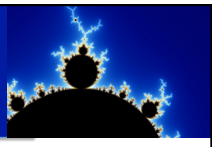
Computer Graphics



Chapter 1: Introduction to Computer Graphics

Class Activity

– Who am I?

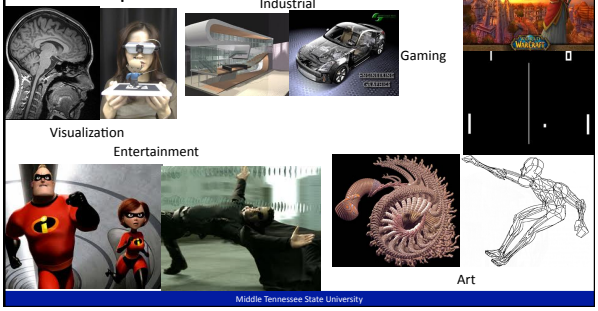
– My name
– A fact about myself
– My favorite example of computer graphics

Syllabus

- Lets go through it together…

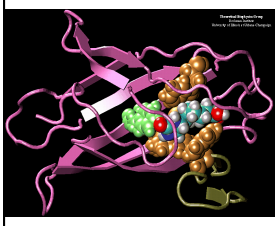
What are computer graphics?

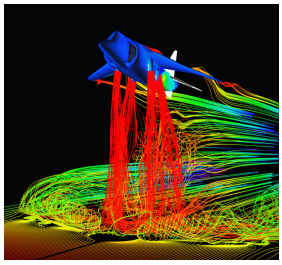
- Pictures generated by a computer
- Examples?



What are computer graphics?

- Scientific Visualization

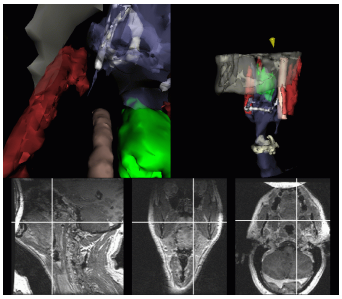




Airflow around a Harrier Jet *(NASA Ames*

What are computer graphics?

- Medical Visualization

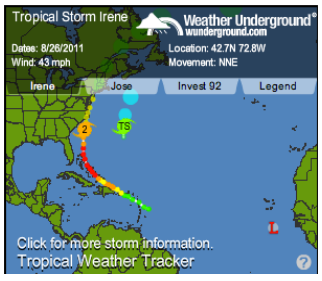


MIT: Image-Guided Surgery Project

The Visible Human Project

What are computer graphics?

- Hurricane Weather forecast



Real? CGI?

Real? CGI?

Real? CGI?

Real? CGI?

Real? CGI?

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?

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

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…

Computer Graphics Tools

Hardware	Software

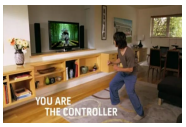
• Video monitors
• CPU
• Input devices
  – Mouse
  – Data glove
  – Etc…
• Graphics cards (GPU)
• Printers
	• Operating system
	• IDE
	• Compiler
	• Graphics routines/API
	  – Windowing
	  – Scene description
	  – Modeling
	• Editors
	  – Photoshop, paint, etc

Enabling Modern Computer Graphics

- Hardware revolution
  - Moore's Law: every 12-18 months, computer power improves by a factor of 2 in price / performance as feature size shrinks
  - 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 ProTM 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: AIseek Intia Processor

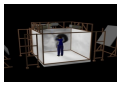
Enabling Modern Computer Graphics

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

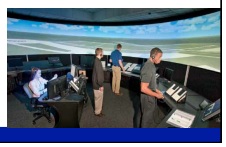


Enabling Modern Computer Graphics

- 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



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!

Graphics Research

- SIGGRAPH
  - 2011 video http://www.youtube.com/watch?v=JK9EEE3RsKM
  - Take a look at past years' SIGGRAPH videos on youtube

Graphics Basics

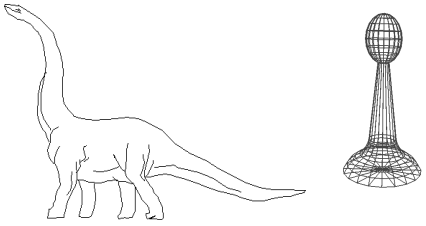
- What computer-generated (CG) game or movie is your favorite?
- What makes CG graphics look realistic?
- What are pictures made up of?
- How do you manipulate these objects?

