Computer Graphics: A Brief History....
A Brief History of Computer Graphics

1885 - CRT (Cathode Ray Tube)
A Brief History of Computer Graphics

1887 - Edison patents motion picture camera

1888 - Edison and Dickson record motion picture photos on a wax cylinder
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1926 – J.L. Baird invents the television.

30 line vertical, black and red scan.
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Whirlwind: early graphics using VectorScope (1951)

first CAD system (IBM 1959)
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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)
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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.
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1966

- Ralph Baer creates the 1st consumer CG product: Odyssey Pinball
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1967

GE introduces first full colour real time flight simulator for NASA
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

MSP430
Pong
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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.
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1974

- Intel develop the 8080 processor.

1975

- **Mandelbrot** plots fractals

- Bill Gates starts Microsoft
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1976
- Steve Jobs and Steve Wozniak start Apple.

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

1978
- Superman wins Oscar for special effects.
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1979
- Alien wins oscar for visual effects.

1980
- The Empire Strikes Back wins oscar for visual effects.
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1980

- Disney’s TRON is the first live action film with over 20 mins of computer animations.
- Seagate Technology releases the HDD for PCs
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1981

IBM introduces the first IBM PC (16 bit 8088 chip)

- Raiders of the Lost Ark wins an oscar for visual effects.
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1982

The Genesis Effect (ILM) for Startrek II is the first all computer animated visual effects shot for film.
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1983

- First Coke Polar Bears Commercial
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1984

• Pixar Opens
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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.
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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
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1996

Indepedence 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.
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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

5DT
Fifth Dimension Technologies
www.5DT.com
Picture Elements

- Points
- Polylines
- Text
- Filled Regions
- Raster Images

**Attributes**: how an output primitive appears; e.g., color and thickness
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: \((x_0, y_0), (x_1, y_1), (x_2, y_2), 
\ldots, (x_n, y_n)\).
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.
A raster image is a picture made up of pixels of differing shades and colours.
A raster image is stored in a computer as an array of numerical values.

The array is known as a pixel map or bitmap.
3 Principal Sources of raster images:

1. Hand-Designed Images
   ![Hand-Designed Image](image1.png)

2. Computed Images
   ![Computed Image](image2.png)

3. Scanned Images
   ![Scanned Image](image3.png)
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 wire frame 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

a). 

b).

```
1 0 0 0 0 0 0 0
1 1 0 0 0 0 0 0
1 1 1 0 0 0 0 0
1 1 1 1 0 0 0 0
1 1 1 1 1 0 0 0
1 1 1 1 1 1 1 0
1 1 1 1 1 1 1 1
1 1 1 1 1 0 0 0
1 0 1 1 1 0 0 0
1 0 0 0 1 1 0 0
0 0 0 0 1 1 0 0
0 0 0 0 0 1 1 0
0 0 0 0 0 0 1 1
0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
```
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

- 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

- pixels can have more than two values
- classified by the number of bits needed to represent a pixel intensity level, **pixel depth** or number of **quantization** levels
- bits have possible gray levels
  - 2 bits/pixel = 4 gray levels
  - 4 bits/pixel = 16 gray levels
  - 8 bits/pixel = 256 gray levels
- 8 bit gray-scale images are common
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.
A Common Correspondence Between Color Value and Perceived Color

<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
• 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 Displays

- Video Displays (Cathod-Ray Tube CRT)
- Flat Panel Displays (LCD & Plasma)
- Hard Copy
  - Laser Printers
  - Dot Matrix Printers
  - Ink-Jet Printers
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:
• 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.
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
frame buffer

- Graphics program executes in CPU, filling the frame buffer with values to display
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.
Display Scanning

**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 $\text{LUT}[0]..\text{LUT}[63]$.
- 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
- System bus
- Scan controller
Function of Scan Controller

- CPU
- System memory
- Frame buffer
- Scan controller
- Converter
- Display surface
- System bus
Graphics Display Device Operation

- **Frame Buffer**: Pixel at address \([x, y]\) at (639, 0) and (639, 479).
- **Scan Controller**: Logical address to geometric position.
- **Display Surface**: Spot at \((x, y)\) at x = 639, y = 479.
- **Convert Pixel Value to Color**: Frame buffer to display surface.
Video Monitor Operation

- Based on cathode ray tube (CRT).

[Diagram showing a cathode ray tube with labels for scan controller, DAC's, red, green, blue, electron beam guns, deflection coils, frame buffer (6 planes), pixel value, spot, x, y.]
Video Monitor Operation

- 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.
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.