Introduction

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Computer Graphics

- Computer Graphics is the process of rendering static images or animation on computer screen in an efficient way.
- Images includes text and other types of data.
- Images including characters are objects with some geometric shapes and colors.
- Each object is render on the screen with different style and size.

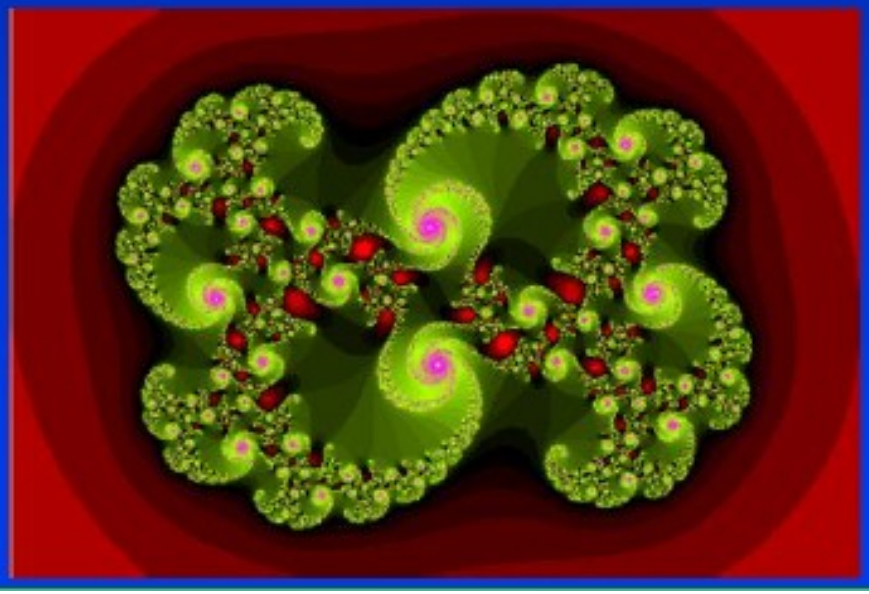
What is Computer Graphics?

- The creation of, manipulation of, analysis of, and interaction with pictorial representations of objects and data using computers.

  - Dictionary of Computing

- A picture is worth a thousand words.

  - Chinese Proverb



1000 words (or just 94 words), many letters though…

It looks like a swirl. There are smaller swirls at the edges. It has different shades of red at the outside, and is mostly green at the inside. The smaller swirls have purple highlights. The green has also different shades. Each small swirl is composed of even smaller ones. The swirls go clockwise. Inside the object, there are also red highlights. Those have different shades of red also. The green shades vary in a fan, while the purple ones are more uni-color. The green shades get darker towards the outside of the fan …

Why Computer Graphics?

- About 50% of the brain neurons are associated with vision
- Dominant form of computer output
- Enable scientists (also engineers, physicians, and general users) to observe their simulation and computation
- Enable them to describe, explore, and summarize their datasets (models) and gain insights
- Enrich the discovery process and facilitate new inventions

Why Computer Graphics?

- Applications (In essence, computer graphics is application-driven)
  - Entertainment: Movies, Video games
  - Graphical user interface (GUI)
  - Computer aided design and manufacturing (CAD/CAM)
  - Engineering analysis and business
  - Medical applications
  - Computer Art
  - Engineering Analysis
  - Scientific visualization / simulation
  - Virtual Reality

Movies

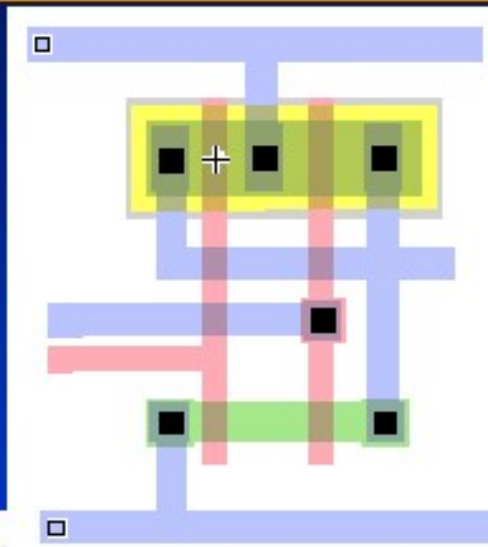
- If you can image it, it can be done with computer graphics!
- More than one billion dollars on special effects.
- No end in sight for this trend!

Video Games

- Important driving force
- Focus on interactivity
- Try to avoid computation and use various tricks