Elements of Pictures

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

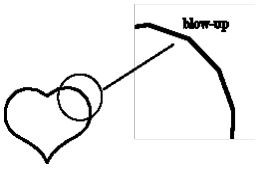
Polylines

- A polyline is a connected sequence of straight lines.



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.

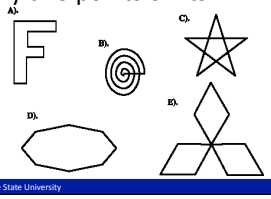


Polylines

- 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
- Polylines 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), ..., (x_n, y_n).

Polylines

- 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?



Polyline Attributes

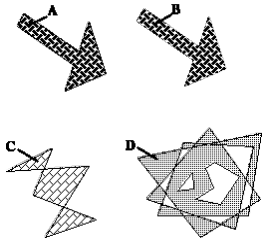
- Color, thickness and stippling of edges, and the manner in which thick edges blend together at their endpoints.
- Typically all the edges of a polyline are given the same attributes.

Polyline Attributes

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

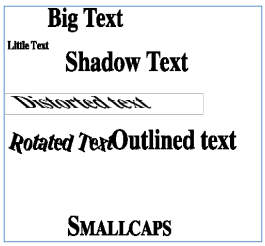
Filled Regions

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



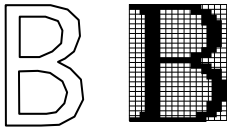
Text

- 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.



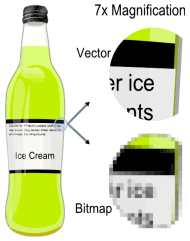
Text Attributes

- 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.



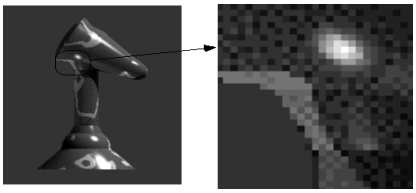
Vector vs. Raster

- 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?



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

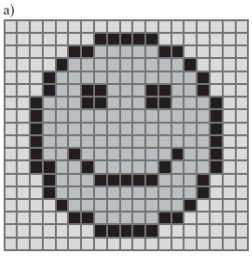


Pixmaps and Bitmaps

- 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?

Pixmaps and Bitmaps Example

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

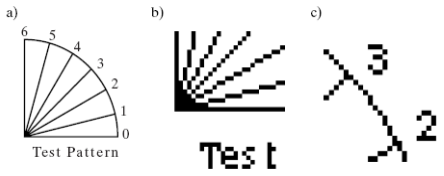


Creating Pixmaps and Bitmaps

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

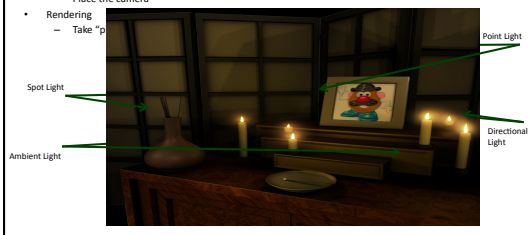
The "Jaggies"

- 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).



Modeling vs. Rendering

- Modeling
  - Create models
  - Apply materials to models
  - Place models around scene
  - Place lights in scene
  - Place the camera
- Rendering
  - Take "p

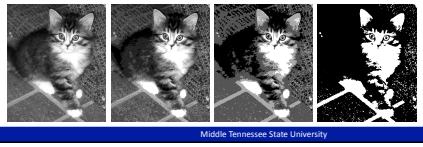


Grayscale

- 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.

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.



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.

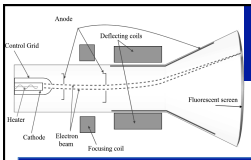
Color

- 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.

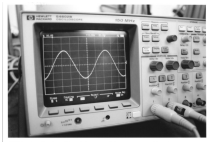
Data transfer

- 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?

