

Computer Graphics



## Chapter 1: Introduction to Computer Graphics

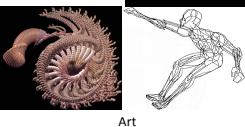
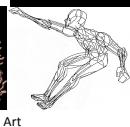
### Class Activity

- My name is ...
- This summer I worked at ... / I went to ... / I had fun doing ...
- My favorite example of computer graphics is ...
  - Computer game?
  - Animated movie?
  - Display?
  - Other application?

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### What are Computer Graphics (CG)?

- Pictures generated by computer

			
<small>Visualization</small>	<small>Entertainment</small>	<small>Industrial</small>	<small>Gaming</small>
			
<small>Entertainment</small>			<small>Art</small>

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### Real? CGI?



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### Real? CGI?



<http://chengbindu.cgsociety.org/art/flower-duchengbin-maya-mental-ray-zbrush-flowers-in-full-bloom-3d-1035525>

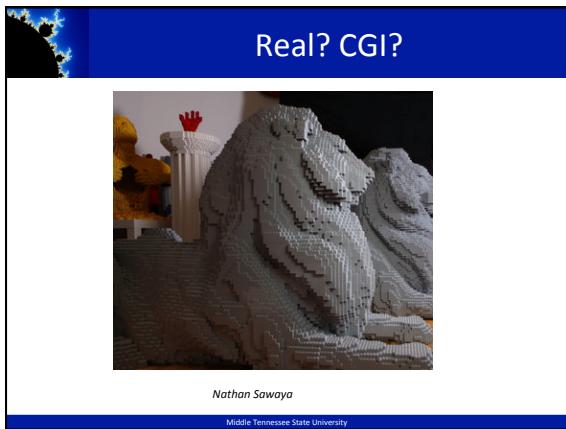
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### Real? CGI?



"Balloon Flower" by Jeff Koons, sold at Christie's London's auction for \$25.7 million

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## Graphics Research

- SIGGRAPH
  - 2016 Technical Paper Preview Trailer
    - <https://www.youtube.com/watch?v=dQBJ0r5Pj5s>
  - 2015 Technical Paper Preview Trailer
    - <https://www.youtube.com/watch?v=XrYkEhs2FdA>
  - 2014 Technical Paper Preview Trailer
    - <https://www.youtube.com/watch?v=u3Z1hDwGEmM>
- Computer Graphics Society

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## Modeling vs. Rendering

- Modeling
  - Create models
  - Apply materials to models
  - Place models around scene
  - Place lights in scene
  - Place the camera
- Rendering
  - Take “picture” with camera



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## History of Computer Graphics

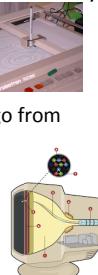
- <http://www.youtube.com/watch?v=LzZwiLUVaKg>
  - In what years does Computer Graphics originate?
  - What is the name of the Computer developed at MIT that helps US Navy to calculate trajectory of the rockets?
  - What is the name of the first interactive program developed at MIT?
  - In which year was 3D graphics started?
  - What is the first object the computer scientists used to test various techniques for CGI?
- An extensive description of the history of Computer Graphics and Animation can be found at:
  - <http://design.osu.edu/carlson/history/lessons.html>

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## 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 too high
  - Computers slow, expensive, unreliable

*CRT: Cathode Ray Tube*

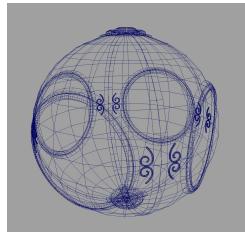


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## Computer Graphics: 1960-1970

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

wireframe representation of sun object



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## 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
    - Line clipping algorithm

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## Display Processor

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

Host → Display processor → CRT  
Display list

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

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## 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

IFIPS      International Federation of Information Processing Societies  
GKS      Graphical Kernel System  
ISO      International Standards Organization

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## Raster Graphics

- Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*

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## Raster Graphics

- Allows us to go from lines and wire frame images to filled polygons

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## 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

A *frame buffer* is a portion of RAM containing a bitmap that is driven to a video display from a memory buffer containing a complete frame of data.

