story (1995)**

The first movie from the Toy Story series was the first feature-length film made entirely with CGI animation.

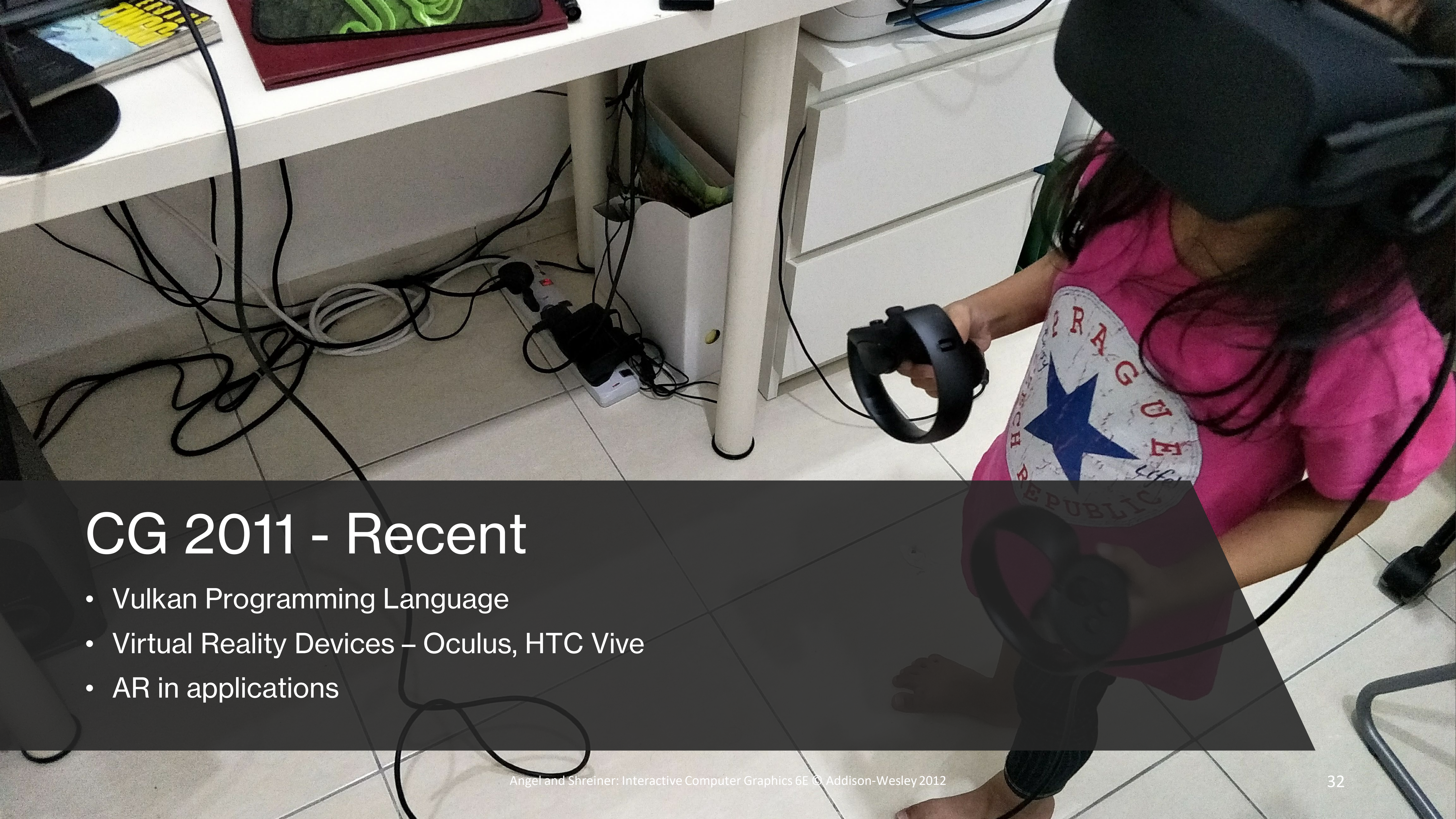
60 AT 60



# 3D Game History?

# CG: 2000-2010

- Photorealism
- Graphics cards for PCs dominate market
  - Nvidia, ATI
- Console with High End Graphics
- Powerful Smartphone with great graphics capabilities
- Computer graphics routine in movie industry: Maya, Lightwave
- Programmable pipelines



# CG 2011 - Recent

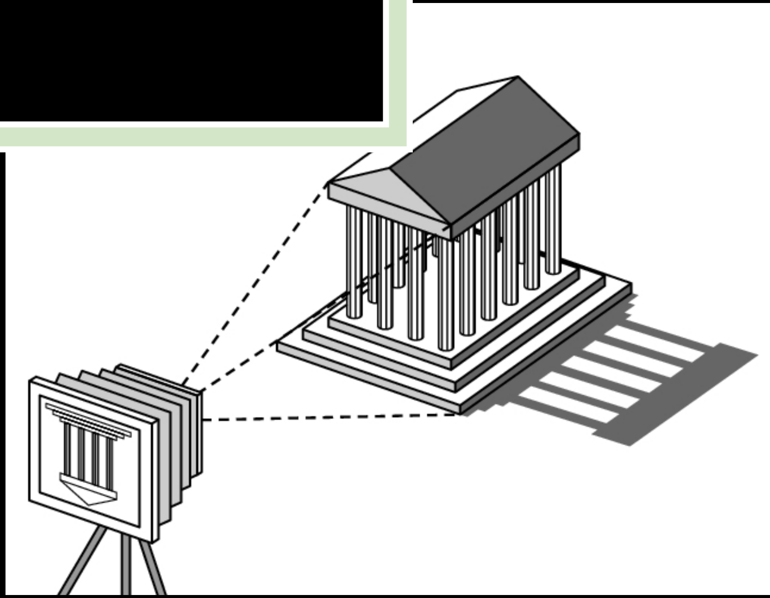
- Vulkan Programming Language
- Virtual Reality Devices – Oculus, HTC Vive
- AR in applications

# Image Formation

# Image Formation

- In computer graphics, we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system

# Elements of Image Formation

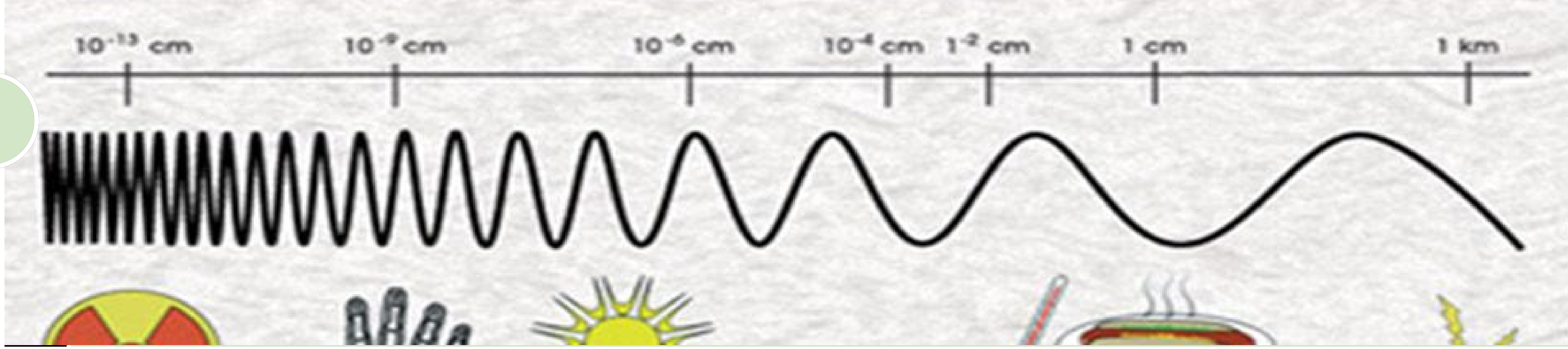


- Objects
- Viewer
- Light source(s)

- 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)

# What is light?

- Light  consists of electromagnetic waves.
- Electromagnetic radiation includes:



# Light

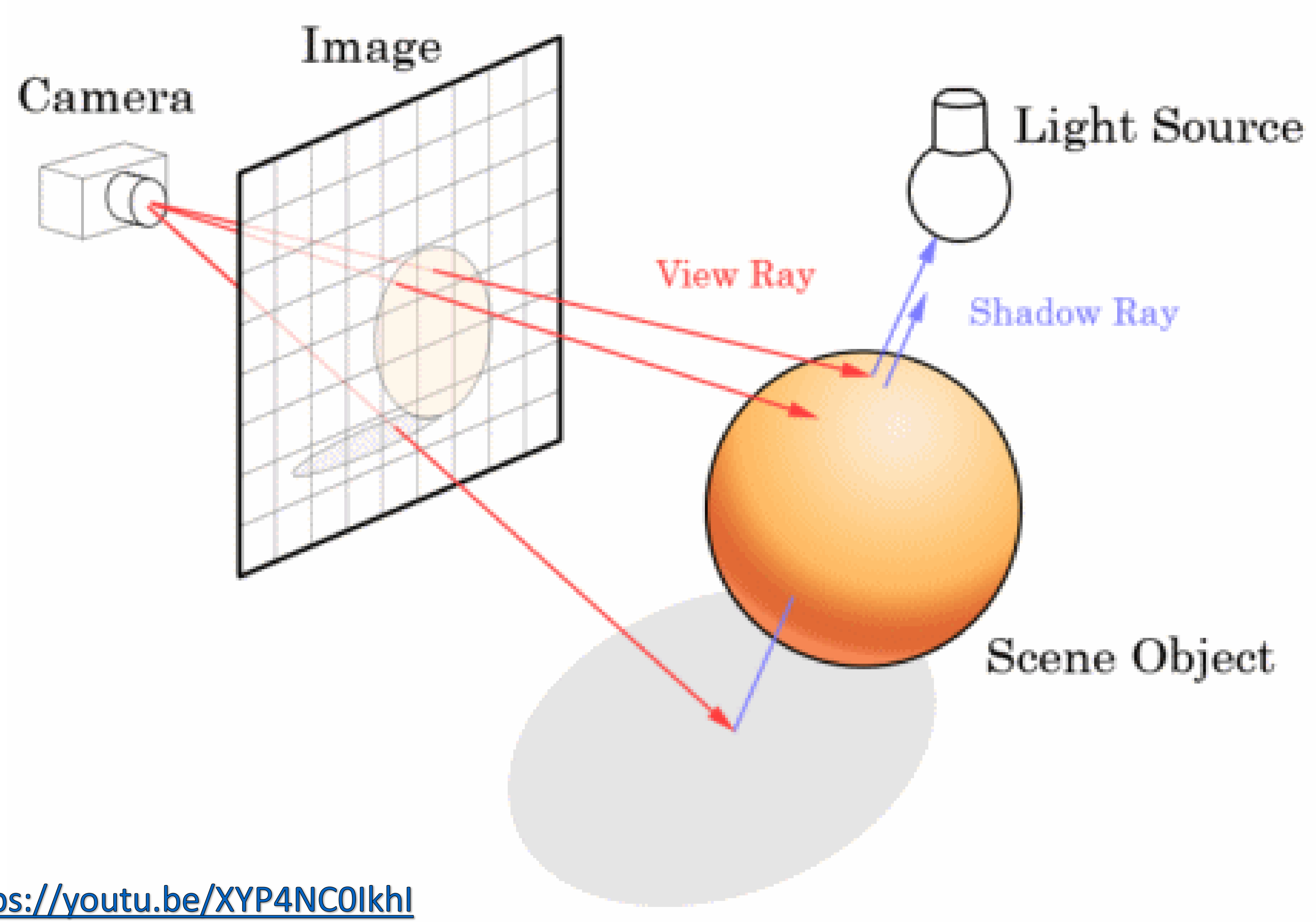
*Light* is the part of the electromagnetic spectrum that causes a reaction in our visual systems

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

Long wavelengths appear as reds and short wavelengths as blues

# What is ray tracing?

Ray tracing is a lighting technique that brings an extra level of realism to games. It emulates the way light reflects and refracts in the real world, providing a more believable environment than what’s typically seen using static lighting in more traditional games.




https://youtu.be/XYP4NC0IkhI


38
67
RTX
ON
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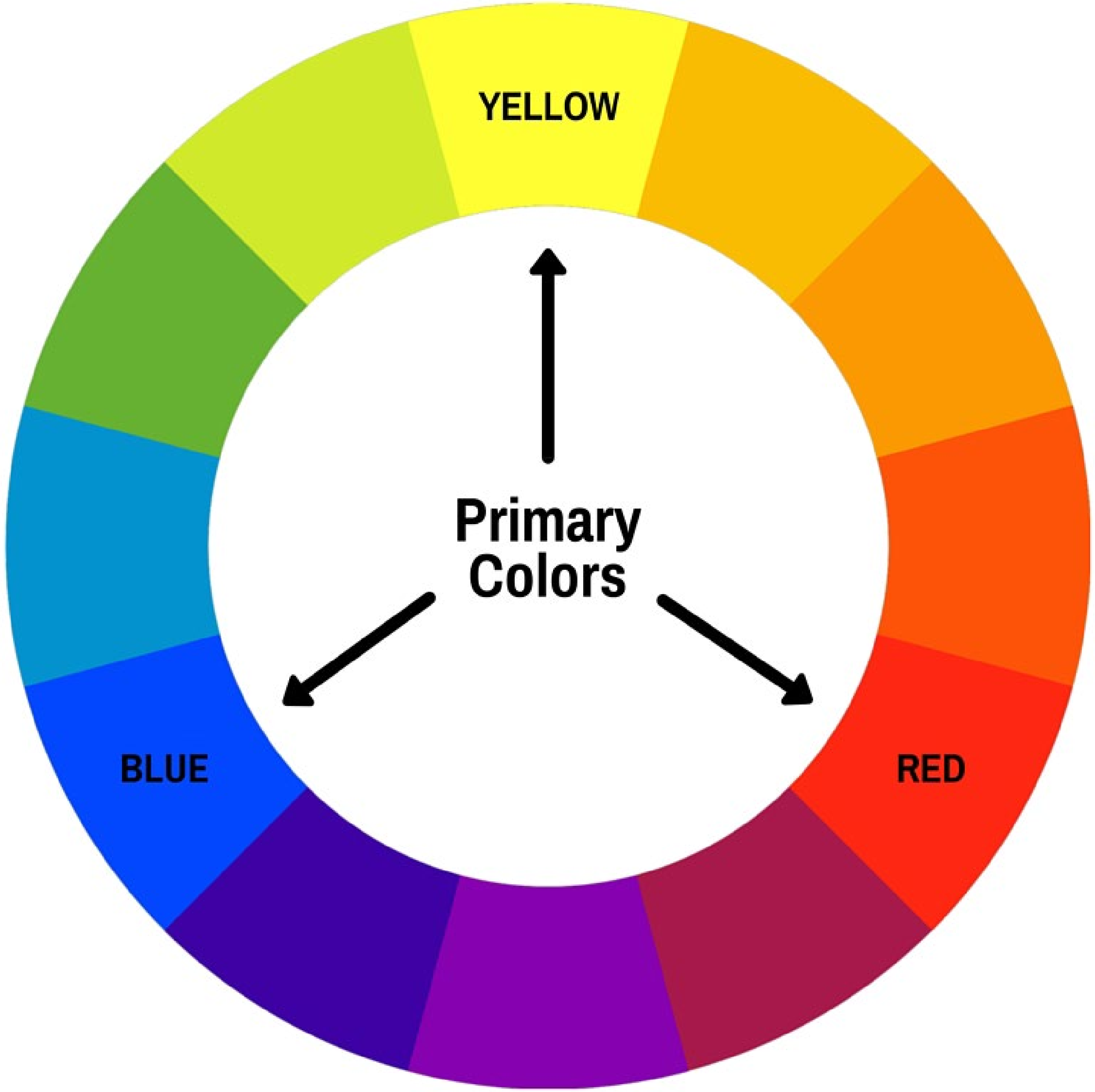
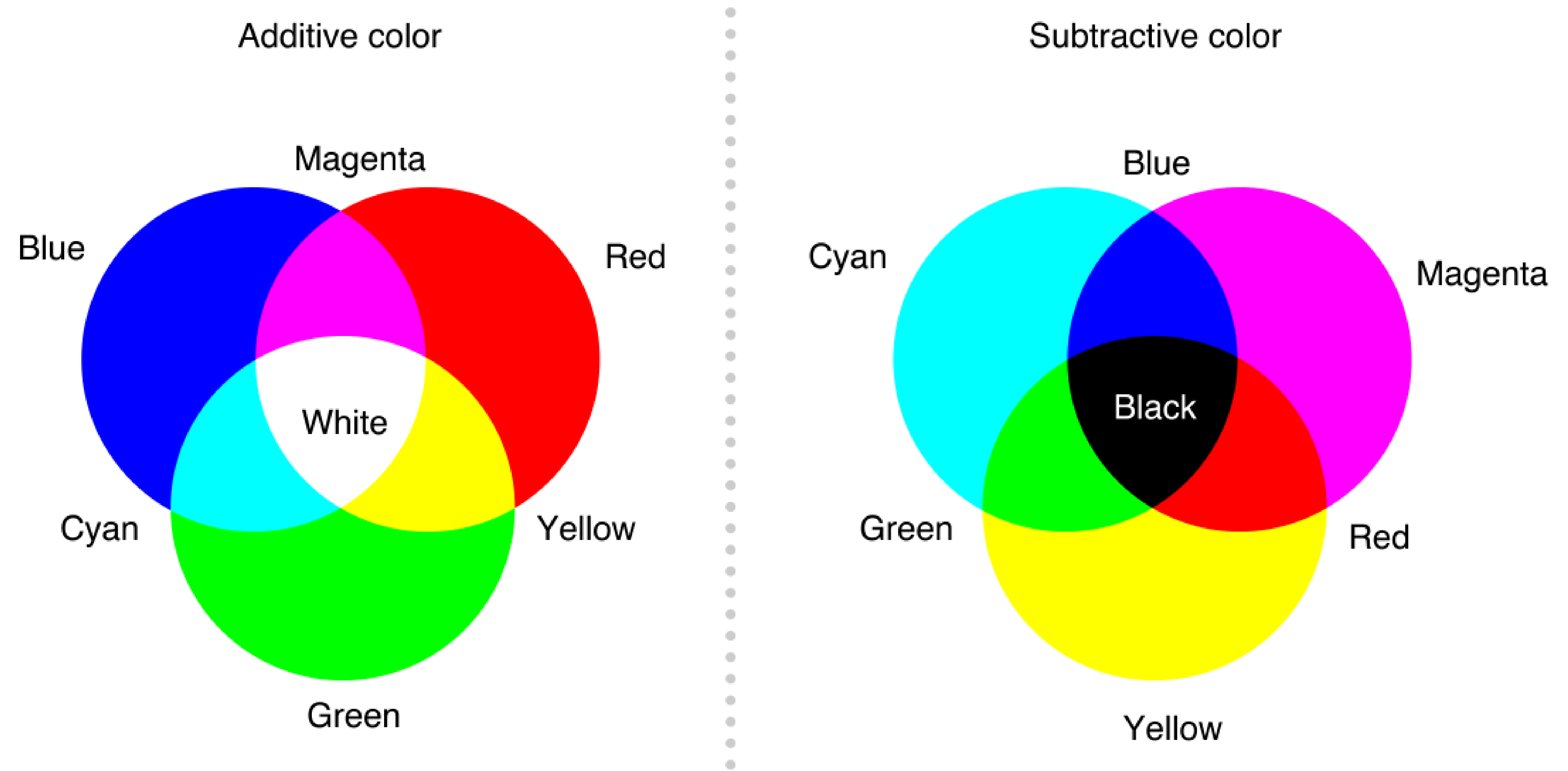
RTX
OFF

