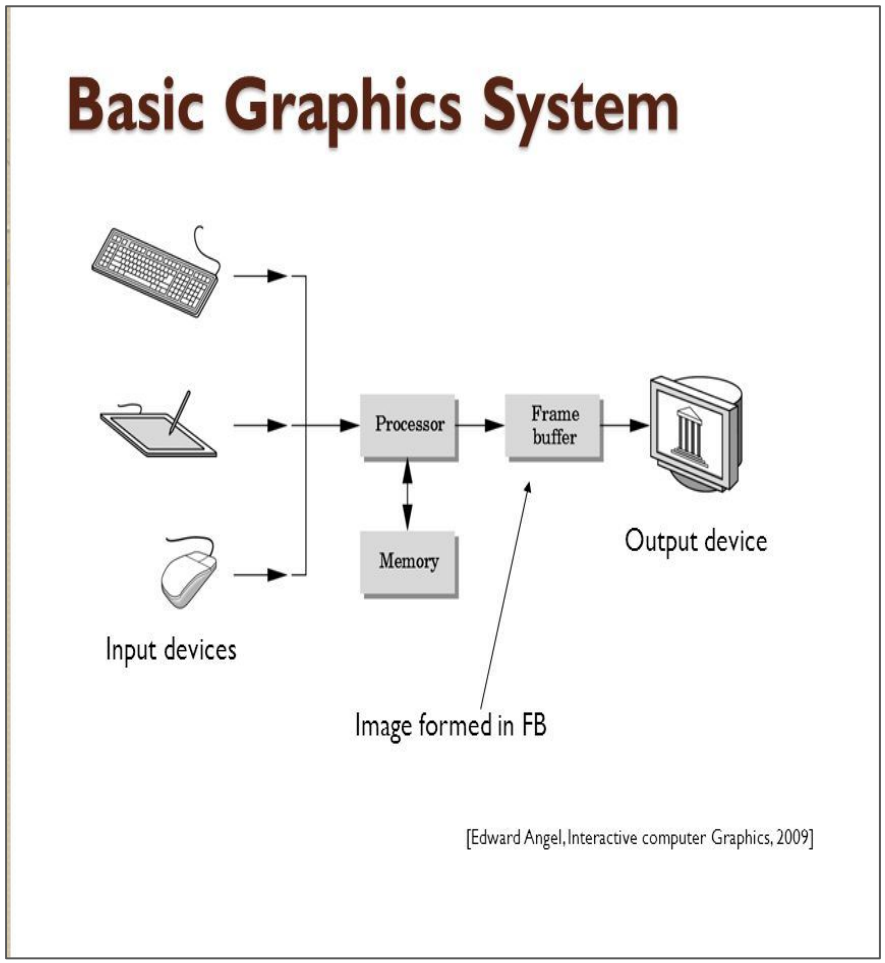
Graphics System and Simplified Pipeline

CSE606: Computer Graphics
Jaya Sreevalsan Nair, IIIT Bangalore
January 08, 2025

Introduction to Graphics Systems

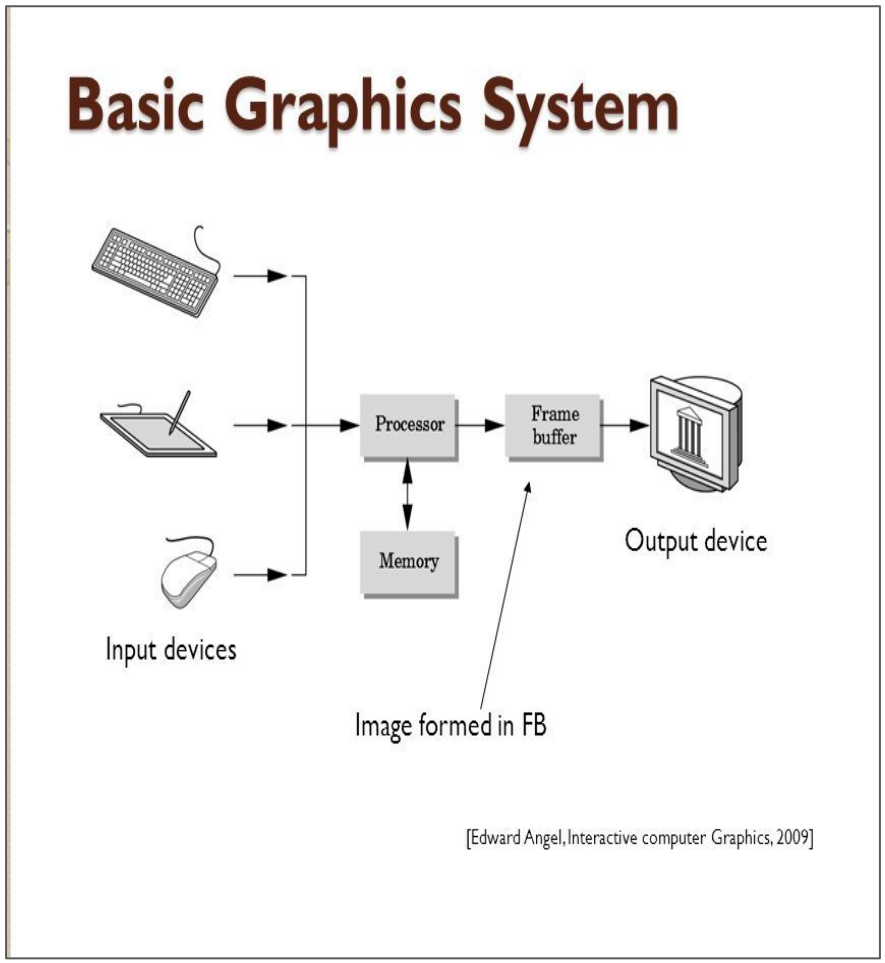