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## Computer Graphics: 1980-1990

Realism comes to computer graphics

smooth shading      environment mapping      bump mapping

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## 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)
  - Pixar's RenderMan:  
<https://renderman.pixar.com/view/movies-and-awards>
- Networked graphics: X Window System
- Human-Computer Interface (HCI)

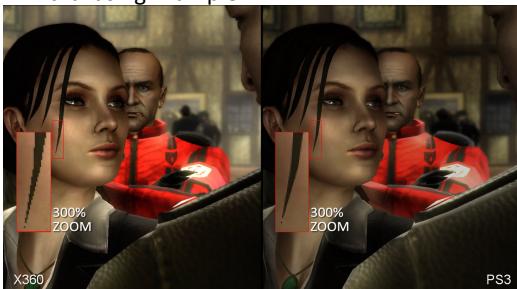
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## Computer Graphics: 1990-2000

- OpenGL API
- Completely computer-generated feature-length movies (Toy Story) are successful
- New hardware capabilities
  - Texture mapping
  - Blending
  - Accumulation: antialiasing
  - Stencil buffers:
    - Limit the area of rendering
    - Work with depth buffer to create special effects per pixel basis

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## Computer Graphics: 1990-2000

- Anti-aliasing Example

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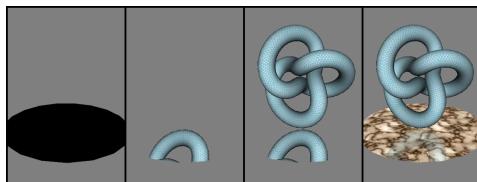
## Computer Graphics: 1990-2000

- Stencil buffer example

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## Computer Graphics: 1990-2000

- Stencil buffer for reflection generation example



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## Computer Graphics: 2000-2010

- Photorealism
- Graphics cards for PCs dominate market
  - Nvidia, ATI
- Game boxes and game players determine direction of market
- Computer graphics routine in movie industry: Maya, Lightwave
- Programmable pipelines
- New display technologies

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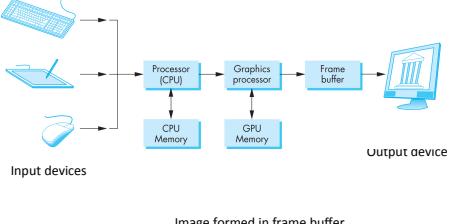
Computer Graphics 2011-

- Graphics is now ubiquitous
    - Cell phones
    - Embedded
  - OpenGL ES and WebGL
  - Alternate and Enhanced Reality
  - 3D Movies and TV
  - Newer display technology

## Realities of Computer Graphics

- Generally very computationally expensive
    - More realistic=more time/computation
    - Hardware/software is very specialized and complex
  - This is NOT a game programming or graphic design course
    - This course will help you if these are your interests
  - Lots of math!
    - You shouldn't be afraid of...
      - Matrices
      - Vectors
      - Geometry
  - Good APIs exist to make our lives easier
    - more on this later...

## Basic Graphics System



## Computer Graphics Tools

## Hardware

- Video monitors
  - Input devices
    - Mouse
    - Data glove
    - Etc...
  - CPU
  - Graphics cards (GPU)
  - Printers

Software

- Operating system
  - IDE
  - Compiler
  - Graphics routines/API
    - Windowing
    - Scene description
    - Modeling
    - Shading
    - ...
  - Editors
    - Photoshop, Blender, paint, etc

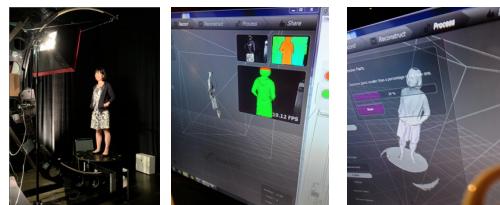
# Enabling Modern Computer Graphics

- **Hardware revolution**
    - Moore's Law: every 12-18 months, computer power improves by a factor of 2
    - Significant advances in commodity graphics chips every 6 months, outrunning CPU chip advance
      - CPU: Intel Itanium 2 dual core has 1.7 billion transistors total
      - GPU: Radeon HD 5850 dual core has 1.8 billion per core
    - Newest processors are 64-bit, dual/quad/8 core
      - Intel Core 2 Quad™, AMD Athlon64 X2™, Mac Pro/MT Quad/8-Core
    - Graphic subsystems
      - Offloads graphics processing from CPU to chip designed for doing graphics operations fast
      - nVidia GeForce™, ATI Radeon™
      - GPUs, being so fast are used for special purpose computation, also being ganged together to make supercomputers

# Enabling Modern Computer Graphics

- Input Devices

- Mouse, tablet & stylus/touchscreen, force feedback, other game controllers (e.g., Wii), scanner, digital camera (images, computer vision), etc.