- In video games, ray tracing is essentially a system of simulating how light travels, interacts with various objects in the environment, and ultimately reaches our eyes.

# Three-Color Theory





Additive color
Magenta
Blue
Red
White
Cyan
Yellow
Green
Subtractive color
Blue
Cyan
Magenta
Black
Green
Red
Yellow

# 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)

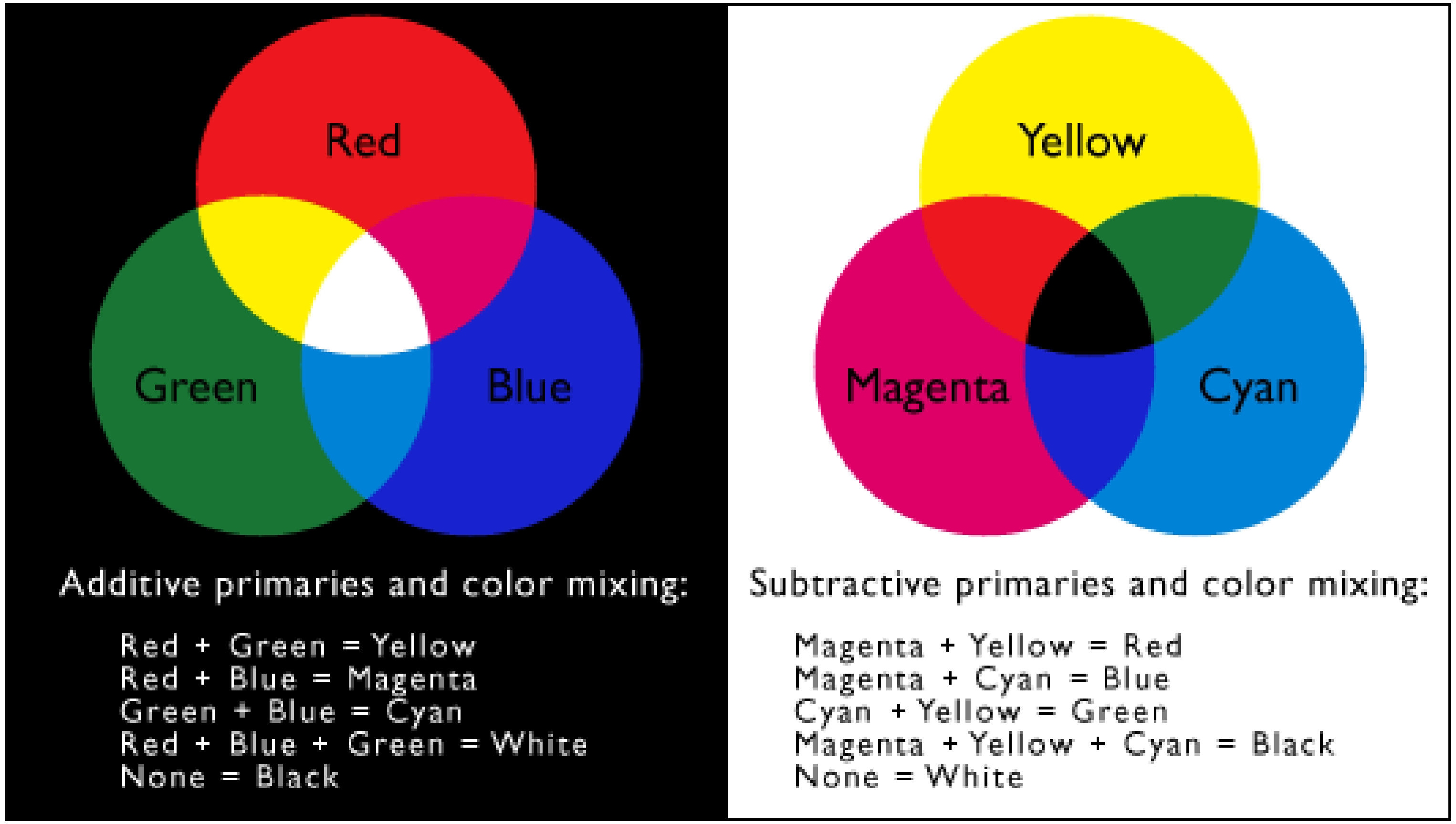
## Subtractive color

Form a color by filtering white light with cyan (C), Magenta (M), and Yellow (Y) filters