Computer-Aided Design

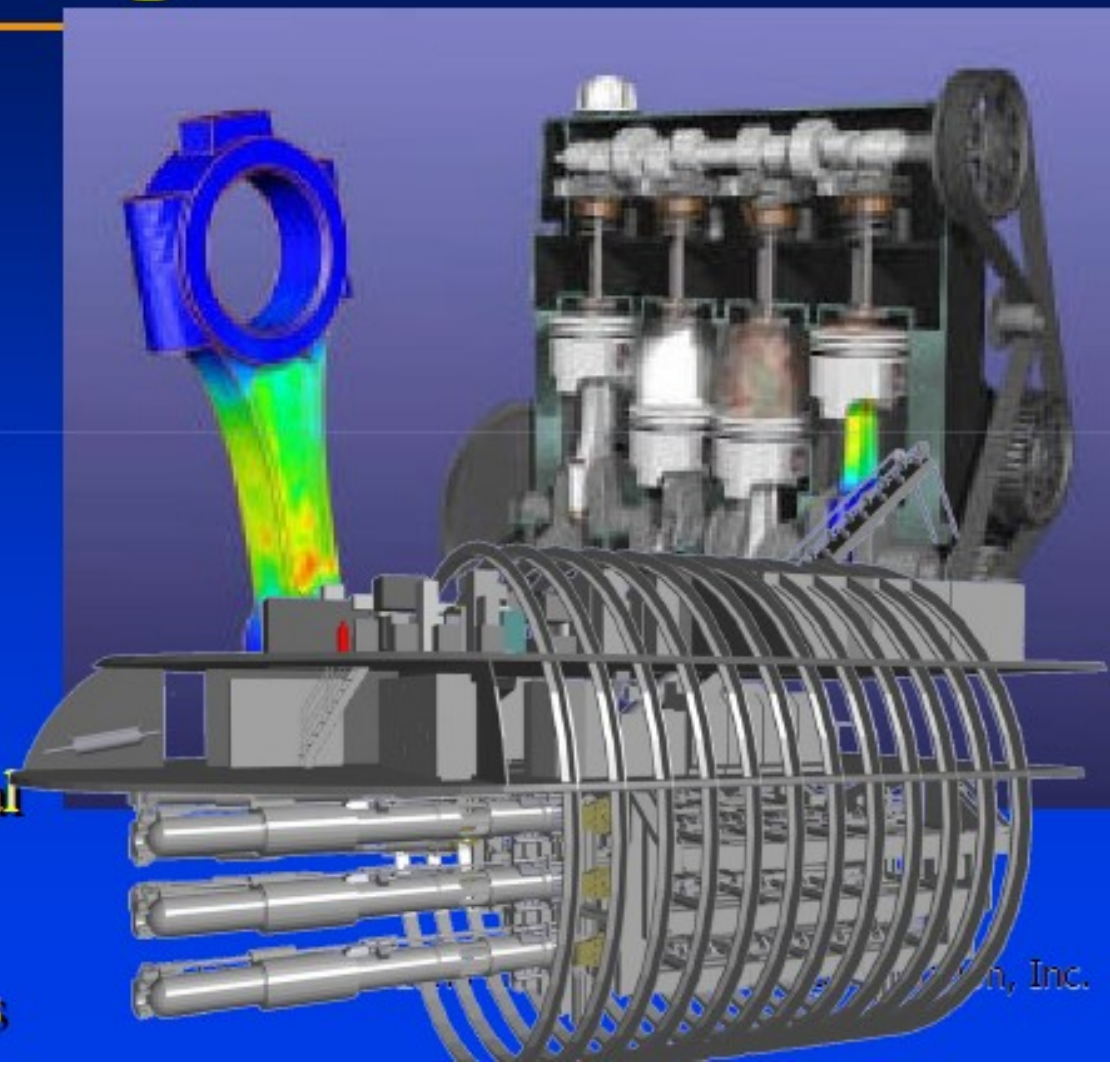
- Significant impact on the design process
- Mechanical, electronic design
  - entirely on computer
- Architectural and product design
  - Migrate to the computer



UGS: towards virtual manufacturing

Engineering Design

- Engineering & Architecture Software
- Buildings, aircraft, automobile, computers, appliances, etc.
- Interactive design (mesh editing, wire-frame display, etc.)
- Standard shape database
- Design of structural component through numerical simulation of the physical operating environment
- Testing: real-time animations

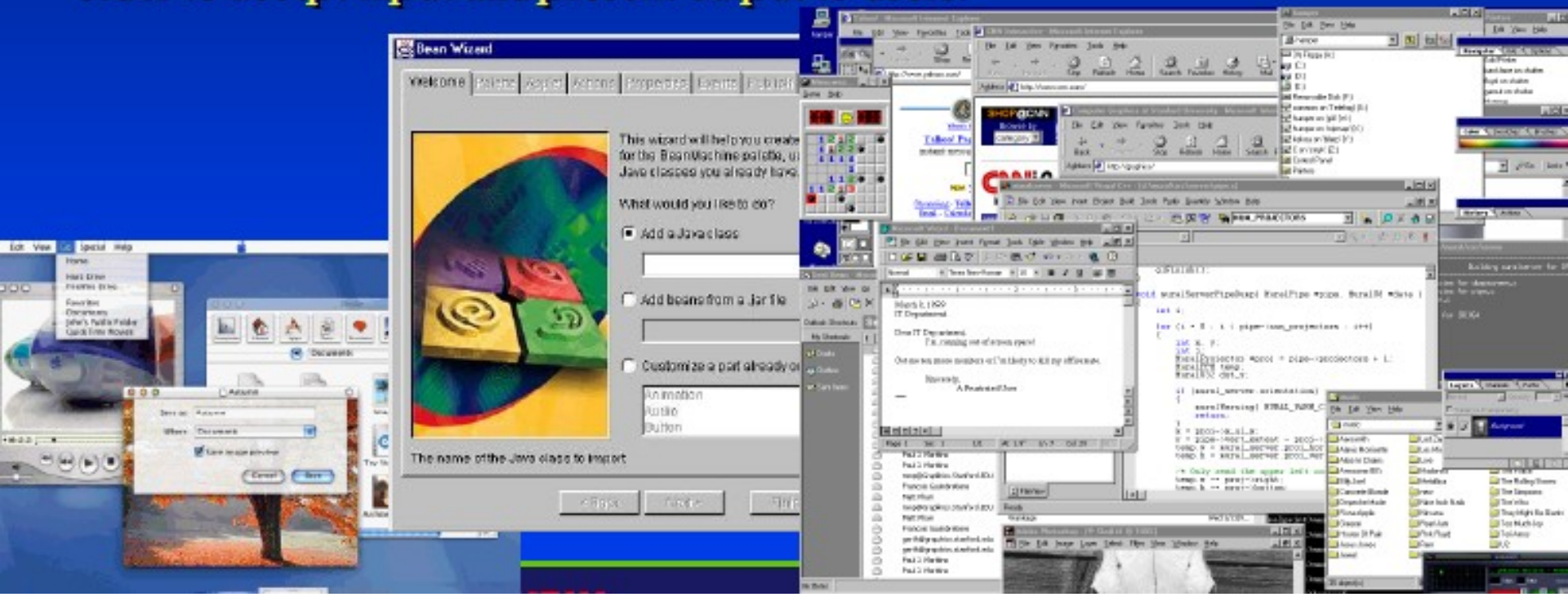


Textile Industry

- Fashion design
- Real-time cloth animation
- Web-based virtual try-on applications

