A Brief History of Computer Graphics

1885 - CRT (Cathode Ray Tube)

1887 - Edison patents motion picture camera

1888 - Edison and Dickson record motion picture photos on a wax cylinder

1926 – J.L. Baird invents the television.

30 line vertical, black and red scan
A Brief History of Computer Graphics

1962
- Sketchpad developed by Ivan Sutherland
  - Lightpen used to create engineering drawings directly on the CRT.
  - Memory structures to store objects.
  - Rubber-banding of lines
  - Zoom in and out on the display
  - And the ability to make perfect lines, corners, and joints.
  - PDP-1 (DEC)

1962
- SpaceWar created by Steve Russell
  - First computer game
  - Multiplayer game
  - The "a", "s", "d", "f" keys control one of the spaceships.
  - The "k", "l", ",", "" keys control the other.
  - The controls are spin one way, spin the other, thrust, and fire.

1963
- IBM creates the 360 models
  - One of the first general purpose mainframes
- SRI develops the mouse.

1966
- Ralph Baer creates the 1st consumer CG product: Odyssey Pinball

1967
- GE introduces first full color real time flight simulator for NASA

1968
- John Whitney: Permutations
  In "Permutations," (1968) he delineates a marvellous and exciting new world. One senses a choreographer. The movements are reminiscent of traditional ballet. The shapes follow the dictates of formal geometry more than those of abstract painting. Movement is three-dimensional and the ambition for a more polished three-dimensional shaded space is apparent.
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1972
- ATARI
- Pong

1973
- Michael Crichton’s “Westworld” uses 2D graphics
- First time computer is used for image manipulation.
- Featured scenes that showed audiences the world viewed by the eye circuitry of a synthetic human (played by a very real Yul Brenner) in a future Western theme park. This effect was achieved with 2D computer graphics tools mostly derived from image processing techniques.

1974
- Intel develop the 8080 processor.

1975
- Mandelbrot plots fractals
- Bill Gates starts Microsoft

1976
- Steve Jobs and Steve Wozniak start Apple.

1977
- Academy of Motion Pictures Art and Sciences introduces Visual Effects category for Oscars.
- Star Wars wins Oscar for special effects.
- Superman wins Oscar for special effects.

1979
- Alien wins Oscar for visual effects.

1980
- The Empire Strikes Back wins Oscar for visual effects.
1980
- Disney’s TRON is the first live action film with over 20 mins of computer animations.
- Seagate Technology releases the HDD for PCs.

1981
- IBM introduces the first IBM PC (16 bit 8088 chip)
  - Raiders of the Lost Ark wins an oscar for visual effects.

1982
- The Genesis Effect (ILM) for Star Trek II is the first all computer animated visual effects shot for film.

1983
- First Coke Polar Bears Commercial

1984
- PIXAR Opens

1985
- The Last Starfighter is the first live action feature film with realistic computer animation of highly detailed models.
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1989
- The Abyss is the first movie to include convincing 3D character animation.

1990
- Windows 3.0 ships

1993
- Myst

1994
- Playstation and N64 released

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1995
- Quake Released by Id Software
- The first fully 3D computer animation feature film is released.
  - Can you remember what it was?
  - Toy Story

1996
- Independence Day wins Oscar for visual effects.

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1997
- Titanic wins Oscar for visual effects.
- Pixar wins Oscar for best short film: Geri’s Game

1998
- Armageddon
- Mouse Hunt
- Bugs Life

1999
- The Matrix
- Star Wars: The Phantom Menace
- Disney’s Tarzan
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2000
- Sony Playstation II
- Walking with Dinosaurs

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2002
- Microsoft's XBOX

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2002
- Academy of Motion Pictures introduces a category for BEST ANIMATED FEATURE.
- ...and the winner was...
  - Shrek!!

Medicine

- Bimaxillary Osteotomy

Simulation/Training

- Flight

Simulation/Training

- Haul Truck Driving
Polylines

A polyline is a connected sequence of straight lines.

Polylines (2)

- 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 (3)

- Simplest polyline: a single straight line segment.
  - A line segment is specified by its two endpoints, say \((x_1, y_1)\) and \((x_2, y_2)\). A drawing routine for a line might look like `drawLine(x1, y1, x2, y2);`
- Dot: `drawDot(x1, y1);`

Polylines (4)

- 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 (5)

- A polygon has its first and last points connected by an edge.
- If no two edges cross, the polygon is called simple. Only A) and D) are simple.
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 (2)

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

Text

Text is the written form of language.