Introduction: System and Components



System function: to generate graphical output from input data (geometry, position, signals - image, etc.).

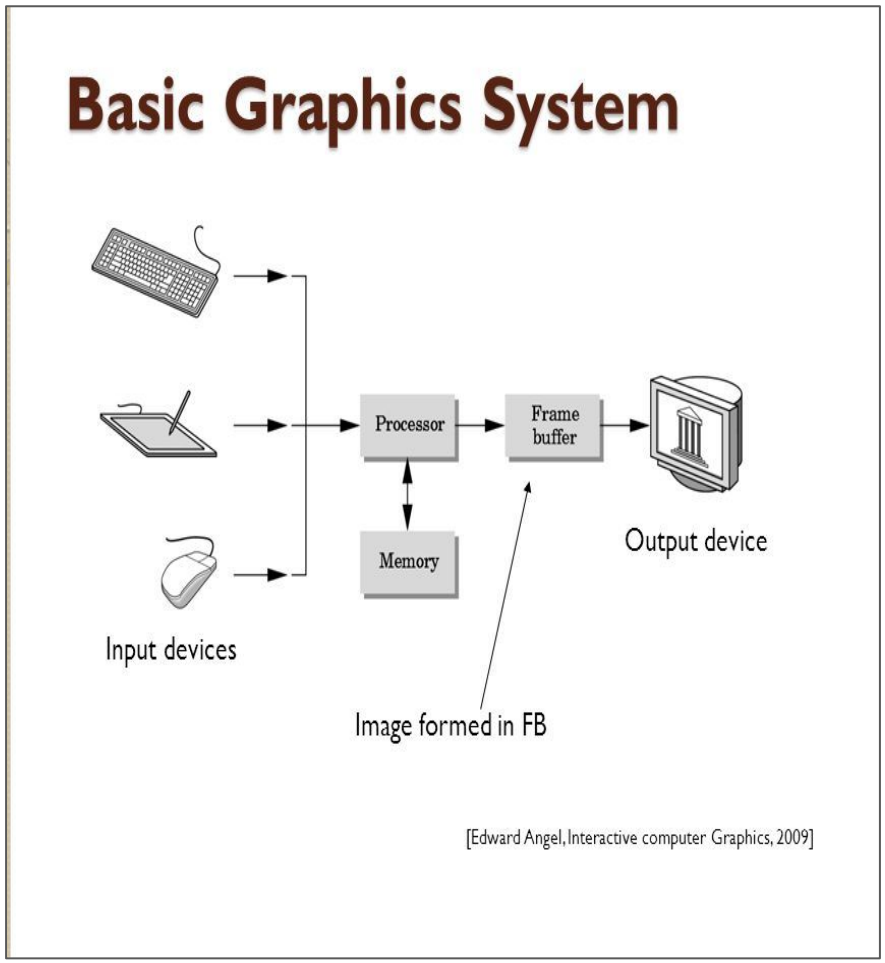
System components: input devices, processor, memory, frame buffer, output devices.

