

Computer Graphics



Chapter 1: Introduction to Computer Graphics

Class Activity

- Who am I?
- My name
- A fact about myself or share my summer experience
- My favorite example of computer graphics

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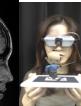
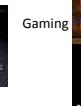
 Syllabus

- Lets go through it together...

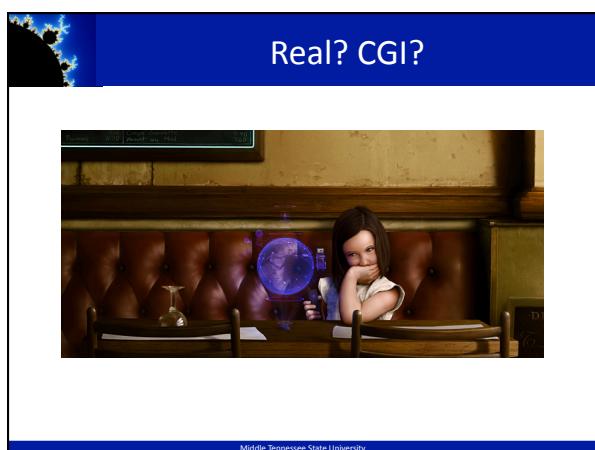
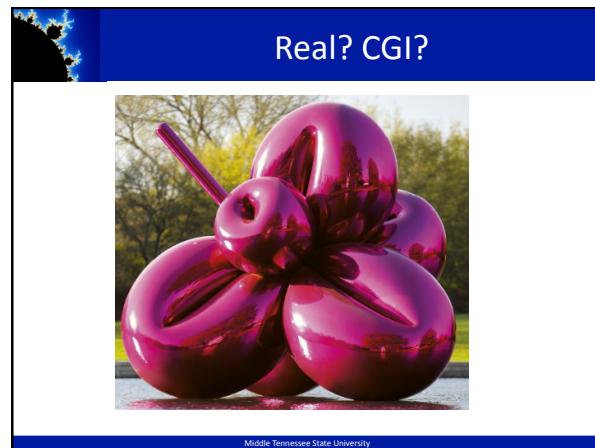
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What are computer graphics?

- Pictures generated by a computer
- Examples?

				Industrial
Visualization			Gaming	
				Entertainment
				Art

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Real? CGI?



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History of Computer Graphics

- <http://www.youtube.com/watch?v=LzZwiLUVaKg>
(History of Computer Animation - P1)
 - 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?

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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
- In this class we will focus on API graphics, but we will look briefly at ray tracing as well

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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...

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Computer Graphics Tools

Hardware	Software
<ul style="list-style-type: none"> Video monitors CPU Input devices <ul style="list-style-type: none"> Mouse Data glove Etc... Graphics cards (GPU) Printers 	<ul style="list-style-type: none"> Operating system IDE Compiler Graphics routines/API <ul style="list-style-type: none"> Windowing Scene description Modeling Editors <ul style="list-style-type: none"> Photoshop, paint, etc

Enabling Modern Computer Graphics

- Hardware revolution**
 - Moore's Law: every 12-18 months, computer power improves by a factor of 2 in price / performance
 - 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™ 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
 - GPU has led to development of other dedicated subsystems
 - Physics: nVidia PhysX PPU (Physics Processing Unit)
 - Artificial Intelligence: Alseek Intia Processor

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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.

a)  b) 

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Enabling Modern Computer Graphics

- Many form factors**
 - Cell Phones/PDAs (e.g., iPhones), Laptop/Desktops
 
- 3D immersive virtual reality systems**
 - MTSU Aerospace Dept Air Traffic Control (ATC) Simulation
 - SimCraft
 - 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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 Graphics Research

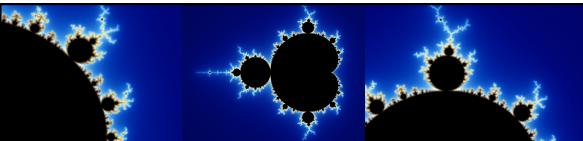
- SIGGRAPH
 - 2012 video <http://www.youtube.com/watch?v=cKrng7ztpog&feature=relmfu>
 - 2011 video <http://www.youtube.com/watch?v=JK9EEE3RsKM>

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 Graphics Basics

- What computer-generated (CG) game or movie is your favorite?
- What makes CG graphics look realistic?
- What are pictures made up of?
- How do you manipulate these objects?