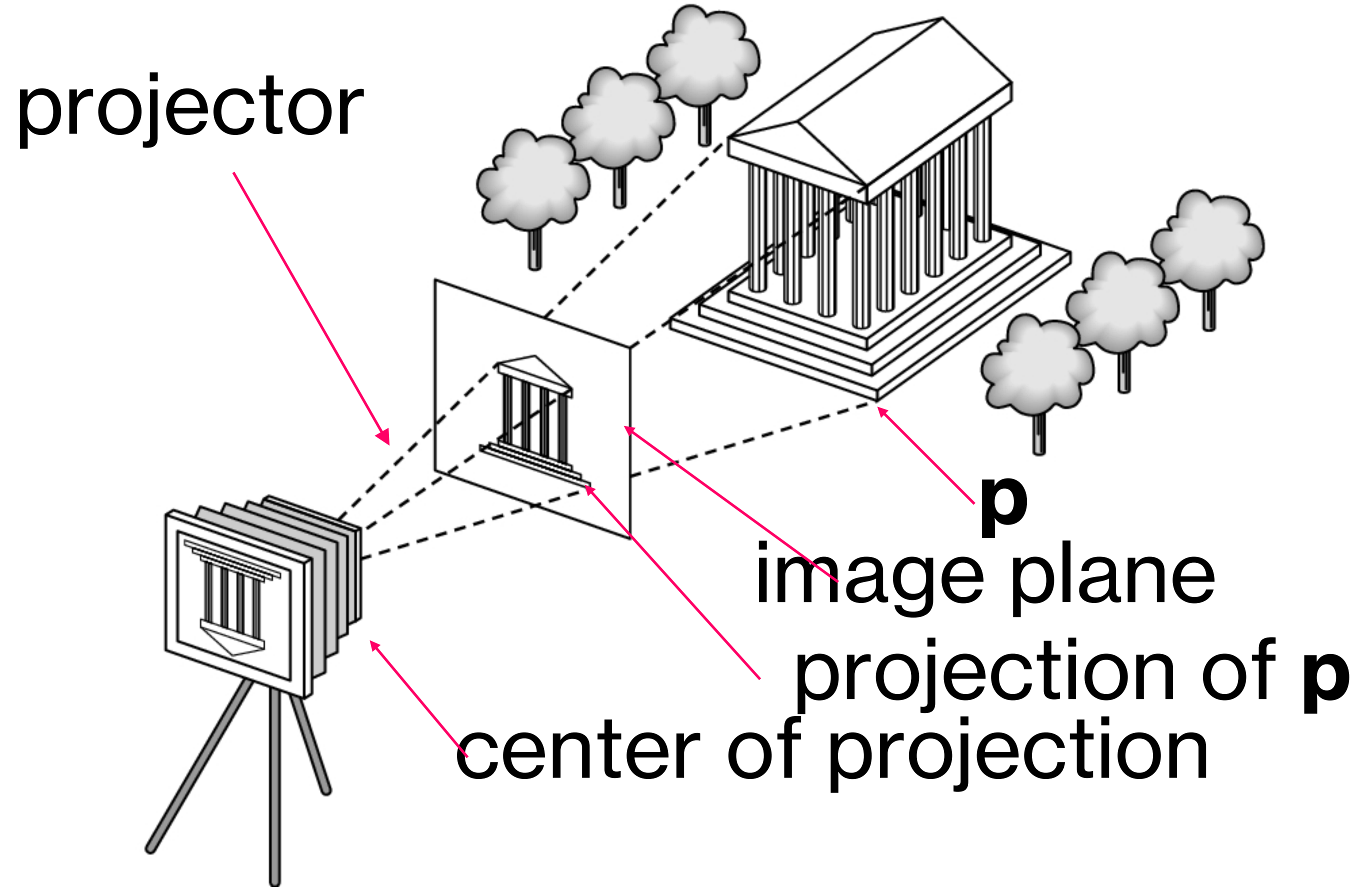
- Light-material interactions
- Printing
- Negative film

https://physics.stackexchange.com/questions/23830/why-is-there-a-difference-between-additive-and-subtractive-trichromatic-color-th