Input Devices



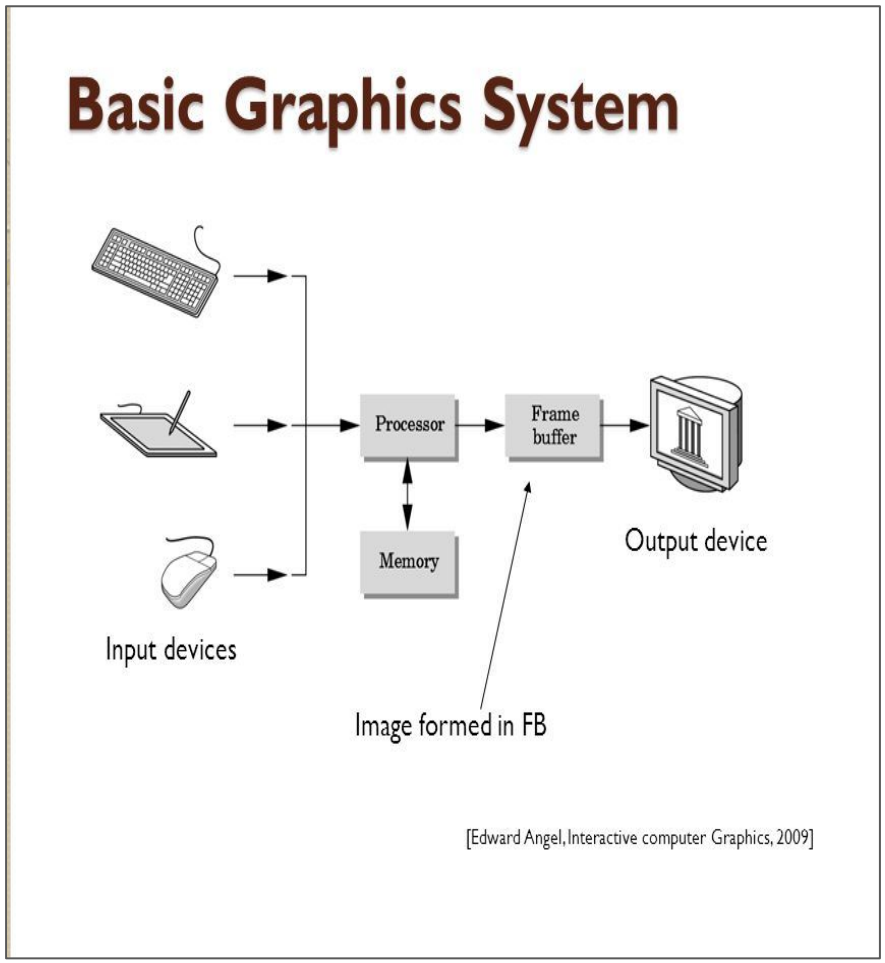
- a.k.a. Pointing Devices:
  - Provide positional information on display.
  - Provide feedback signals from user to processor.
- Devices providing multidimensional data:
  - 2-D: Keyboard, mouse, joystick, data tablet
  - 2+-D: Data gloves, computer vision systems
    - Used in gaming, CAD, VR

Output Devices



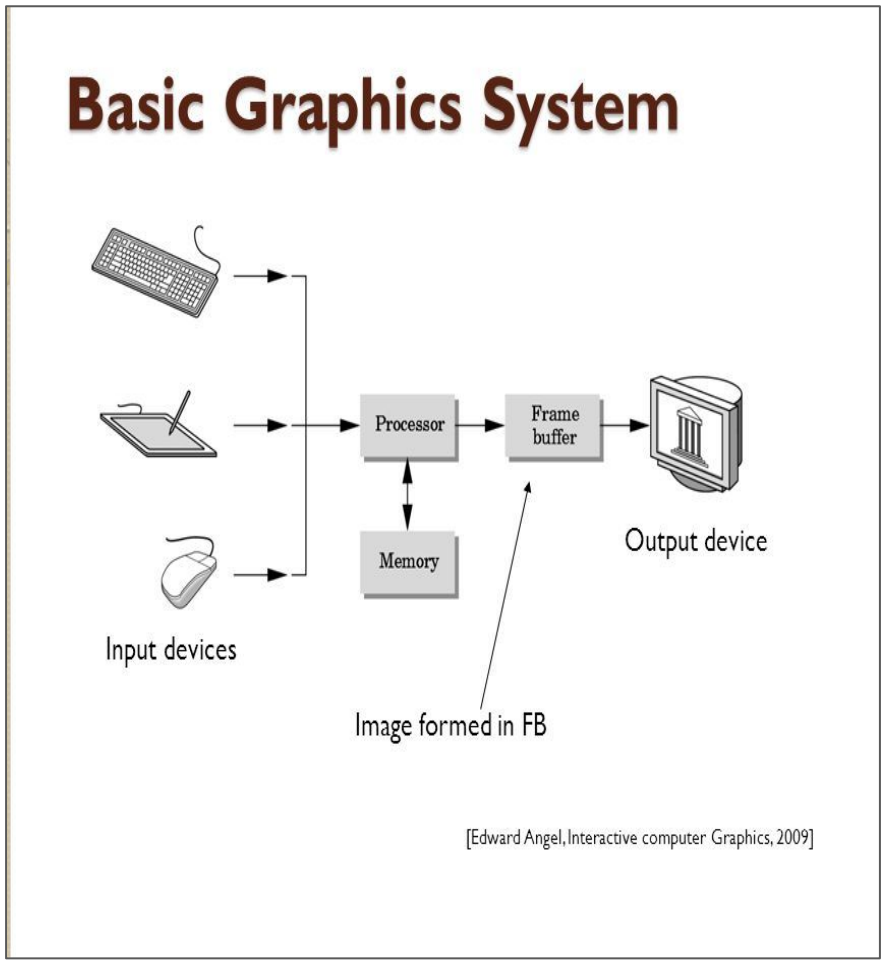
- Raster screens: A two-dimensional grid of respective light-emitting elements.
  - Popular device for display early on: Cathode Ray Tube (CRT).
  - Rapidly replaced by flat-screen technologies.
- Pixel (information) from frame buffer is displayed on display surfaces in 2 ways:
  - Non-interlaced/progressive display: row-by-row, scanline-by-scanline processing.
  - Interlaced display: Odd and even rows are refreshed alternately.