## Input Devices (cont.)

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## Input Devices (cont.)

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## Enabling Modern Computer Graphics

- Cell Phones/PDAs (e.g., iPhones),  
Laptop/Desktops
- Virtual reality
  - Oculus Rift
- 3D immersive virtual reality systems
  - MTSU Aerospace Dept  
Air Traffic Control (ATC) Simulation
  - SimCraft
  - Brown's Cave

Brown's Cave

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## Enabling Modern Computer Graphics

- Software Improvements
  - Algorithms and data structures
    - Modeling of materials
    - Rendering of natural phenomena
    - Acceleration data structures for ray tracing
  - Parallelization
    - Most operations are embarrassingly parallel: changing value of one pixel is often independent of other pixels
  - Distributed and Cloud computing
    - Send operations into ‘cloud’, get back results, don’t care how
    - Rendering even available as internet service!

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## Ray Tracing and Geometric Optics

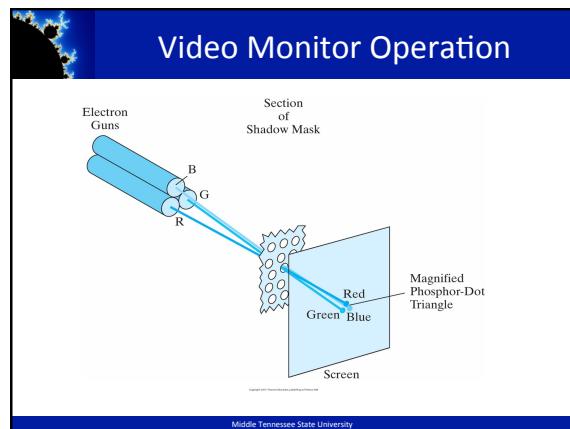
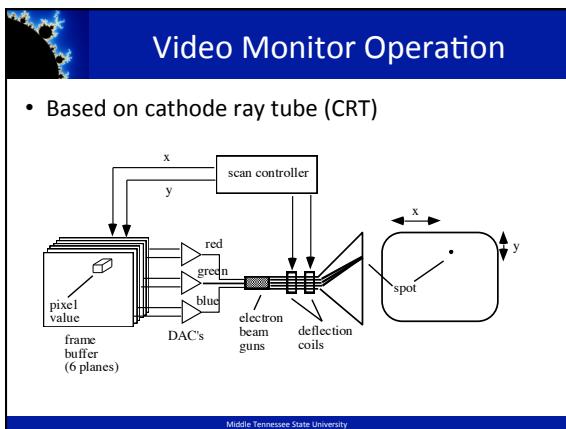
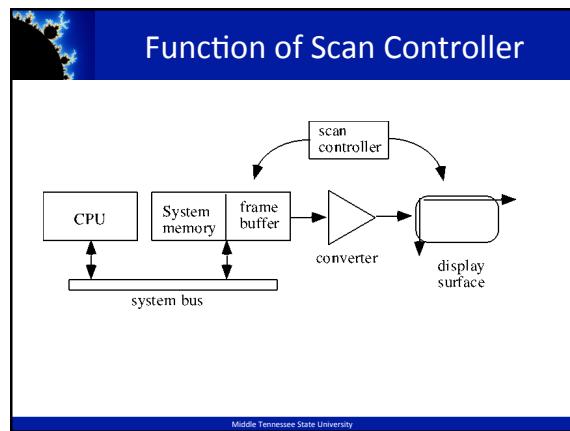
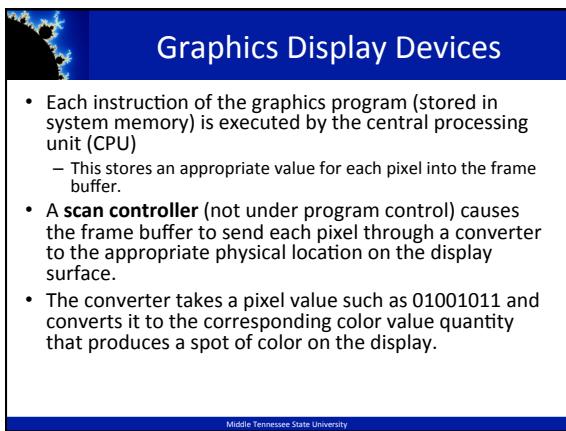
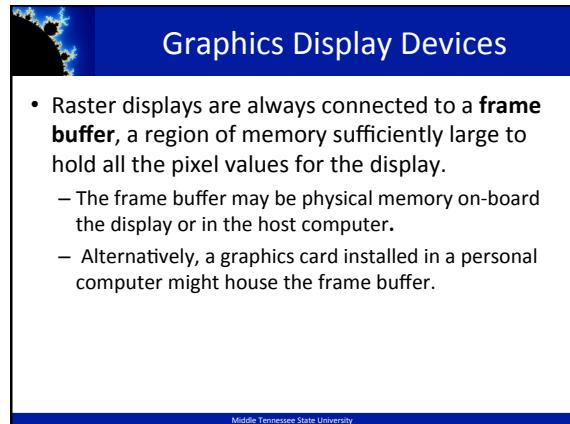
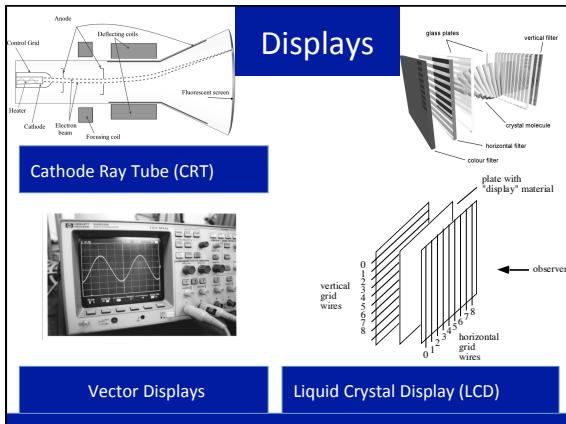
One way to form an image is to follow rays of light from a point source finding which rays enter the lens of the camera. However, each ray of light may have multiple interactions with objects before being absorbed or going to infinity.