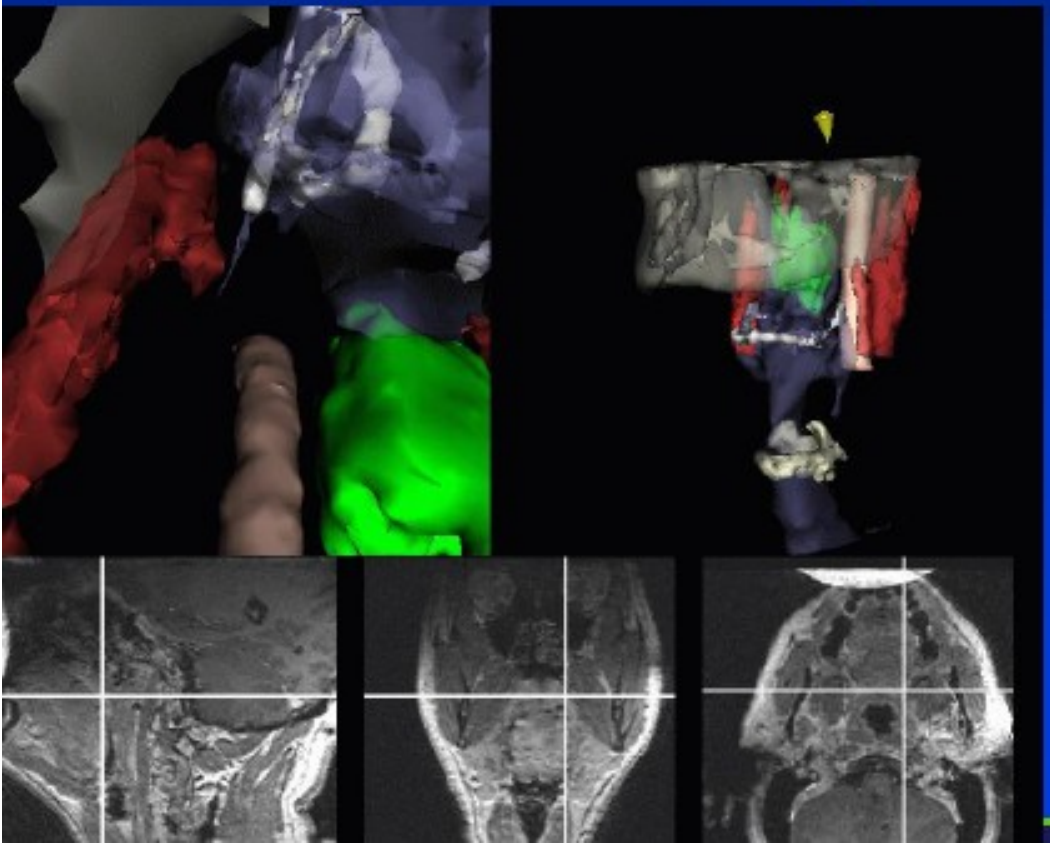
Graphical User Interface: GUI

- Integral part of everyday computing
- Graphical elements everywhere
  - Windows, cursors, menus, icons, etc.
- Nearly all professional programmers must have an understanding of graphics in order to accept input and present output to users.



Medical Applications

- Significant role in saving lives
- Training, education, diagnosis, treatment

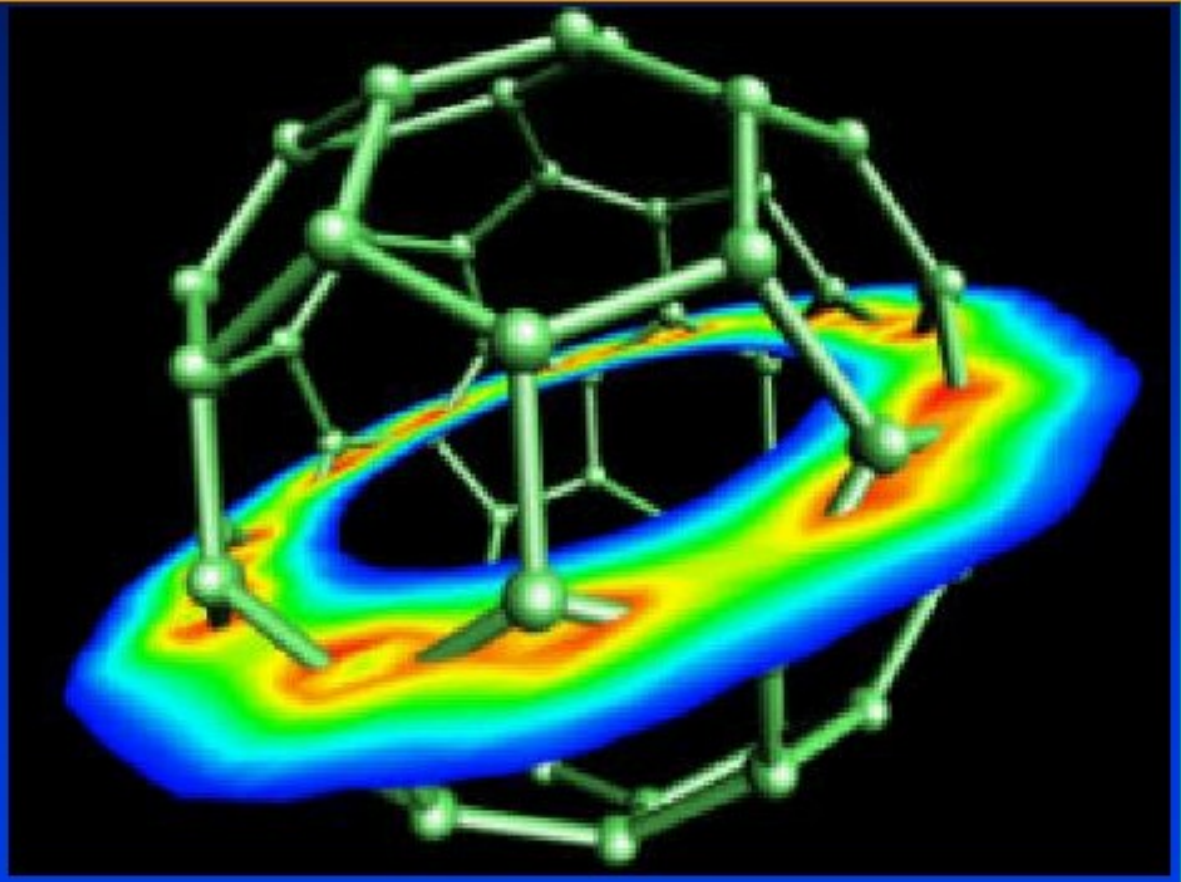


The Visible Human Project

Creation of complete, anatomically detailed 3D representation of human bodies.