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Lets start with some basics

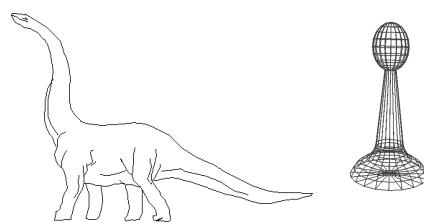
Elements of Pictures

- **Output primitives:**
 - points
 - lines
 - polylines
 - text
 - filled regions
 - raster images
- **Attributes:** how an output primitive appears; e.g., color and thickness.

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Polylines

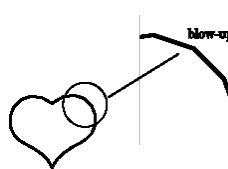
- A polyline is a connected sequence of straight lines.



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Polylines

- A polyline can appear to the eye as a smooth curve. This figure shows a magnification of a curve revealing its underlying short line segments.



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Polylines

- When there are several lines in a polyline, each one is called an **edge**, and two adjacent lines meet at a **vertex**.
- The edges of a polyline can cross one another
- A polyline does not have to be closed
- Polyline vertices are specified as a list of vertices, each given by a coordinate pair: $(x_0, y_0), (x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$.

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Polyline

- A **polygon** has its first and last points connected by an edge.
- If no two edges cross, the polygon is called **simple**.
- A polygon is **convex** if it contains every line segment delimited by any two points on its boundary.
- Which are simple?
- Which are convex?

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Polyline Attributes

- Color, thickness and stippling of edges, and the manner in which thick edges blend together at their endpoints.
- Typically all the edges of a polyline are given the same attributes.

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Polyline Attributes

- Joining ends: "butt-end", rounded ends, mitered joint, and trimmed mitered joint.

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Filled Regions

- The **filled region** (sometimes called *fill area*) primitive is a shape filled with some color or pattern.
- Example: polygons

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Text

- Some graphics devices have both a **text mode** and a **graphics mode**.
- Text in text mode uses a built-in character generator.
- Text in graphics mode is drawn.

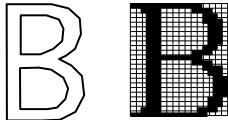
Big Text
Little Text
Shadow Text

Rotated Text
Outlined text

SMALLCAPS

Text Attributes

- Font, color, size, spacing, and orientation.
- Orientation: Characters/strings may be drawn tilted (e.g., vertically).
- Characters are defined by a set of polylines or by dots.



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Vector vs. Raster

- What is the main difference between vector images and dot (raster) images?
- How do they scale?
- What are some examples of where you have seen these problems?
- What are the benefits of dot-based images?

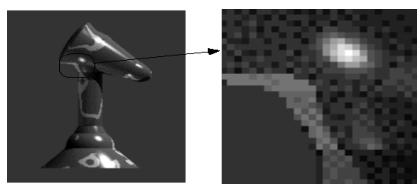
vector vs. raster



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Raster Images

- Rasterization: The process of converting a vector image (shapes) to a raster image (dots)
- Raster images are made up of many small pixels



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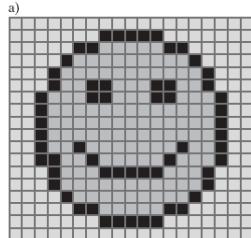
Pixmaps and Bitmaps

- A raster image is stored in a computer as a rectangular array of numerical values.
- The array has a certain number of rows and a certain number of columns.
- Each numerical value represents the value of the pixel stored there.
- The array as a whole is often called a **pixel map** or **bitmap**.
- How many MegaPixels is your computer screen?
– Why do digital cameras have such high resolution?