Frame Buffer

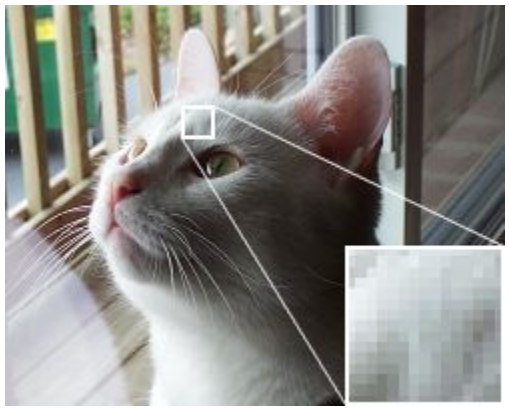


- A picture is a raster (array) of pixels (picture elements).
  - Applicable in all raster-based graphics systems
- Frame Buffer (FB) is the part of memory where the pixels are stored collectively.

Frame Buffer

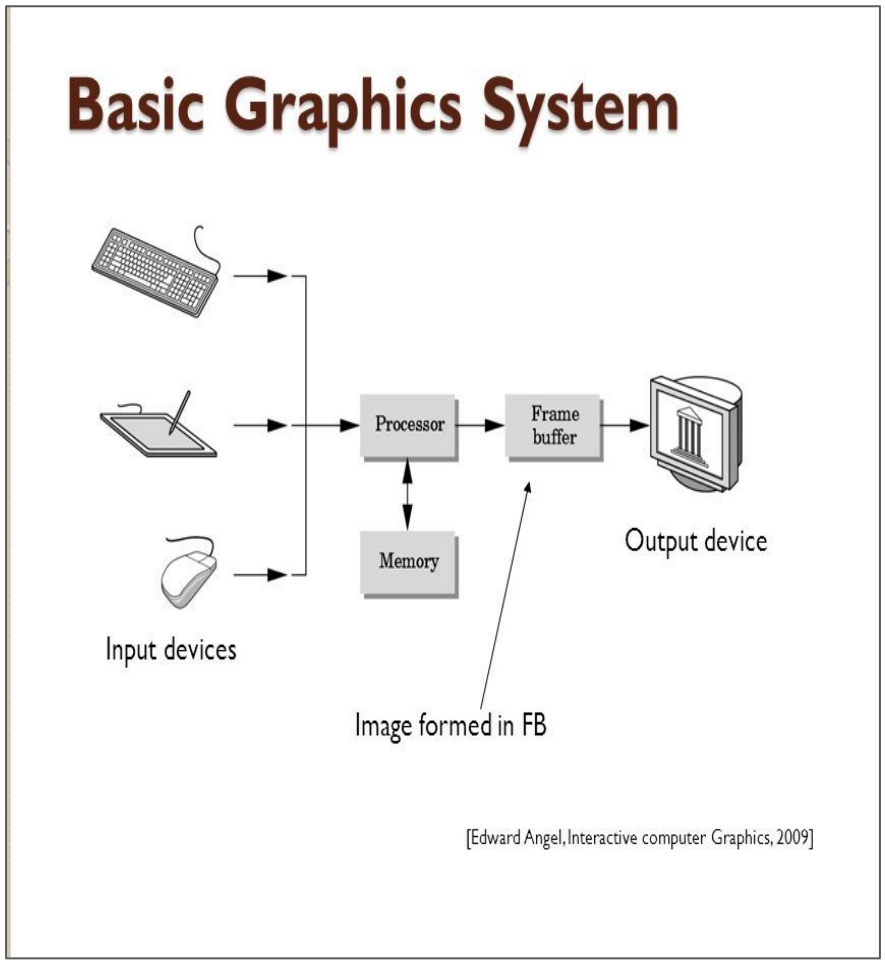


- A picture is a raster (array) of pixels (picture elements).
  - Applicable in all raster-based graphics systems
- Frame Buffer (FB) is the part of memory where the pixels are stored collectively.