Scientific Visualization

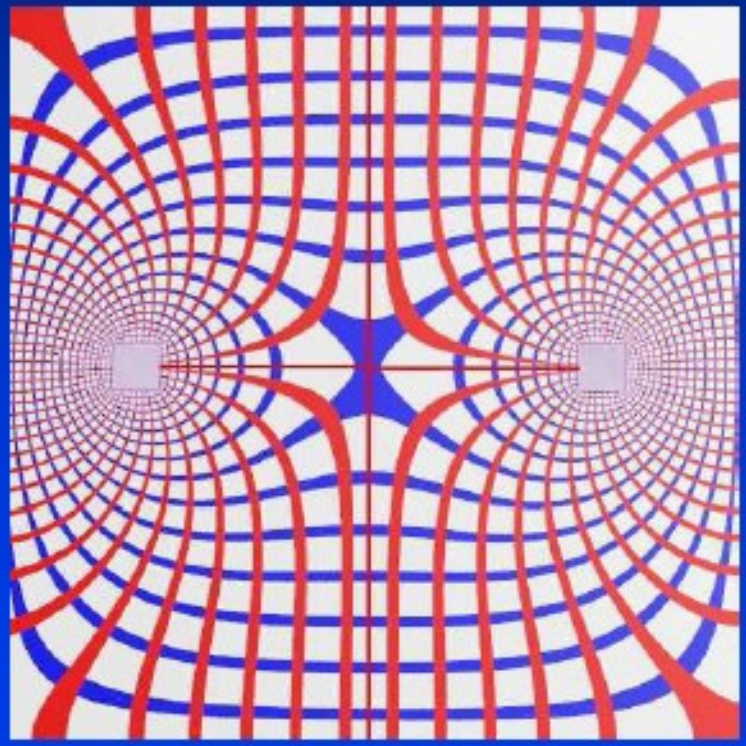
- Scientific data representation
- Picture vs. stream of numbers
- Techniques: contour plots, color coding, constant value surface rendering, custom shapes



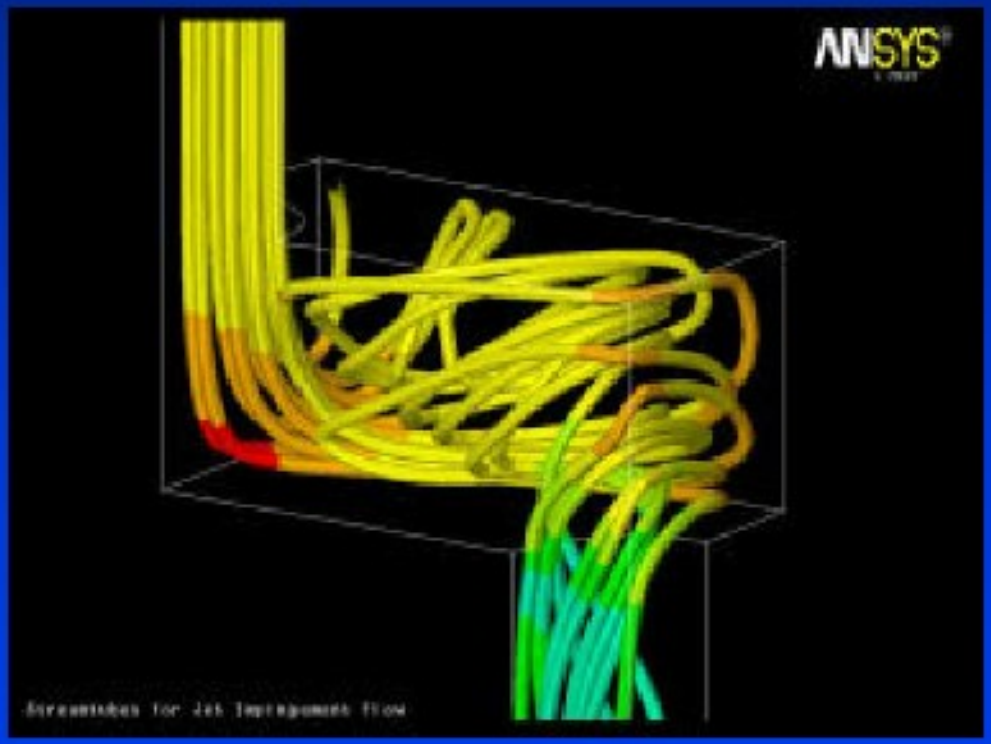
Display of a 2D slice through the total electron density of C-60; Created by Cary Sandvig of SGI

Scientific Visualization / Simulation

Electromagnetic potential field



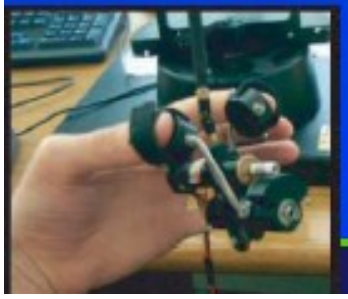
Computational Fluid Dynamics (CFD)



Virtual Reality

- User interacts with objects in a 3D scene
- Special devices (input, output)
- Virtual walkthroughs
- Equipment training (pilots, surgeons, etc.)