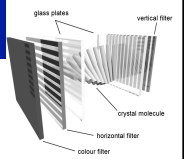
Displays

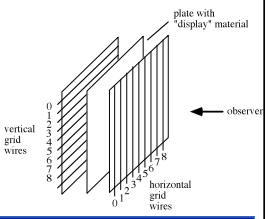


Cathode Ray Tube (CRT)



Vector Displays

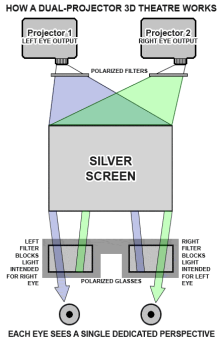




Liquid Crystal Display (LCD)

Other Display Types

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



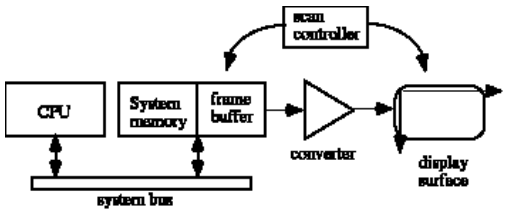
Graphics Display Devices

- 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.

Graphics Display Devices

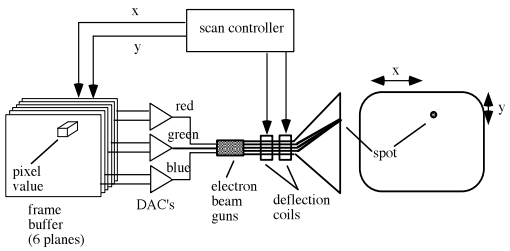
- Each instruction of the graphics program (stored in system memory) is executed by the central processing unit (CPU)
  - This stores an appropriate value for each pixel into the frame buffer.
- A **scan controller** (not under program control) causes the frame buffer to send each pixel through a converter 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.

Function of Scan Controller

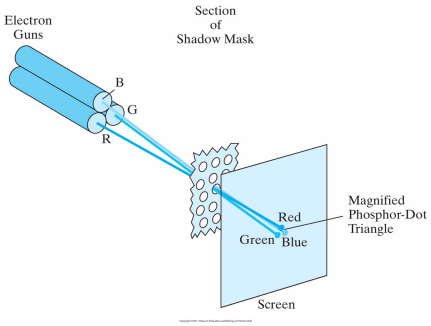


Video Monitor Operation

- Based on cathode ray tube (CRT)

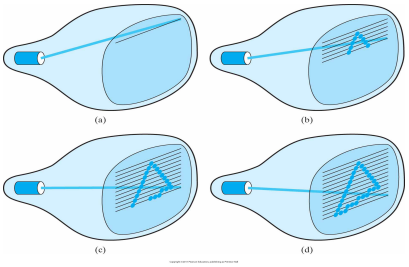


Video Monitor Operation



Video Monitor Operation

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

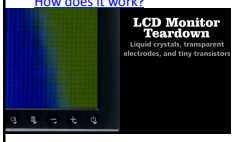


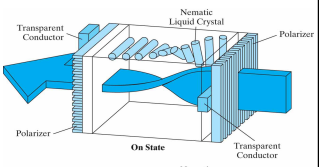
Data Transfer Accelerators

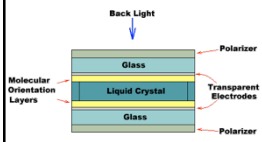
- Using 24- or 32-bit color, how much data must be transferred between the computer and display every second?
  - Operates at 60+Hz
- Fast buses and graphics cards can improve the transfer speed.
- The cards implement the **graphics pipeline**: the nature of the processing steps to display the image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

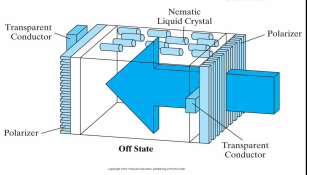
LCD Display

How does it work?









LCD Display

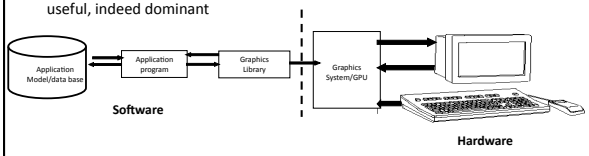
- Thinner and lighter. No tube or electron beams.
- Blocking/unblocking light through polarized crystals. Crystals liquefy when excited by heat or E field.
- A matrix of LC cells one for each pixel.
- No refresh unless the screen changes.
- Color 3 cells per pixel

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

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



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/

Using OpenGL

- Appendix 1 describes how to download and install OpenGL
- Windows
  - http://csf11.acs.uwosh.edu/cs371/visualstudio/
  - Do you want a tutorial on using VS?
- 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/