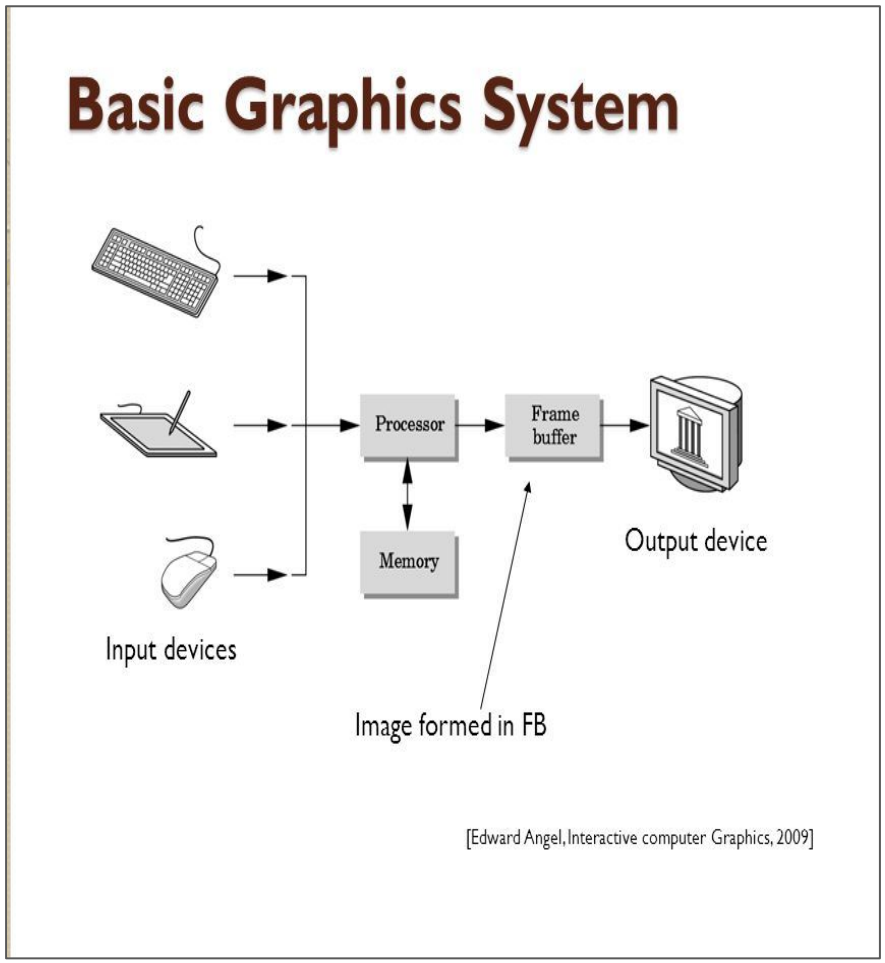
(Image courtesy: Wikimedia Commons.)

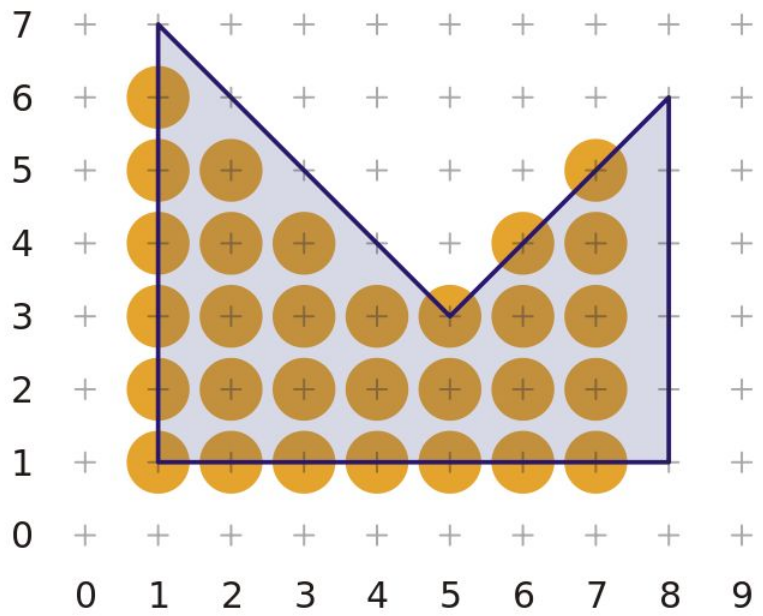
Frame Buffer



- Features of FB:
  - FB resolution: The number of pixels in FB, which influences the detail of the output image.
  - FB depth (or precision): #bits per pixel, which determines size of the color palette that can be represented in the system.
- FB implemented with special memory chips for fast re-display of contents of FB.
  - For systems not for real-time rendering but for high resolution rendering, FB is part of system memory.