orce reflecting gripper



Haptic devices

Force feedback exoskeleton

Haptic workstation

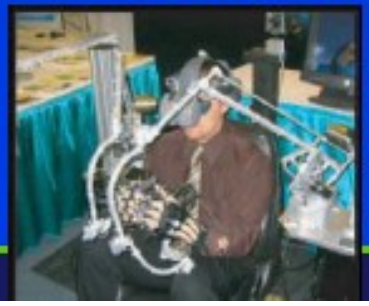
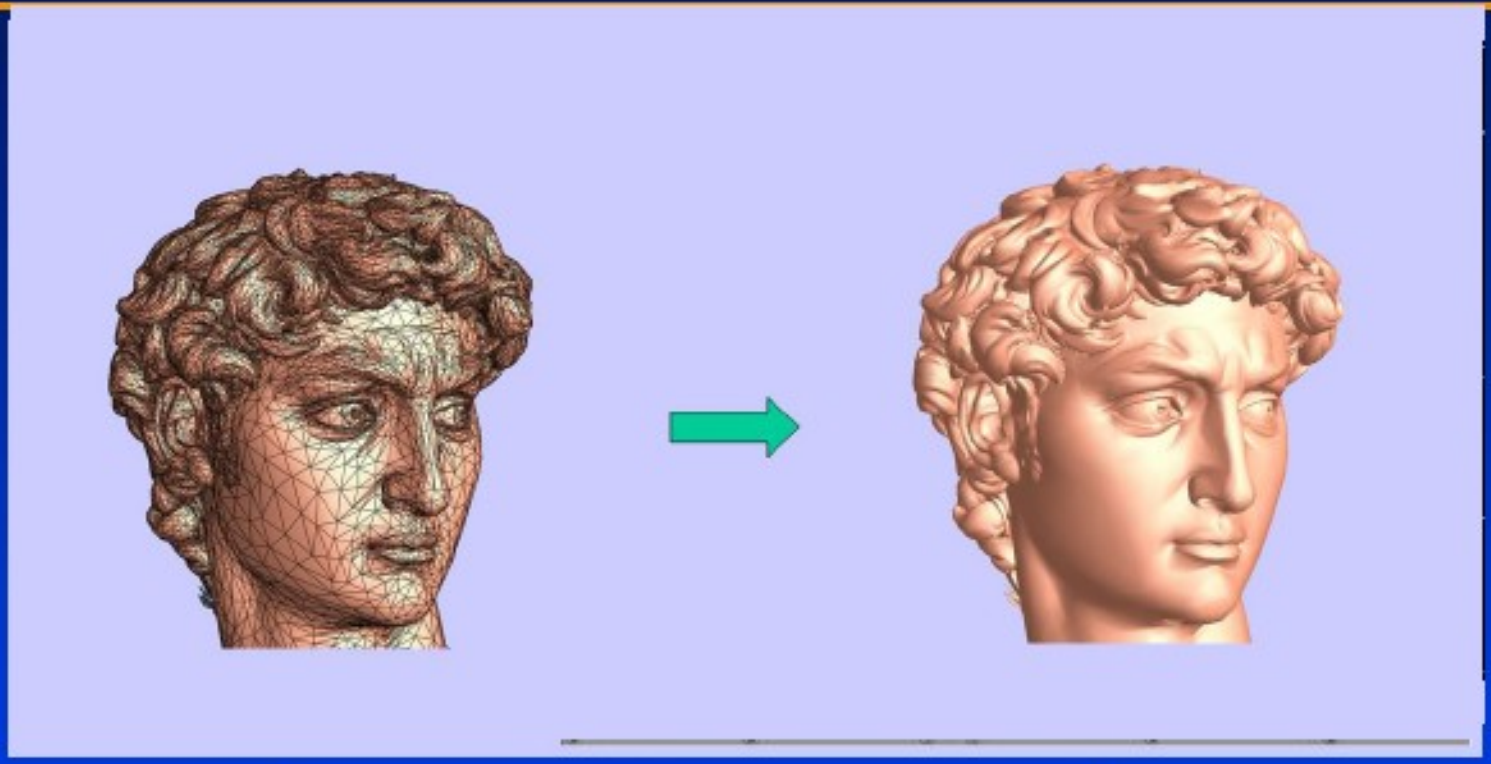
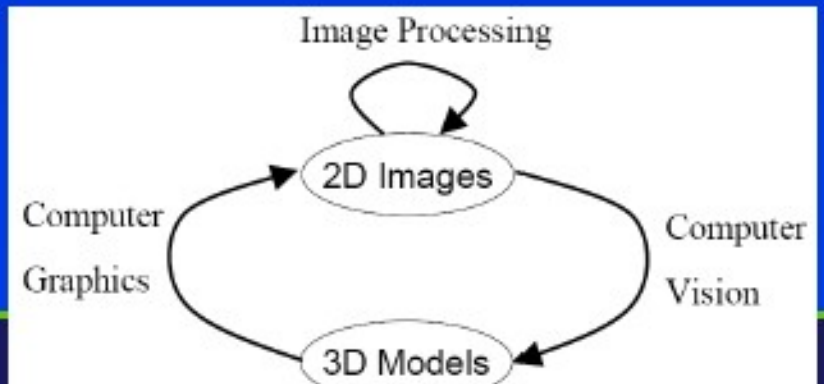