# Additive and Subtractive Color

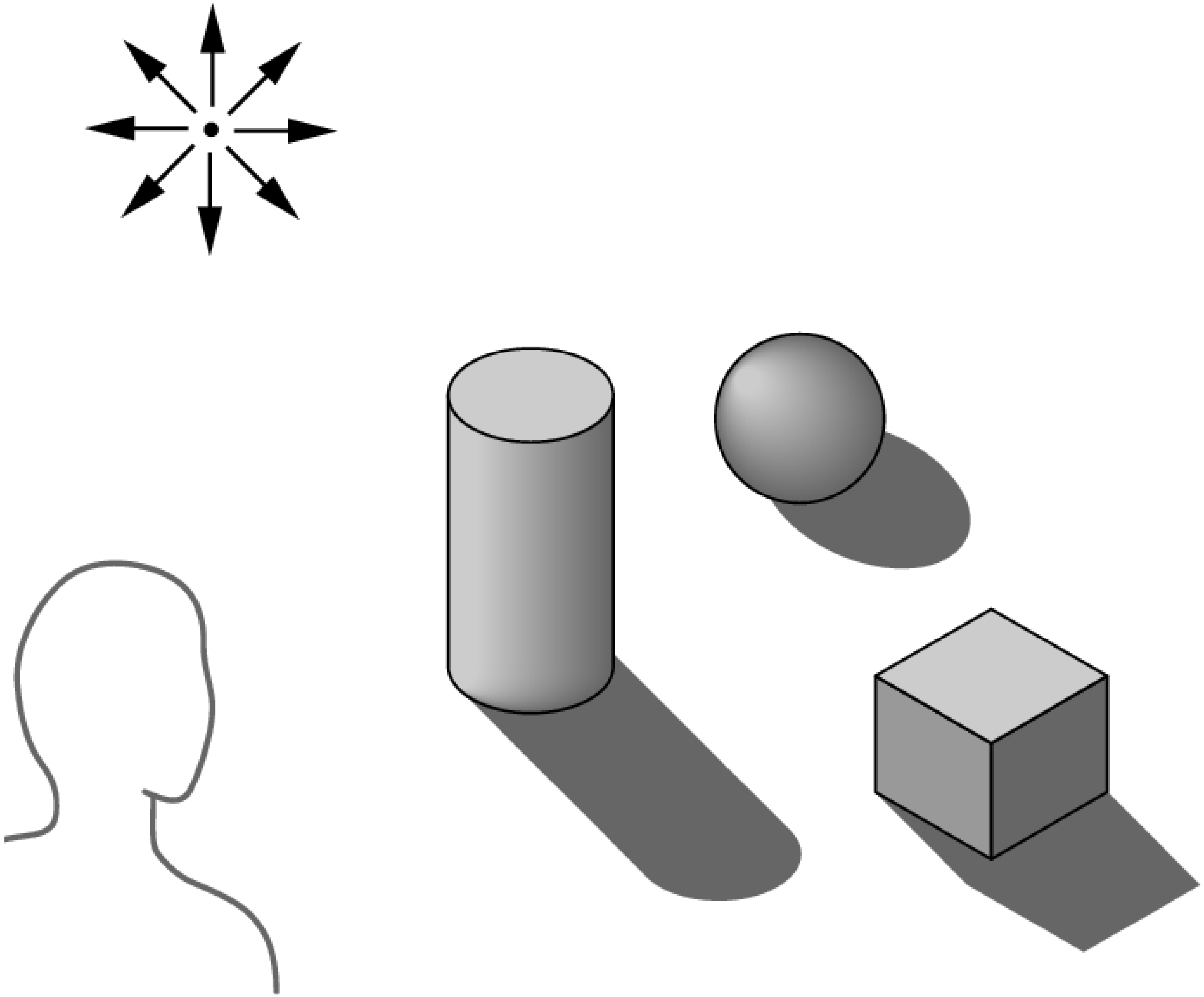


# Synthetic Camera Model

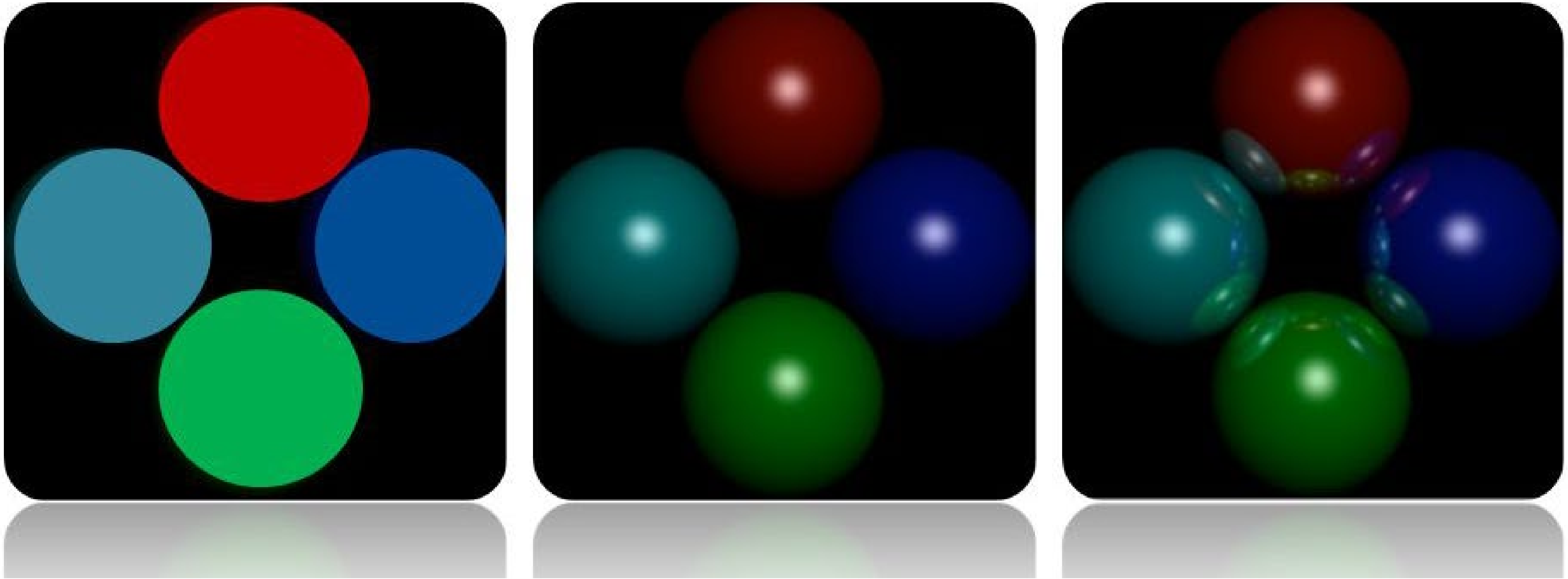


# Global vs Local Lighting

- 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



Without | Local | Global



# Models and Architectures

# Objectives

| Learn | Introduce | Examine |
|---|---|---|
| Know the basic design of a graphics system | Introduce pipeline architecture | Examine software components for an interactive graphics system |

# Image Formation Revisited

Can we mimic the synthetic camera model to design graphics hardware software?

Application Programmer Interface (API)

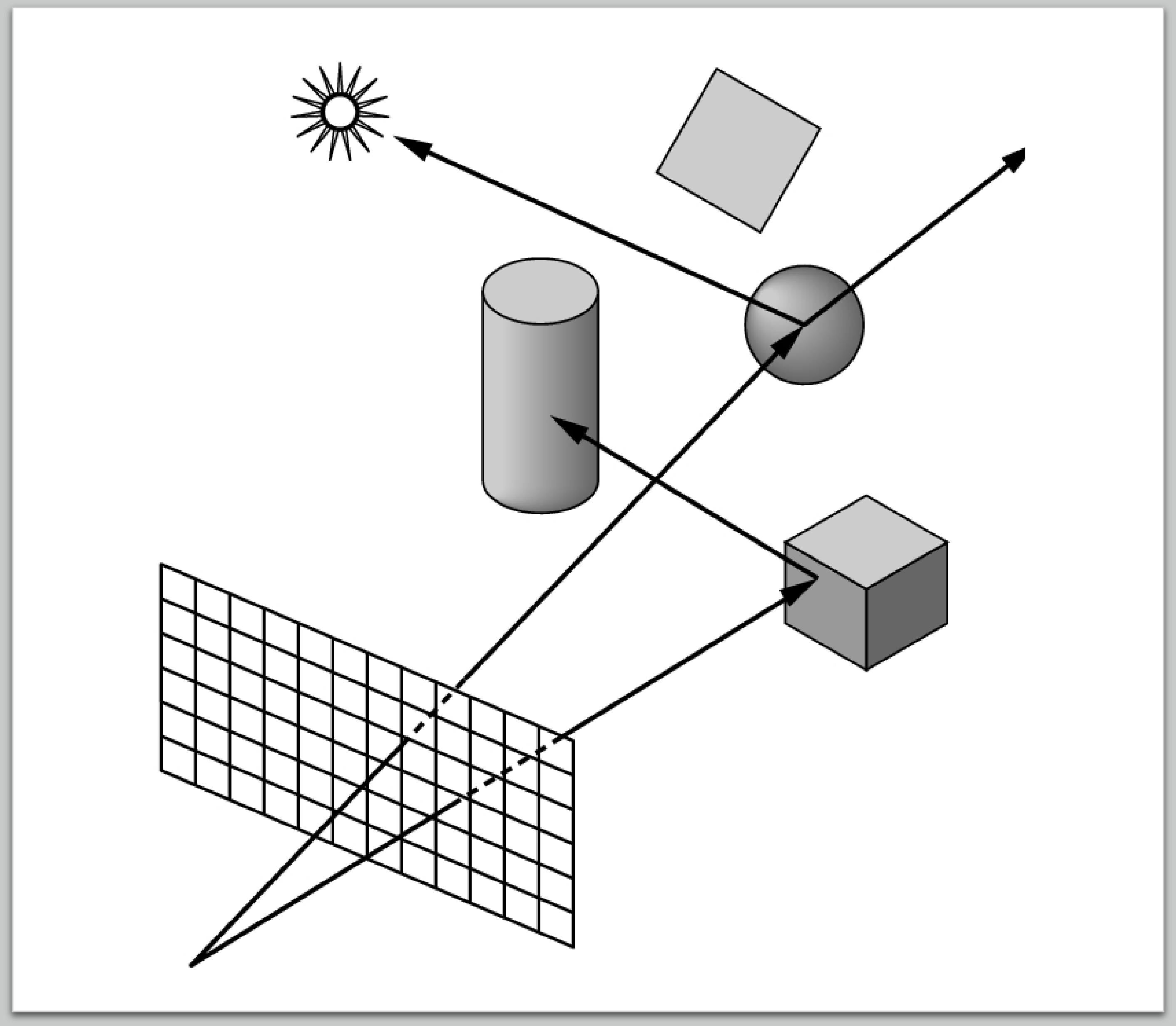
- Need only specify
  - Objects
  - Materials
  - Viewer
  - Lights

But how is the API implemented?

# Physical Approaches

- **Ray tracing**: follow rays of light from center of projection until they either are absorbed by objects or go off to infinity
    - Can handle global effects
        - Multiple reflections
        - Translucent objects
    - Slow
    - Must have whole data base

  available at all times



# Physical Approaches

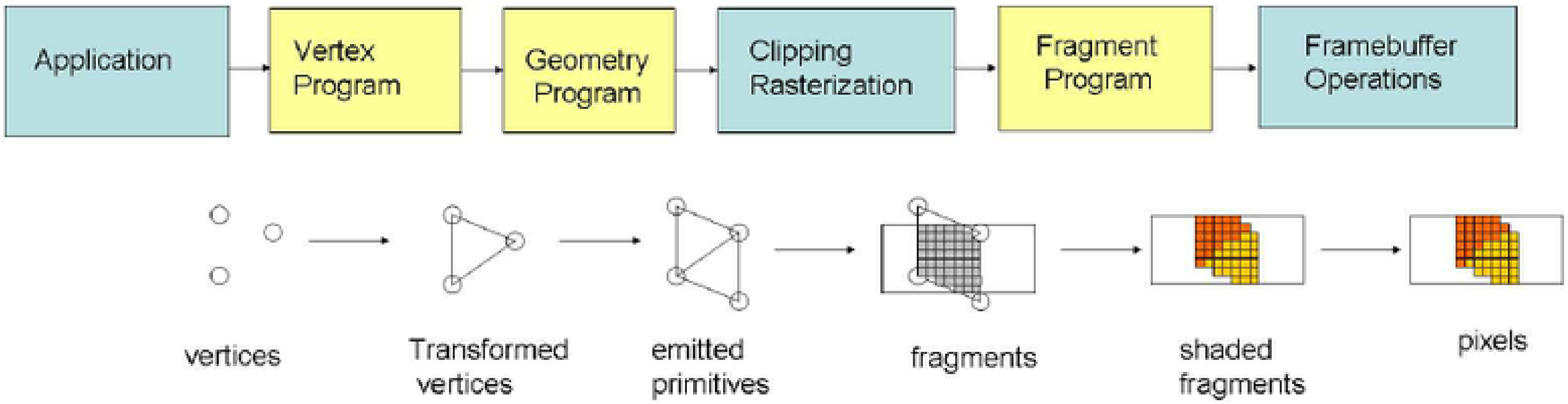
- **Radiosity**: Energy based approach
  - Very slow