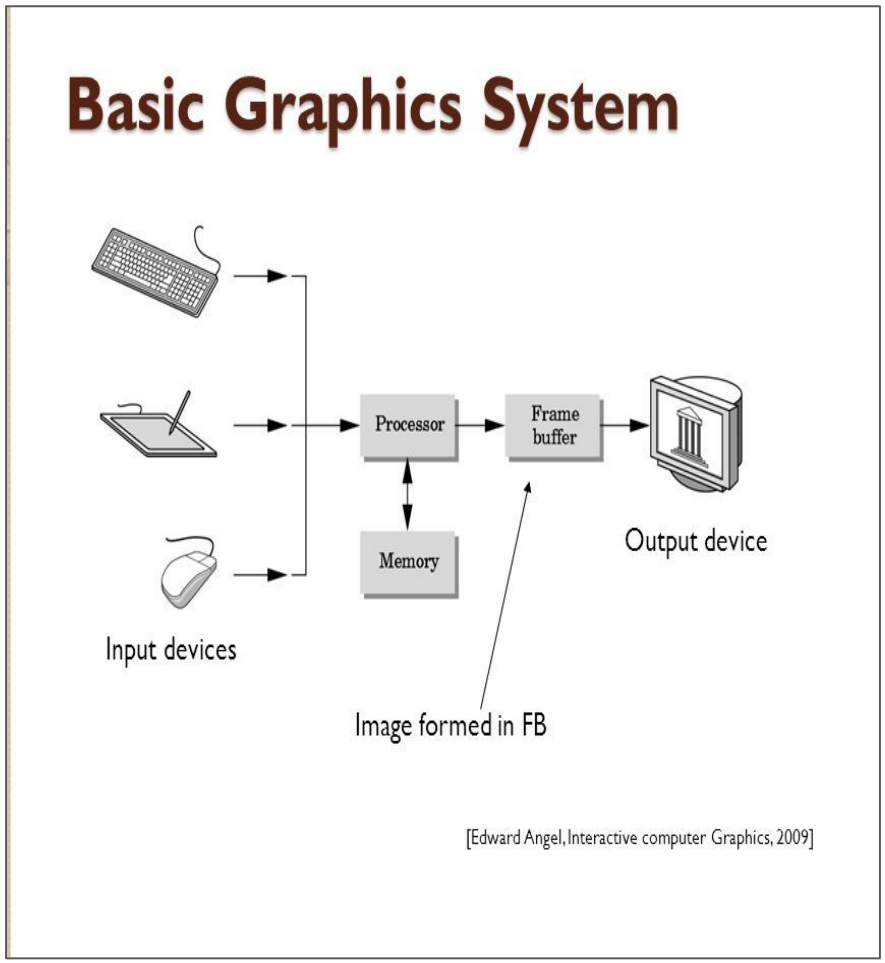
Processor



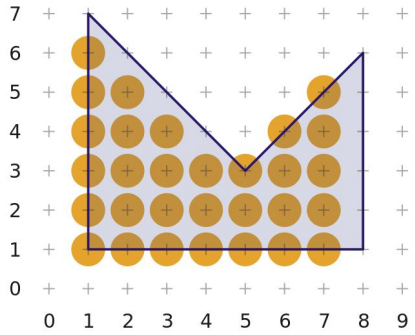


Scan Conversion of a Polygon.
(Image courtesy: Wikimedia Commons.)

Processor

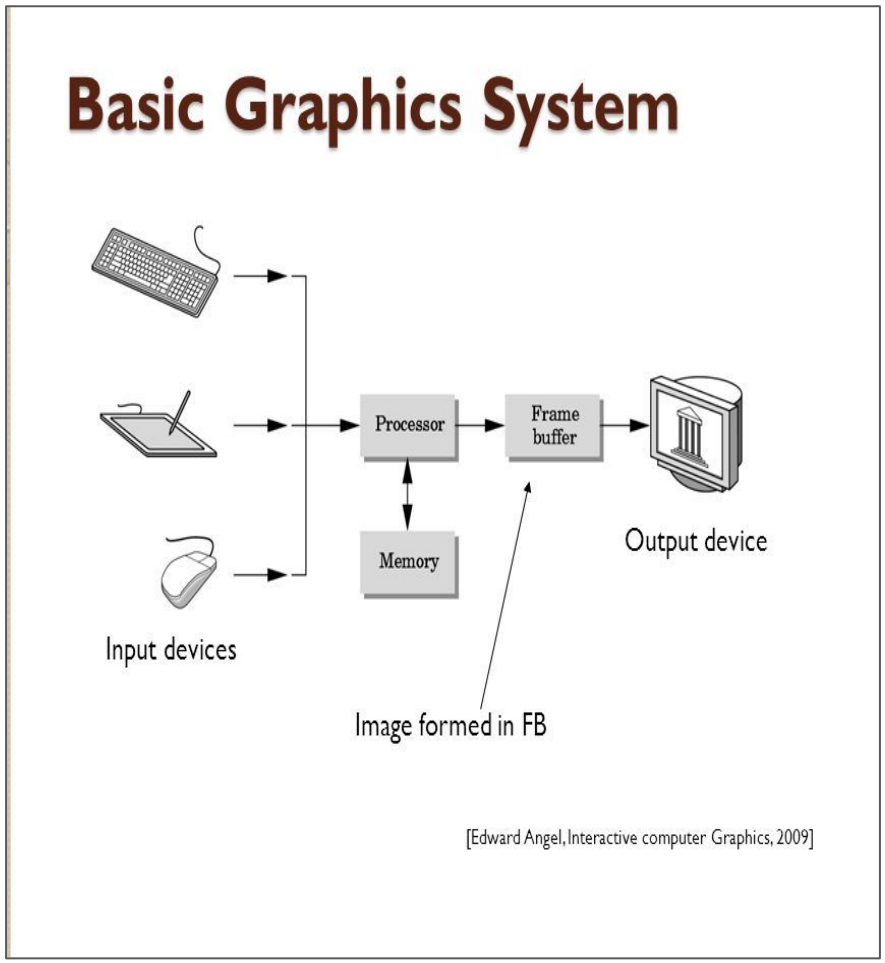


- Graphical processing is primarily **Rasterization** or **Scan Conversion**,
  - which is conversion of geometric entities to pixel information.
  - includes specifying location of entity on the pixels and color of pixels.