Image Processing, Analysis, and Synthesis



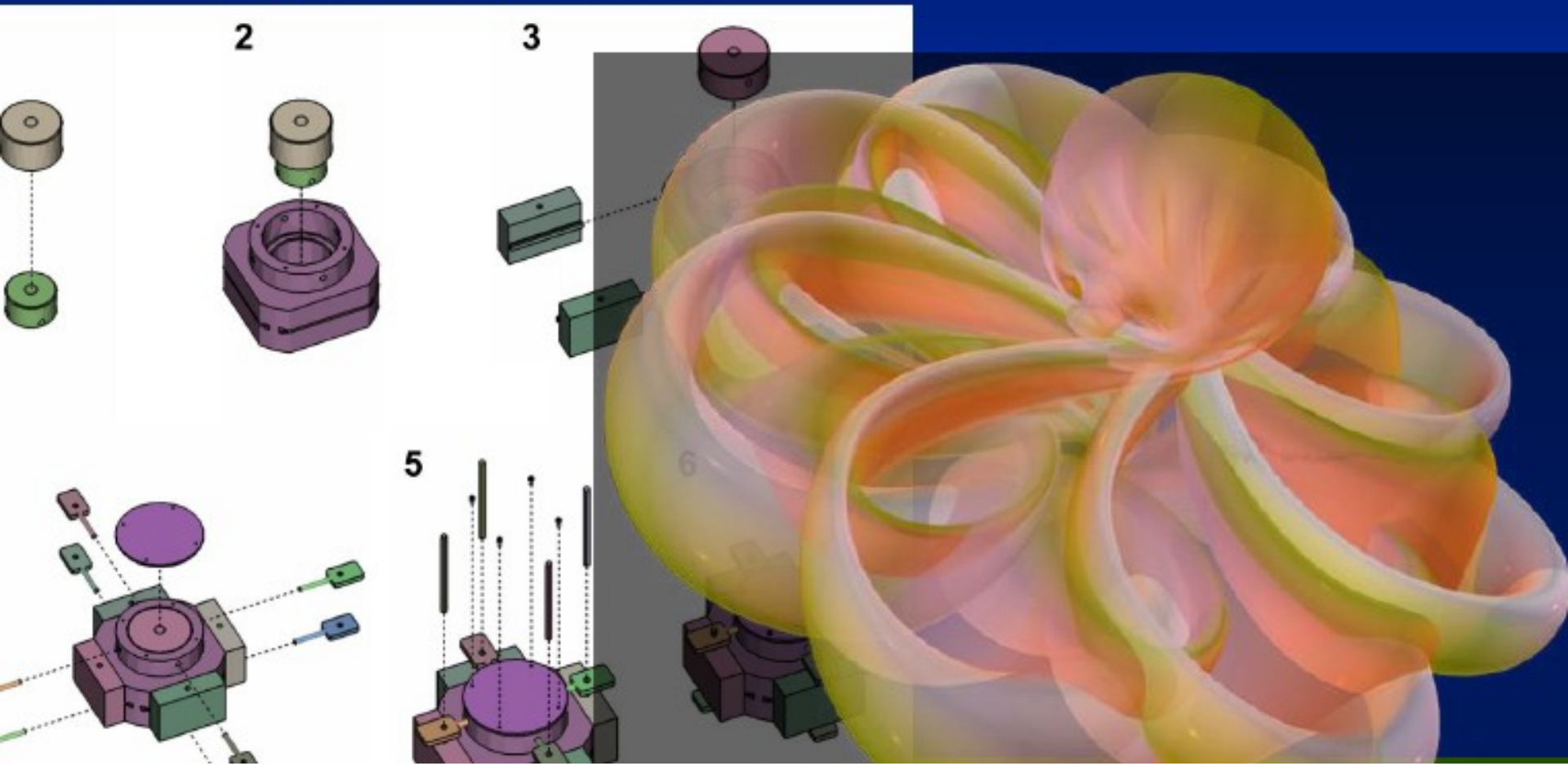


Computer Art

- Digital Sculpting

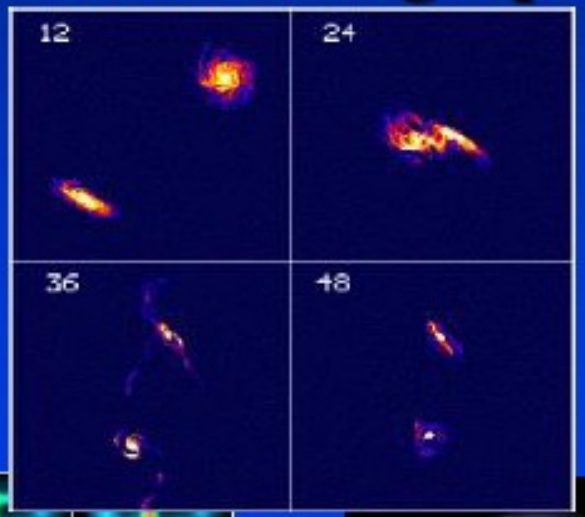
Graphics Applications

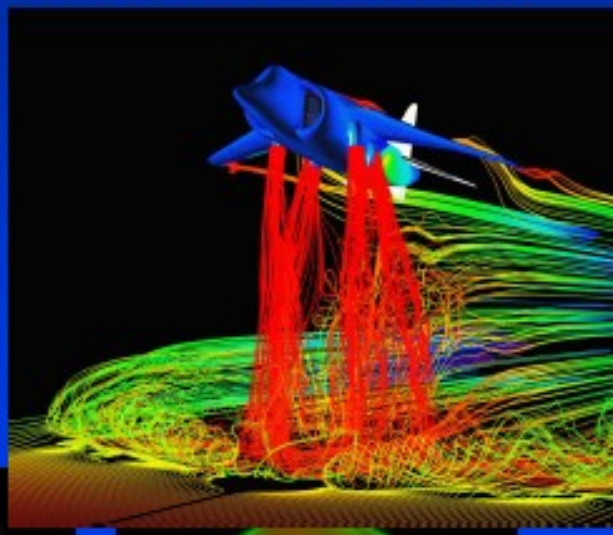
- Training and education

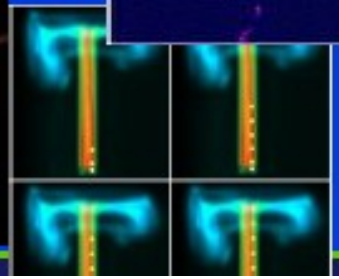


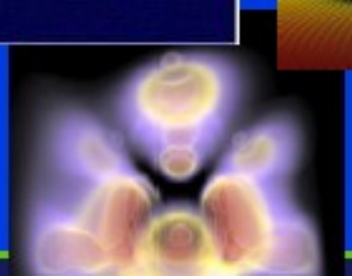
Why Visualization

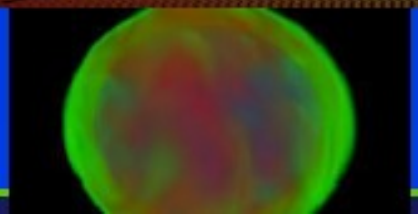
Visualization is a method of extracting meaningful information from complex or voluminous datasets through the use of interactive graphics and imaging