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Pixmaps and Bitmaps Example

- The numbers show the values in the upper left 6 rows x 8 columns of the image.



b)

2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	7
2	2	2	2	2	7	7	1
2	2	2	2	7	1	1	1
2	2	2	7	1	1	1	1
2	2	2	7	1	7	7	7
2	2	2	7	1	7	7	7

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Creating Pixmaps and Bitmaps

- Scanned images.
- Hand designed images, created by person.
- Computed images, using an algorithm.

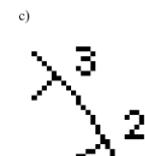
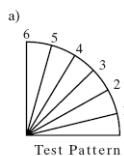


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The “Jaggies”

- Any close-up version of a pixmap will show that the image is composed of pixels rather than lines
- Thus the lines also appear jagged (the Jaggies).



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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"

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Grayscale

- Two pixel values in an image is called **bi-level**, or a **1 bit per pixel** image. Colors are black and white.
- 2^n pixel values in an image requires n bits per pixel and gives 2^n shades of gray.
 - Most commonly, n is 2, 4, or 8, producing 4, 16, or 256 shades of gray.

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Grayscale

- An image with 8 bits per pixel may be reduced to fewer bits per pixel by truncating values.
- Gradations of gray may change to a uniform shade of gray.
- Below: 6, 3, 2, and 1 bit per pixel.

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Color

- Color is usually described as a combination of red, green, and blue light.
- Each pixel is a 3-tuple: e.g., (23, 14, 51), for red (R), green (G), and blue (B).
- The total number of bits allowed for R, G, and B values is the **color depth**.
 - A color depth of 8 is often used: 3 bits each for R and G, and 2 bits for B.

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Color

- Commonly the 8-bit depth is used as an index into a table of colors (a “color look-up table, or color LUT”.)
- 16 bit color results in ~65,000 colors**
- True color** images have a color depth of 24 or 32 bits.
 - The color representation is excellent, but such images require huge amounts of memory to store.

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Data transfer

- Resolution- size of the window
 - pixels x pixels
- Refresh rate- number of times per second the window is redrawn
 - Hz = times/sec
- Lets compute how many bits are needed to display a 320x200 window in B&W...
 - 480x600 window with 8 bit color...16 bit...
 - What if it is a video with a refresh rate of 10 Hz and it is 30 seconds long?

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Displays

Cathode Ray Tube (CRT)

Liquid Crystal Display (LCD)

Vector Displays

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Graphics Display Devices

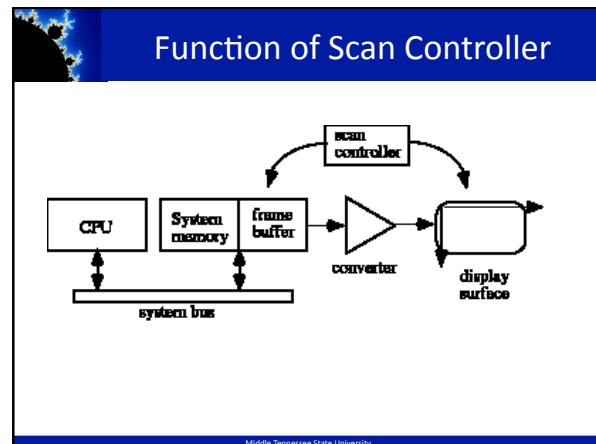
- Raster displays are always connected to a **frame buffer**, a region of memory sufficiently large to hold all the pixel values for the display.
 - The frame buffer may be physical memory on-board the display or in the host computer.
 - Alternatively, a graphics card installed in a personal computer might house the frame buffer.

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Graphics Display Devices

- Each instruction of the graphics program (stored in system memory) is executed by the central processing unit (CPU)
 - This stores an appropriate value for each pixel into the frame buffer.
- A **scan controller** (not under program control) causes the frame buffer to send each pixel through a converter to the appropriate physical location on the display surface.
- The converter takes a pixel value such as 01001011 and converts it to the corresponding color value quantity that produces a spot of color on the display.