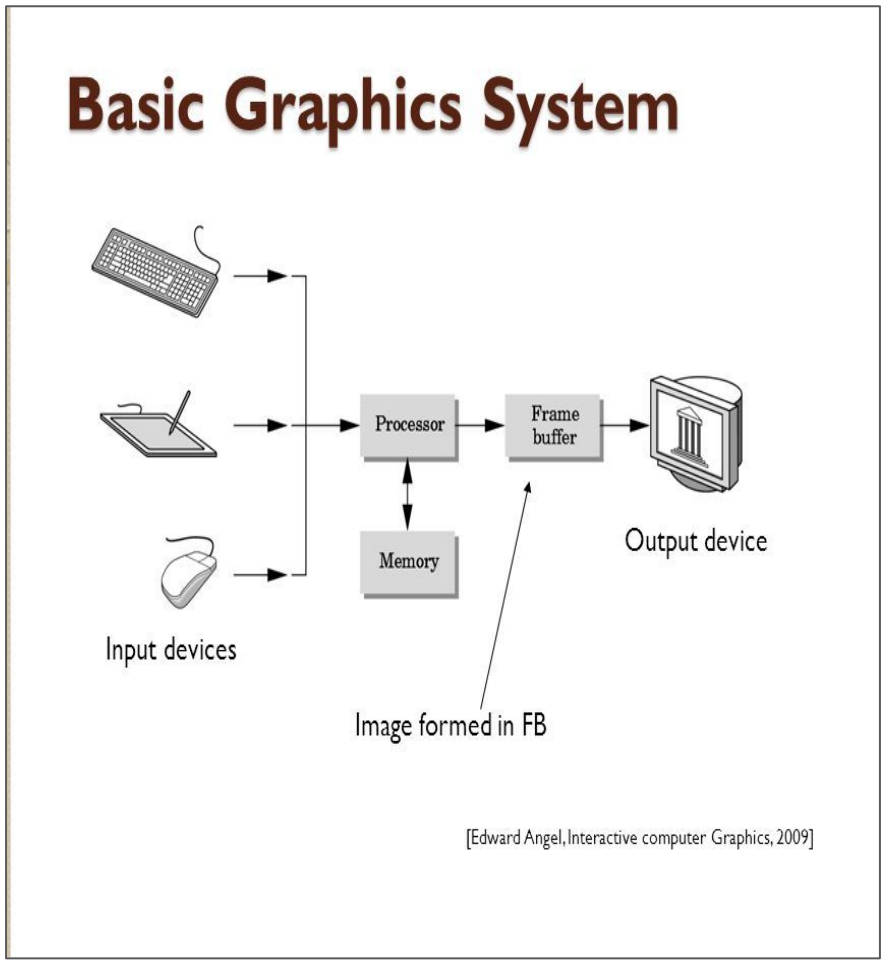
Scan Conversion of a Polygon.
(Image courtesy: Wikimedia Commons.)

Processor



- Earlier, CPU was used for normal compute/processing and graphical processing.
- Today, special-purpose Graphics processing units (GPU) uses hardware accelerator to fill up FB.
  - GPU can be part of motherboard or graphics card.
  - Hence FB may be included in the graphics card as well.

Memory



- Memory is allocated for graphics processing in a dedicated graphics card.
  - Needed for serious gaming, VR
  - Uses a lot of power, and hence needs a separate fan
- Integrated graphics card uses shared memory.
  - Cheaper systems

https://www.makeuseof.com/tag/can-shared-graphics-finally-compete-with-a-dedicated-graphics-card/

Graphics Architecture - Simplified Pipeline

Graphics Programming

Ingredients

- Objects
  - geometry, color/material
- Scene
  - composition with objects
- Lighting
  - instances, positions, properties
- Projection Plane (for Image Generation)
  - position, properties

Graphics Programming

Implementation

- Conversion of 3D objects to 2D image
- Color assignment to each pixel
  - Information from object properties and location
  - Information from light properties and location
  - Interaction between objects and light