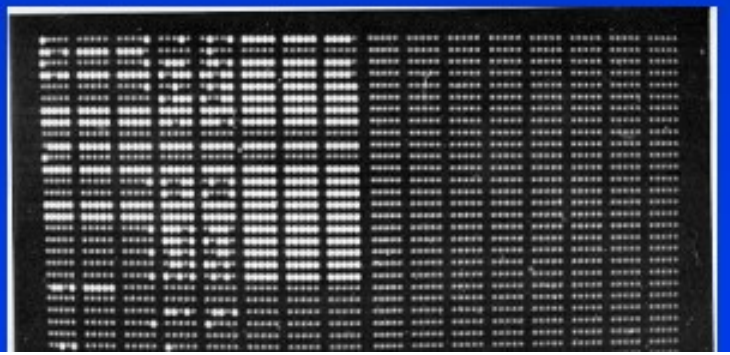
Why Visualization

- Enable scientists (also engineers, physicians, general users) to observe their simulation and computation
- Enable them to describe, explore, and summarize their datasets (models) and gain insights
- Offer a method of SEEING the UNSEEN
- Reason about quantitative information
- Enrich the discovery process and facilitate new inventions

Where Are We Coming From: TEX

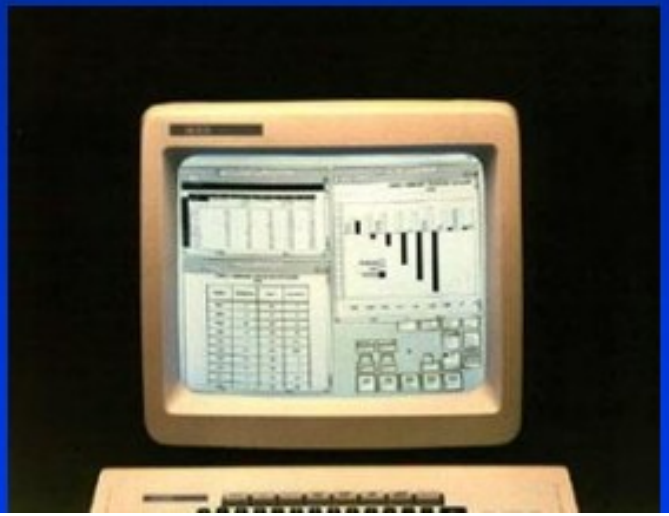
Manchester Mark I

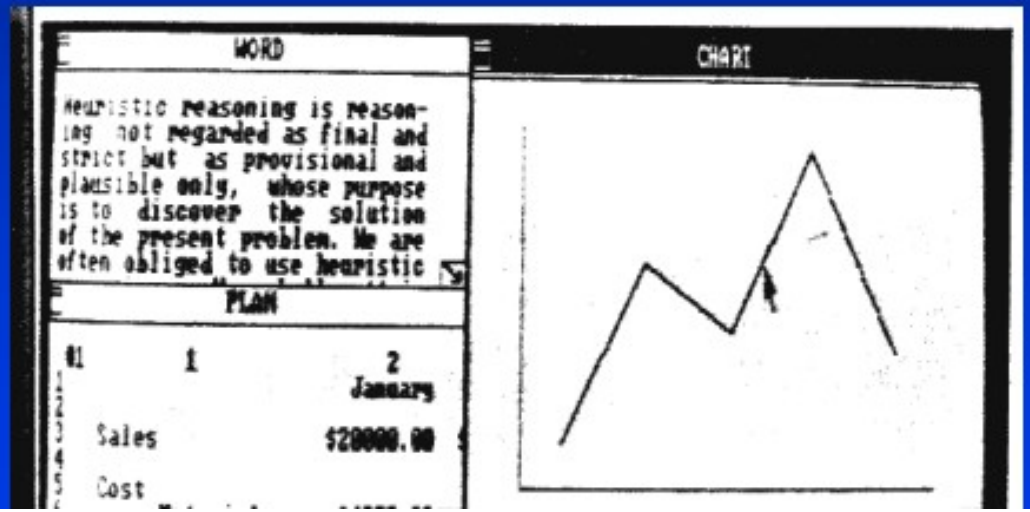
Display →



From Text to GUIs

- Invented at PARC about 1975. Used in the Apple Macintosh, and now prevalent everywhere.





Display Hardware

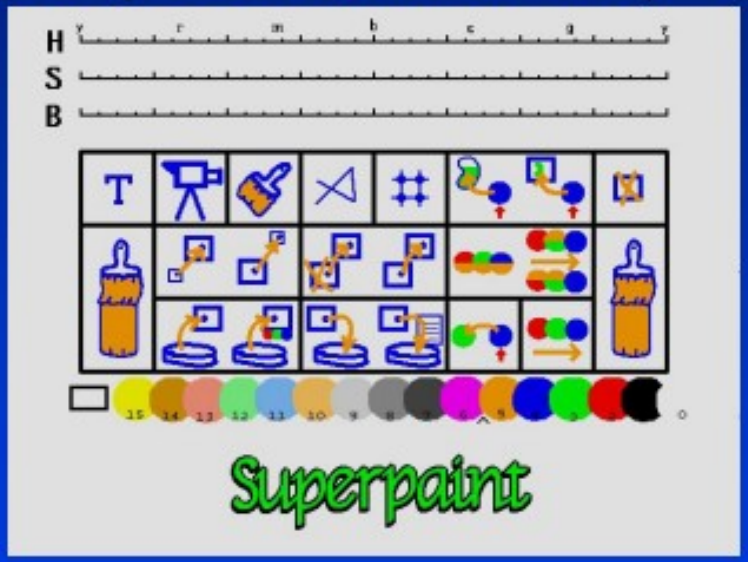
- Vector displays
  - 1963 – modified oscilloscope
  - 1974 – Evans and Sutherland Picture System

Ivan Sutherland (1963) – SKETCHPAD Drawing

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system
- Many of concepts for drawing in current systems
  - Pop-up menus
  - Constraint-based drawing
  - Hierarchical modeling

Paint Systems

- SuperPaint system: Richard Shoup, Alvy Ray Smith (PARC, 1973-79)



- Nowadays, image processing programs like Photoshop can draw, paint, edit, etc.