# Practical Approach

Process objects one at a time in the order they are generated by the application

Can consider only local lighting

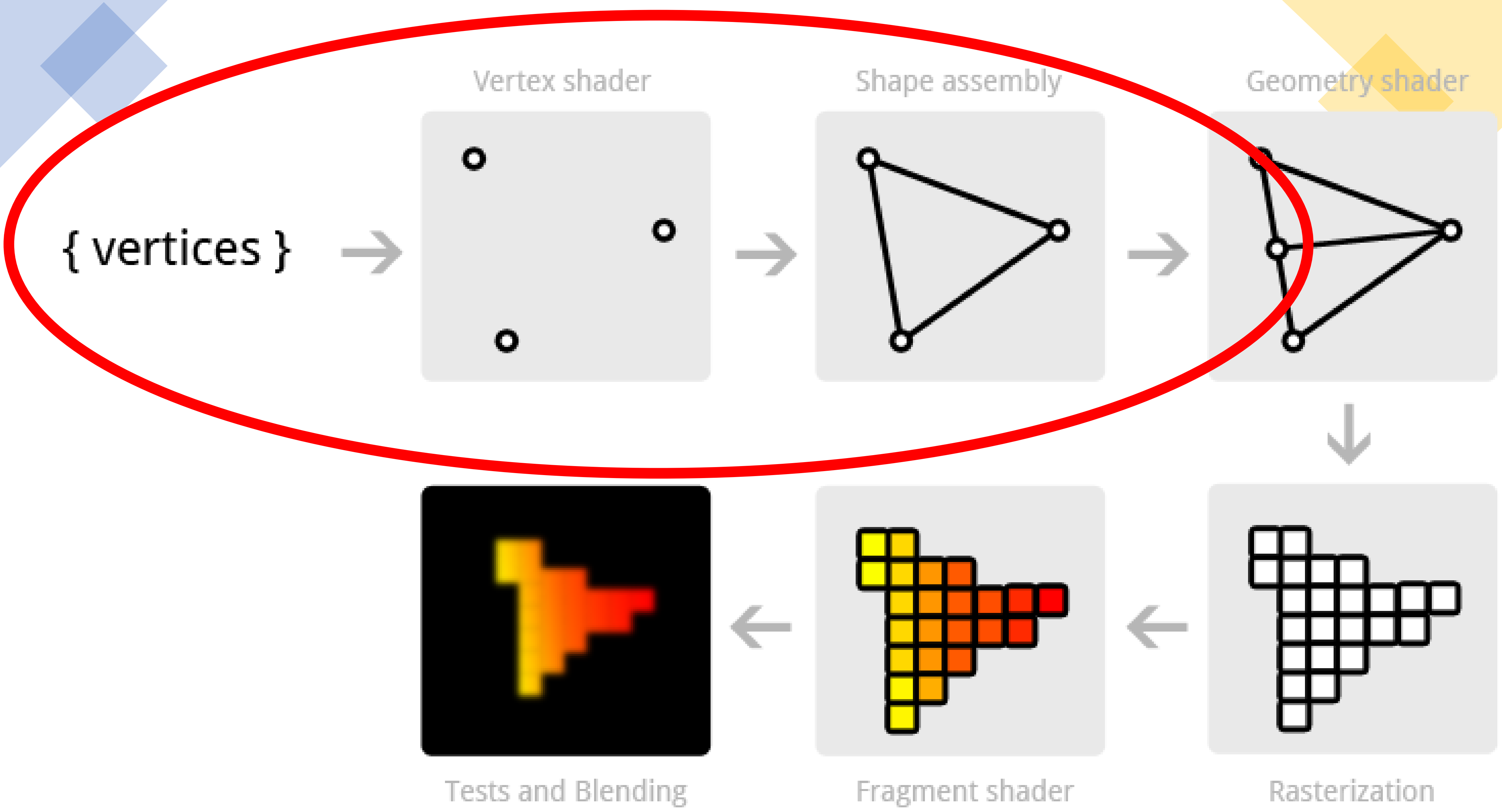
All steps can be implemented in hardware on the graphics card


Application
Vertex Program
Geometry Program
Clipping Rasterization
Fragment Program
Framebuffer Operations
vertices
Transformed vertices
emitted primitives
fragments
shaded fragments
pixels

# Pipeline

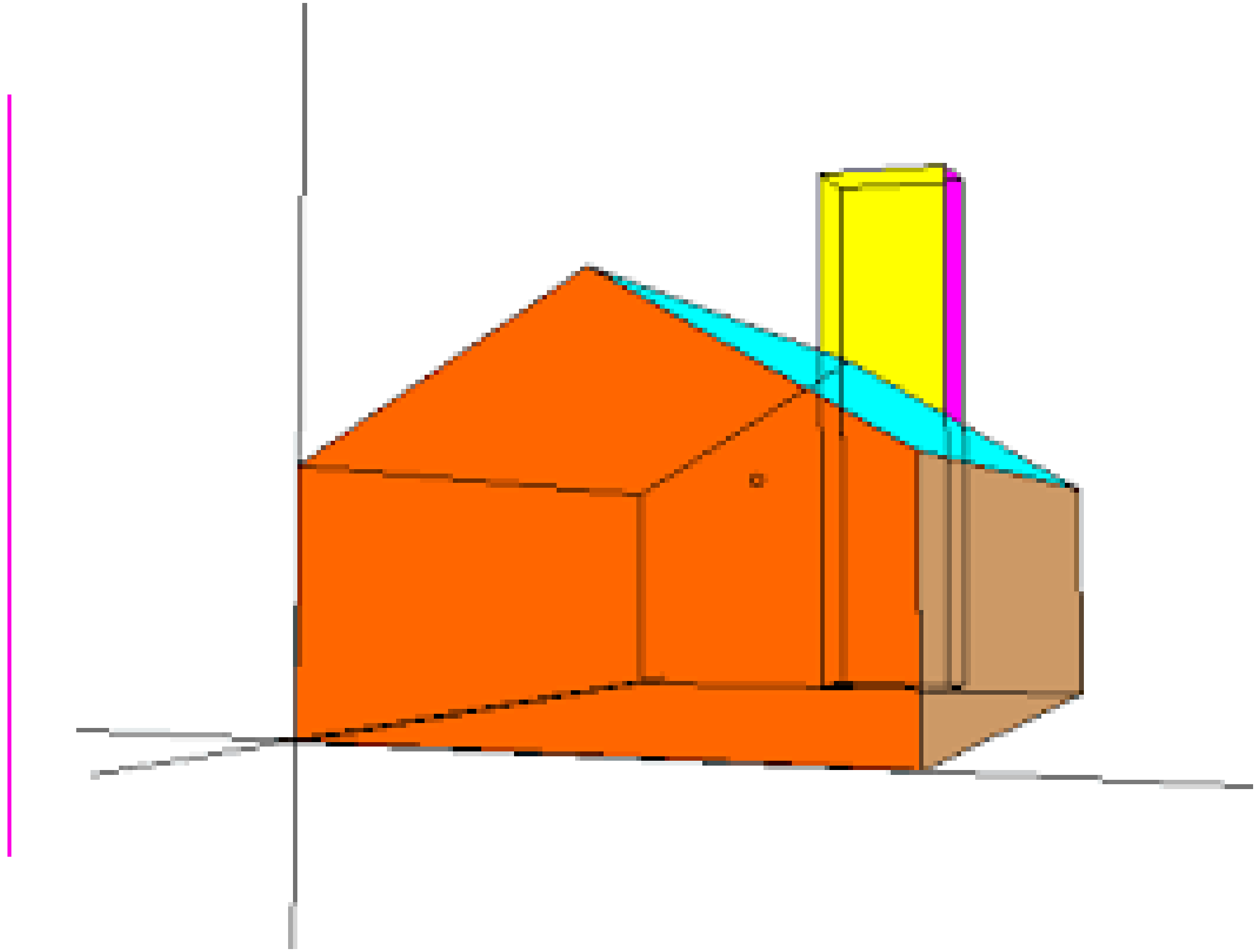
# Vertex Program or Processing

- 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


{ vertices }
Vertex shader
Shape assembly
Geometry shader
Rasterization
Fragment shader
Tests and Blending