Textual symbols are represented on the computer screen as characters.

Raster Image

A raster image is a picture made up of pixels of differing shades and colours.

Raster Image

A raster image is stored in a computer as an array of numerical values.

The array is known as a pixel map or bitmap.

Raster Image

3 Principal Sources of raster images:

1. Hand-Designed Images
2. Computed Images
3. Scanned Images
Raster Graphics

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

Raster Graphics cont’d

- A raster image is made up of many small cells (pixels, for “picture elements”), in different shades of gray. (Right: magnified image showing pixels.)

Raster Graphics cont’d

- Allows us to go from lines and wireframe images to filled polygons

Raster Images

- Common in Computer Graphics
  - incorporate images in scenes (texture mapping)
  - result of generated scene
- Bi-level image
  - pixels can have one of two values (0 and 1)
  - requires one bit to represent the intensity of each pixel
    - 0: no intensity (black)
    - 1: full intensity (white)

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.

A Bilevel Image and its Bitmap
Pixmaps and Bitmaps Example

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

```
2 2 2 2 2 2 2
2 2 2 2 2 2 7
2 2 2 2 7 7 7
2 2 2 2 7 1 1
2 2 2 7 1 1 1
2 2 2 7 1 1 7
```

Creating Pixmaps and Bitmaps

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

Grayscale Images

• 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.

Gray-scale Images

• Quantization
  – number of bits representing gray-scale values
  – more bits
    • more gray-scale values
    • higher gray-scale resolution
    • larger image size
  – useful in examining pixels within different
    ranges, so called window and level

Pixel/Colour Depth

Number of bits used to represent the colour/shade of each pixel.

- 4 bits/pixel = 16 levels of grey
**Reduced Image to 6 bits/pixel and 5 bits/pixel**
(pixel value 01110100 is replaced with 0111)

**The Image Reduced to 4 bits/pixel and to 3 bits/pixel**

**The Image Reduced to 2 bits/pixel and 1 bit/pixel**

**Grayscale Image Example**

- 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.

**Pixel/Colour Depth**

Number of bits used to represent the colour/shade of each pixel.

- One bit/pixel = 2 grey/colour levels
- Two bits/pixel = 4 grey/colour levels
- Four bits/pixel = 16 grey/colour levels
- Eight bits/pixel = 256 grey/colour levels

**Color Images**

- Pixel value represents a color, RGB and Color Index (color lookup table)
  - RGB: each pixel is an ordered triple representing the intensity (amount) of red, green, and blue that are summed together (R,G,B)
  - color depth of a pixel is the total number of bits representing red, green, and blue
  - **true-color** images have a depth of 24 bits
    - 8-bits per color
Color Images

- 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.

<table>
<thead>
<tr>
<th>color value</th>
<th>displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,0,0</td>
<td>black</td>
</tr>
<tr>
<td>0,0,1</td>
<td>blue</td>
</tr>
<tr>
<td>0,1,0</td>
<td>green</td>
</tr>
<tr>
<td>0,1,1</td>
<td>cyan</td>
</tr>
<tr>
<td>1,0,0</td>
<td>red</td>
</tr>
<tr>
<td>1,0,1</td>
<td>magenta</td>
</tr>
<tr>
<td>1,1,0</td>
<td>yellow</td>
</tr>
<tr>
<td>1,1,1</td>
<td>white</td>
</tr>
</tbody>
</table>

Graphic Display Devices

- Line Drawing Displays
  - Pen Plotter
  - Flatbed plotters
  - Drum plotters
  - Video Displays
  - Vector Displays

- Raster Displays
  - Video Displays (Cathod-Ray Tube CRT)
  - Flat Panel Displays (LCD & Plasma)
  - Hard Copy
    - Laser Printers
    - Dot Matrix Printers
    - Ink-Jet Printers

Graphics Display Devices

- Graphics displays are either line-drawing devices or raster displays.
- Line-drawing devices:
  - Pen plotter, which moves an ink pen across a (large) sheet of paper. (E.g., seismic wave plotters.)
  - Vector video device, which moves a beam of electrons across the screen from any one point to any other point, leaving a glowing trail.