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## Types of Computer Graphics

- API Driven (OpenGL or DirectX)
  - Real-time - games and visualization
  - Interactive
  - Good quality
- Ray Tracing (Physics Simulation)
  - Offline - film and television
  - Great quality
  - Computationally expensive
- Vector graphics
- In this class we will focus on API graphics, but we will look briefly at ray tracing as well

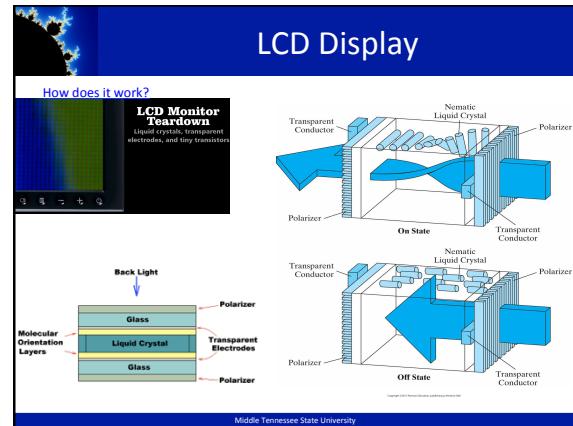
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## Video Monitor Operation

- A raster-scan system displays an object as a set of discrete points across each scan line.

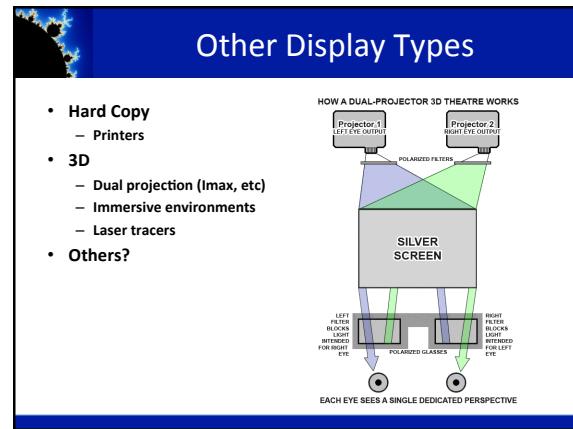
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## LCD Display

- Thinner and lighter. No tube or electron beams.
- Blocking/unblocking light through polarized crystals. Crystals liquefy when excited by heat or E field.
- A matrix of LC cells one for each pixel.
- Color 3 cells per pixel

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## 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*

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