# Projection

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

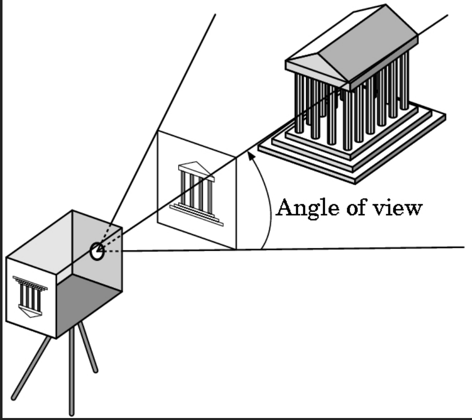


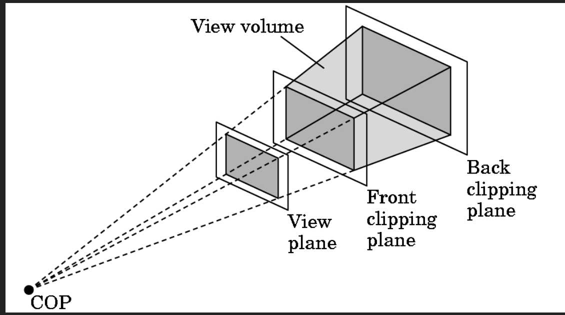
# Geometry Program or Primitive Assembly

Vertices must be collected into geometric objects before clipping and rasterization can take place

- Line segments
- Polygons
- Curves and surfaces

# Clipping



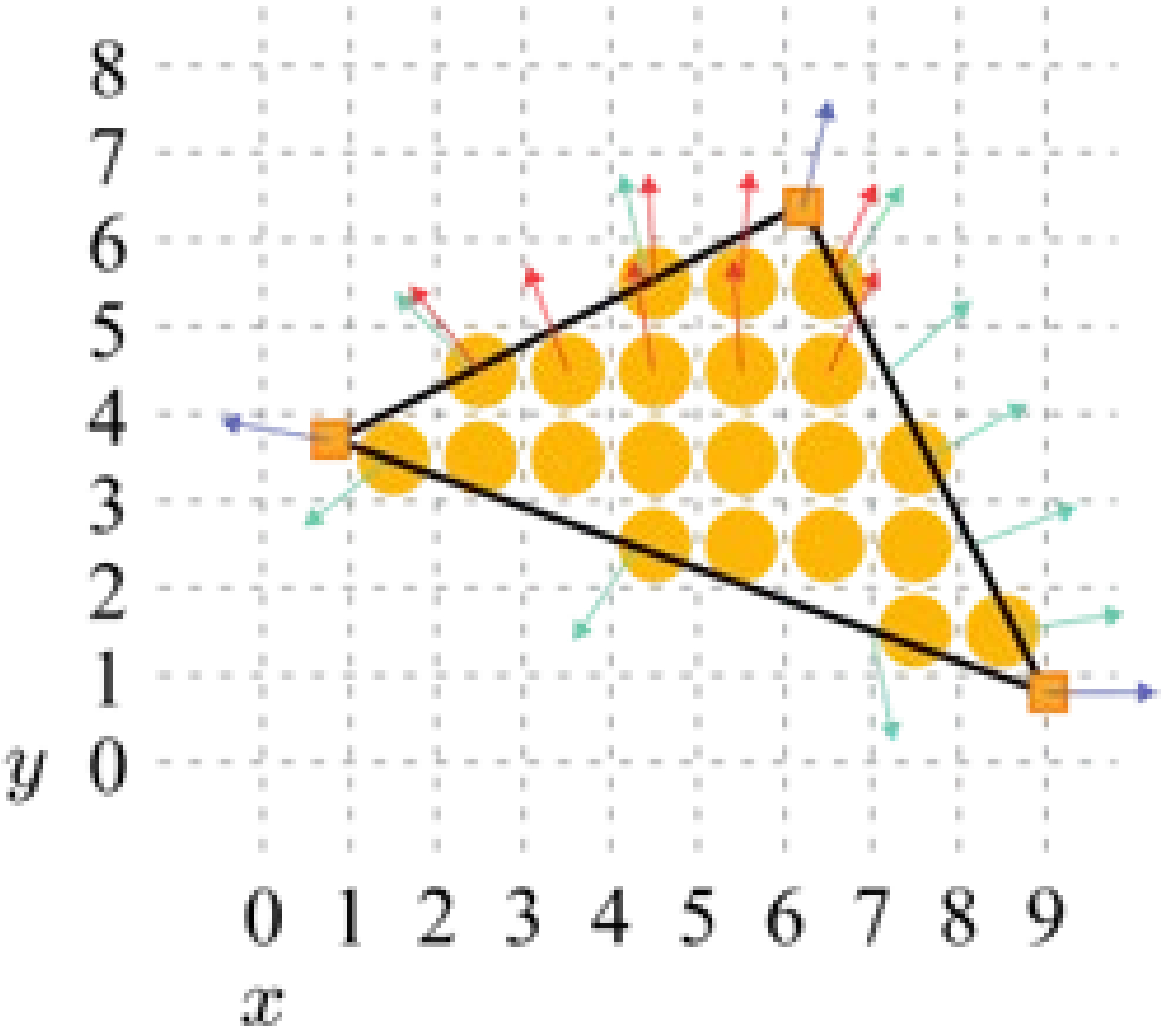




Just as a real camera cannot "see" the whole world, the virtual camera can only see part of the world or object space

- Objects that are not within this volume are said to be *clipped* out of the scene