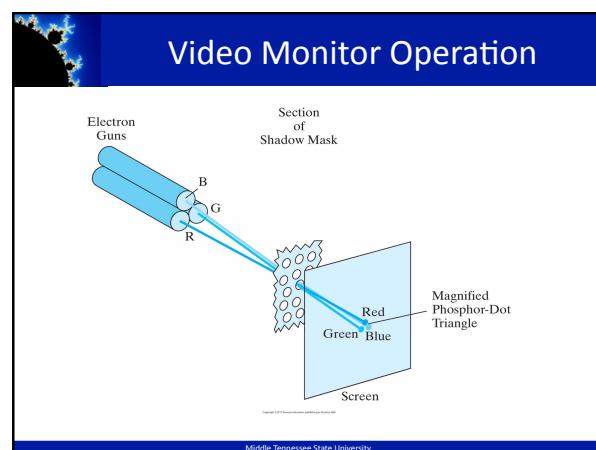
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Video Monitor Operation

- Based on cathode ray tube (CRT)

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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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Data Transfer Accelerators

- Using 24- or 32-bit color, how much data must be transferred between the computer and display every second?
 - Operates at 60+Hz
- Fast buses and graphics cards can improve the transfer speed.
- The cards implement the **graphics pipeline**: the nature of the processing steps to display the image and the order in which they must occur (specified by the graphics language, e.g., OpenGL).

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LCD Display

How does it work?

LCD Monitor Teardown
Liquid crystals, transparent electrodes, and tiny transistors

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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.
- No refresh unless the screen changes.
- Color 3 cells per pixel

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Other Display Types

- Hard Copy
 - Printers
- 3D
 - Dual projection (Imax, etc)
 - Immersive environments
 - Laser tracers
- Others?

EACH EYE SEES A SINGLE DEDICATED PERSPECTIVE

Types of Graphics

- **Animation:** A sequence of frames proceeds at a particular rate
 - Movies
 - Cartoons
- **Interactive Program:** Interactive graphics experience
 - User controls the flow from one frame to another
 - Using an input device such as a mouse or keyboard
 - Computer Games
 - Flash

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Conceptual Framework for Interactive Graphics

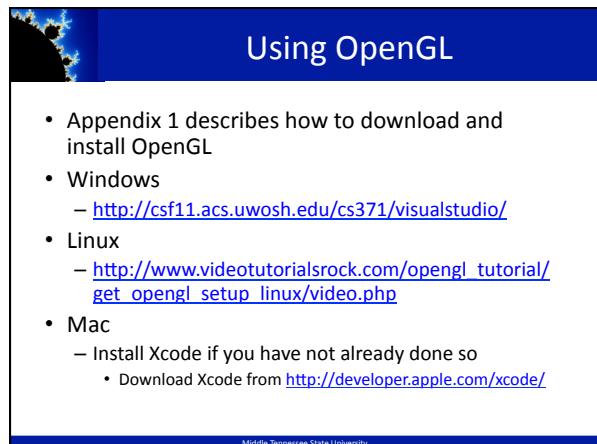
- Graphics library/package is intermediary between application and display hardware (Graphics System)
- Application program maps application objects to views (images) of those objects by calling on graphics library. Application model may contain lots of non-graphical data (e.g., non-geometric object properties)
- User interaction results in modification of model and/or image
- Unlike with FX, images are often means to an end: synthesis, design, manufacturing, visualization,...
- This hardware and software framework is more than 4 decades old but is still useful, indeed dominant

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Case Study- Turtle Graphics

- Addition to the “logo” computer language
- A turtle moves around the screen to draw images
- The turtle has 3 attributes
 - Position
 - Orientation
 - Pen (width, color, etc)
- Commands are given to the turtle relative to its own position
 - “Move forward 20 paces”
 - “Turn left 90 degrees”
 - “Enable pen”
- <http://sonic.net/~nbs/webturtle/>

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Using OpenGL

- Appendix 1 describes how to download and install OpenGL
- Windows
 - <http://csf11.acs.uwosh.edu/cs371/visualstudio/>
- Linux
 - http://www.videotutorialsrock.com/opengl_tutorial/get_opengl_setup_linux/video.php
- Mac
 - Install Xcode if you have not already done so
 - Download Xcode from <http://developer.apple.com/xcode/>

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