Graphics Programming

System Requirements

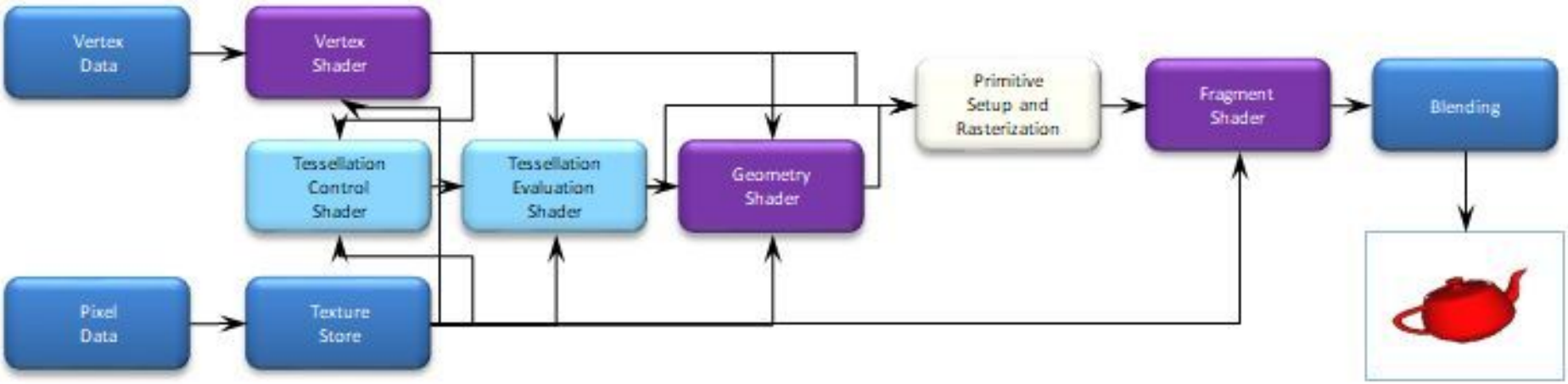
- Desired amount of user interaction
  - Real-time computations for interactive applications
  - No user interaction ⇒ offline rendering
- Desired effects of realism
  - Photo-realism vs functional realism
- Desired frame rate
  - Speed of generating images, refreshing framebuffer

Video of the Day

https://youtu.be/NgcYLIvlp_k

OpenGL now (4.x)

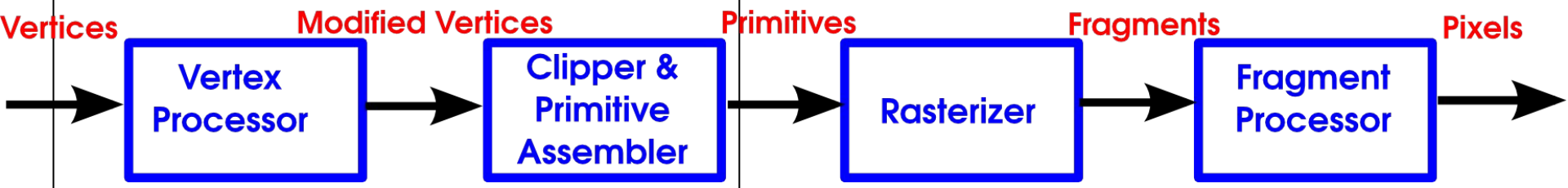
[From Angel and Shreiner]



Graphics Architecture – governing OpenGL

Use pipeline architecture using special VLSI chips.

- Multiple processes in sequence overlap, thus, increasing throughput, and masking latency.
- Latency: (Significant) delay between start and stop of a process.
- Throughput: Result of the entire master process - is significantly high compared to a single process at a time.



Geometric Pipeline.
Image adapted from Interactive Computer Graphics: A Top-Down Approach Using OpenGL.

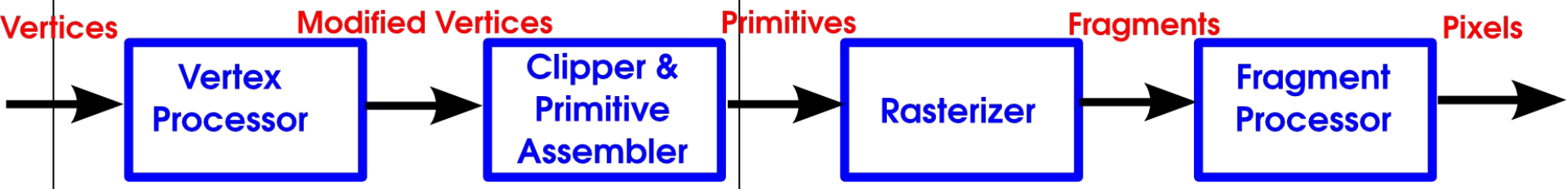
Graphics Architecture – governing OpenGL

Use pipeline architecture using special VLSI chips.

- Multiple processes in sequence overlap, thus, increasing throughput, and masking latency.
- Latency: (Significant) delay between start and stop of a process.
- Throughput: Result of the entire master process - is significantly high compared to a single process at a time.

Fragment:

- A potential pixel, carries information on:
  - Location & color: used for updating the corresponding pixel in FB;
  - Depth: to determine the order of rendering of fragments at a given pixel location.



Geometric Pipeline.
Image adapted from Interactive Computer Graphics: A Top-Down Approach Using OpenGL.

Topics Covered Today

- Graphics systems and its components.
- A glimpse of graphics programming and its pipeline architecture.