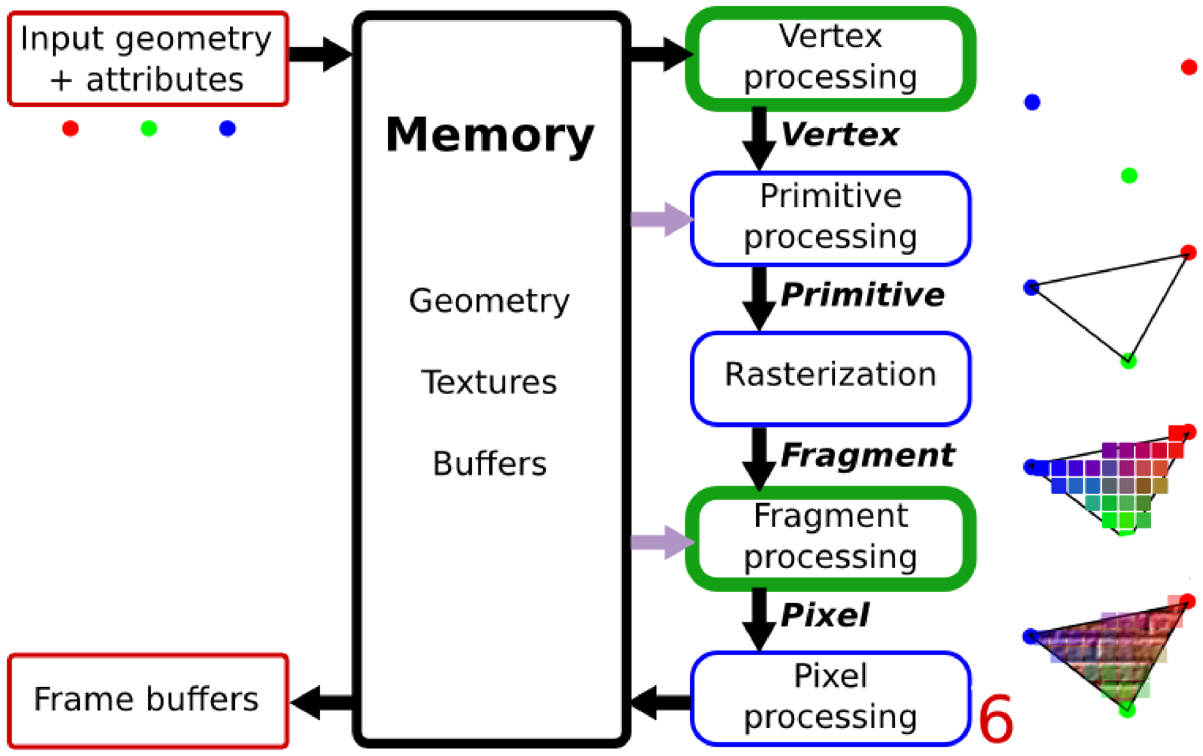
# Rasterization

- 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 bufffer
    - Color and depth attributes
- Vertex attributes are interpolated over objects by the rasterizer



# Fragment Processing

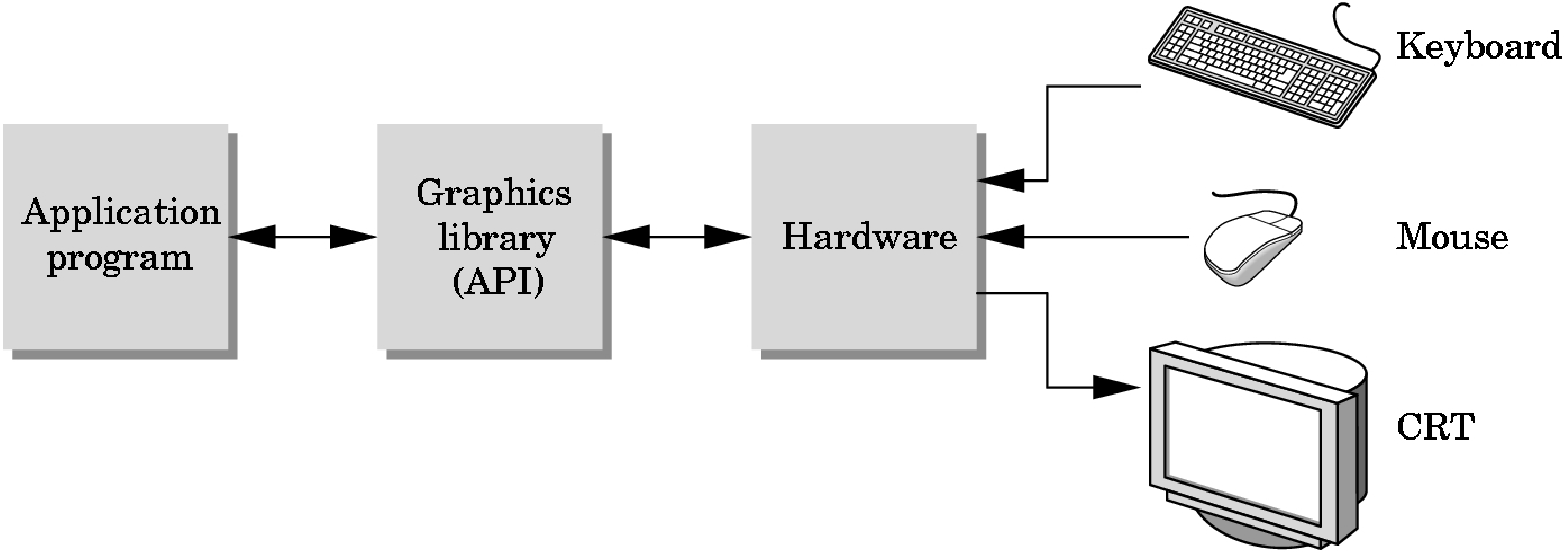
- Fragments are processed to determine the color of the corresponding pixel in the frame buffer
- Colors can be determined by texture mapping or interpolation of vertex colors
- Fragments may be blocked by other fragments closer to the camera
  - Hidden-surface removal



# The Programmer’s Interface

# The Programmer's Interface

- Programmer sees the graphics system through a software interface: the Application Programmer Interface (API)



# API Contents

- Functions that specify what we need to form an image
  - Objects
  - Viewer
  - Light Source(s)
  - Materials
- Other information
  - Input from devices such as mouse and keyboard
  - Capabilities of system

# Object Specification

Most APIs support a limited set of primitives including

- Points (0D object)
- Line segments (1D objects)
- Polygons (2D objects)
- Some curves and surfaces
  - Quadrics
  - Parametric polynomials

All are defined through locations in space or *vertices*

# Example (old style)

type of object

location of vertex

```
glBegin(GL_POLYGON)
  glVertex3f(0.0, 0.0, 0.0);
  glVertex3f(0.0, 1.0, 0.0);
  glVertex3f(0.0, 0.0, 1.0);
glEnd( );
```

end of object definition

# Example (GPU based)

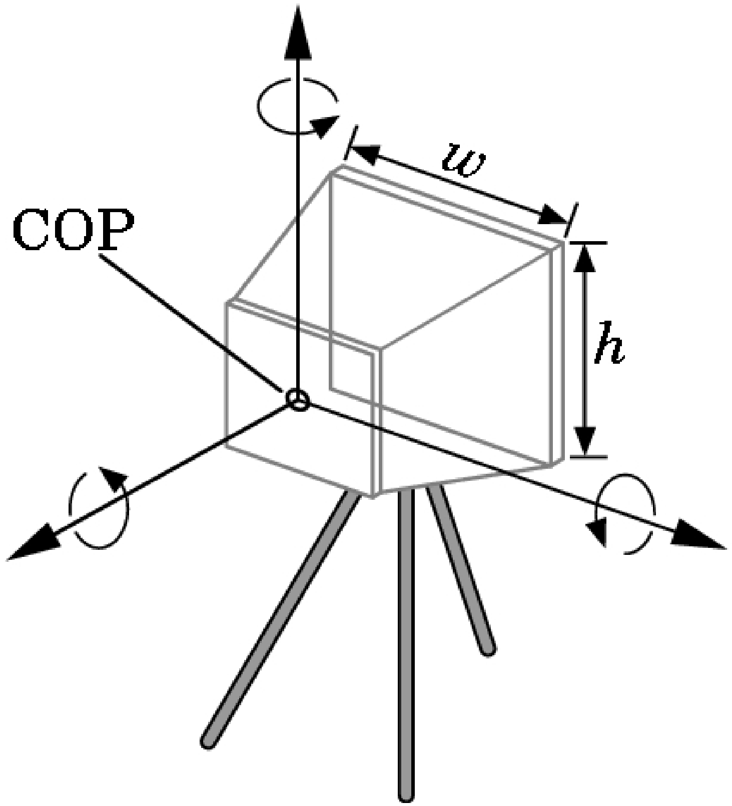
- Put geometric data in an array
- Send array to GPU
- Tell GPU to render as triangle

```
vec3 points[3];
points[0] = vec3(0.0, 0.0, 0.0);
points[1] = vec3(0.0, 1.0, 0.0);
points[2] = vec3(0.0, 0.0, 1.0);
```

# Camera Specification

E. Angel and D. Shreiner: Interactive Computer Graphics 6E © Addison-Wesley 2012

- Six degrees of freedom
  - Position of center of lens
  - Orientation
- Lens
- Film size
- Orientation of film plane



# Lights and Materials

## Types of lights

- Point sources vs distributed sources
- Spot lights
- Near and far sources
- Color properties

## Material properties

- Absorption: color properties
- Scattering
  - Diffuse
  - Specular

The End

Continue on Chapter 2 soon