Raster Display

- Display Surface
  - Image is represented by pixels
  - Display Capture is stored in a frame buffer
  - Pixel value stored in the frame buffer is used to colour a spot on the display surface.
- Scan Process
  - Cathod Ray Tube (CRT)
Graphical Models. Raster Graphics

- Raster: the images are represented as matrices of colored points (pixels).
- Modern monitors, printers

Graphics Display Devices cont’d

- Raster displays:
  - Computer monitor: moves a beam of electrons across the screen from left to right and top to bottom.
  - Printer: does the same thing with ink or toner.
  - Coordinate system used:

Graphics Display Devices cont’d

- 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 onboard the display or in the host computer.
  - Alternatively, a graphics card installed in a personal computer might house the frame buffer.

Raster Displays

- Graphics systems produce raster images primarily because they will be displayed with a raster display
  - common display device on computers
- display surface composed of pixels
  - 480 rows, each containing 640 pixels for a total of 307,000 pixels
  - 1024 rows, each containing 1280 pixels for a total of 1,310,720 pixels

Raster Displays

- More pixels representing a given size screen
  - higher resolution
  - larger amount of memory representing a scene
- built in coordinate system
  - relates a given pixel to a physical location on the screen

Frame buffer

- memory containing pixel and other values
- frame buffer commonly part of the graphics card
- frame buffer must be connected to the raster display device (monitor)
- pixel values are related to displayed intensity
**Display Scanning**

- **Frame Buffer**
  - 2 dimensional matrix
  - Each cell of the matrix represents a pixel on the display
  - The matrix needs to be of sufficient size to hold the colour depth of the display across all pixels.
  - \( Fb[x][y] \) has the colour for pixel \( x, y \)
  - E.g. A display 1024 x 1280 with a colour depth of 24 bits (~16 million colours) needs storage space of around 4 Mb.

- **Frame Buffer with Look-up Table (LUT)**
  - Frame buffer stores index values of colours in a look up table.
  - LUT stores all colours in an array LUT[0]..LUT[63].
  - LUT for 24 bit colour depth requires on 768 bytes of memory (256 for each red, green and blue).
  - Frame buffer can then be smaller. E.g. only has to store an index into the LUT in the 2d matrix.
  - However as the frame buffer becomes smaller not all colours in the LUT can be displayed all the time.

**Scan Converter**

- changes digital pixel values to an analog voltage (intensity) values
- converts memory address into a physical location on the display screen

**Graphics Display Devices**

- Each instruction of the graphics program (stored in system memory) is executed by the central processing unit (CPU), storing 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**

- CPU
- System memory
- Frame buffer
- Converter
- Display surface
**Function of Scan Controller**

A scan controller connects the CPU, system memory, frame buffer, and display surface. The system bus facilitates communication between these components.

**Graphics Display Device Operation**

The scan controller receives logical addresses and converts pixel values to geometric positions on the display surface. The process is repeated 60 times each second to prevent flicker.

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**Video Monitor Operation**

- Based on cathode ray tube (CRT).

  - The digital frame buffer value is converted to an analog voltage for each of R, G, and B by the DAC. Electron guns for each color are deflected to the appropriate screen location.
  - The process is repeated 60 times each second to prevent flicker.

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**Flat Panel Displays**

- Flat panel displays: use a mesh of wires to set color of a pixel.

**Hard Copy Raster Devices**

- In graphics, to reproduce a scene with colors we want a color laser or inkjet printer.
- Printers equipped to use PostScript (a page description language) can generate high quality text and graphics on a printed page.
- A **film recorder** uses a strip of photographic film, exposed by the electron beam as it sweeps over it (once) in a raster pattern. Film recorders are frequently used to make high-quality 35-mm slides, or movies.
Graphics Input Devices

• **Keyboard**: strings of characters;
  – Some keyboards have cursor keys or function keys, which can be used to produce pick input primitives.
• **Buttons**: Sometimes a separate bank of buttons is installed on a workstation. The user presses one of the buttons to perform a pick input function.

Graphics Input Devices

• **Mouse**: changes in position.
  • Software keeps track of the mouse's position and moves a **graphics cursor** — a small dot or cross — on the screen accordingly.
  • The mouse is most often used to perform a locate function. There are usually buttons on the mouse that the user can press to trigger the action.

Graphics Input Devices

• **Tablet**: locate input primitives. A **tablet** provides an area on which the user can slide a stylus. The tip of the stylus contains a micro switch. By pressing down on the stylus the user can trigger the locate.

Graphics Input Devices

• **Joystick and Trackball**: locate and valuator devices.

3-D Graphics Input Devices

• A laser beam scans over the solid object in an x, y raster pattern, measuring the distance between the image capture device and the object.

3-D Graphics Input Devices

• Capturing motion: a device that can track the position of many points on a moving body in real-time, saving the motion for animation or data analysis.