Image Processing

- Digitally alter images, crop, scale, composite
- Add or remove objects
- Sports broadcasts for TV (combine 2D and 3D processing)

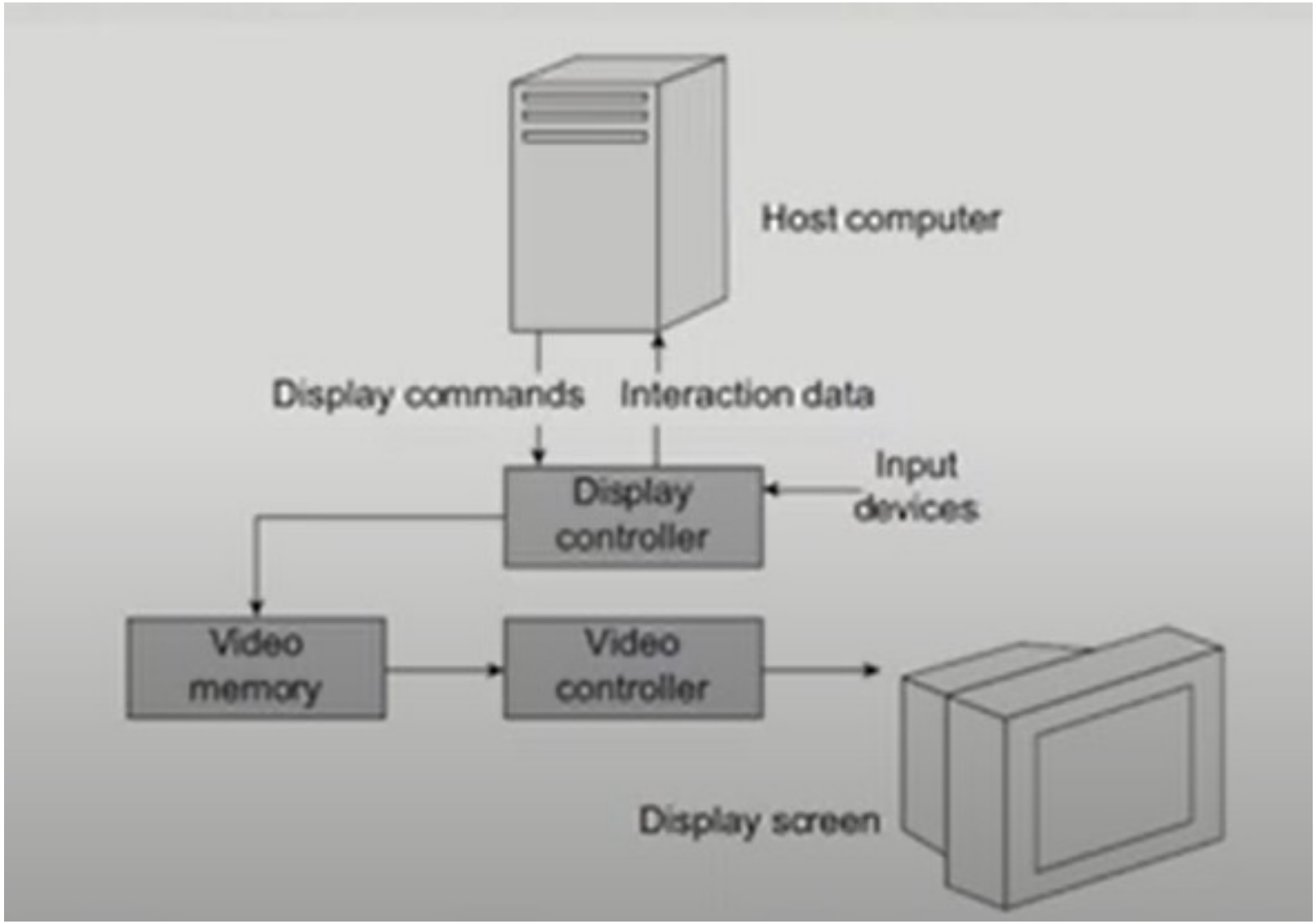
Display Hardware

- Raster displays
  - 1975 – Evans and Sutherland frame buffer
  - 1980s – cheap frame buffers → bit-mapped personal computers
  - 1990s – liquid-crystal displays → laptops
  - 2000s – micro-mirror projectors → digital cinema
- Others
  - stereo, head-mounted displays
  - autostereoscopic displays

Graphics System

- Graphics system is responsible for synthesis and visualization of objects and data.
- It includes display controller, video memory, video controller and display screen.
- All of the graphics system is embedded in graphics card.
- Graphics card is dedicated hardware responsible for synthesis and display of images.
- It takes all the load from CPU for this purpose.

Graphics System



Display Controller

- Takes input from host controller and various input devices.
- Generate image.
- Input devices help us to interact with screen content.
- Image generation is a multi-stage process and takes a lot of computation.
- If it was done by CPU, it will not have time to do other tasks.

Display Controller

- That is why dedicated graphics card is necessary.
- Display unit is the processing unit of graphics card.
- CPU assigns any graphics rendering task to display controller.
- It performs multi-stage operations to synthesize 2D image.

Video Memory

- Display controller generates image in digital format.
- Image generated by display controller is stored in video memory.
- This is also known as VRAM.

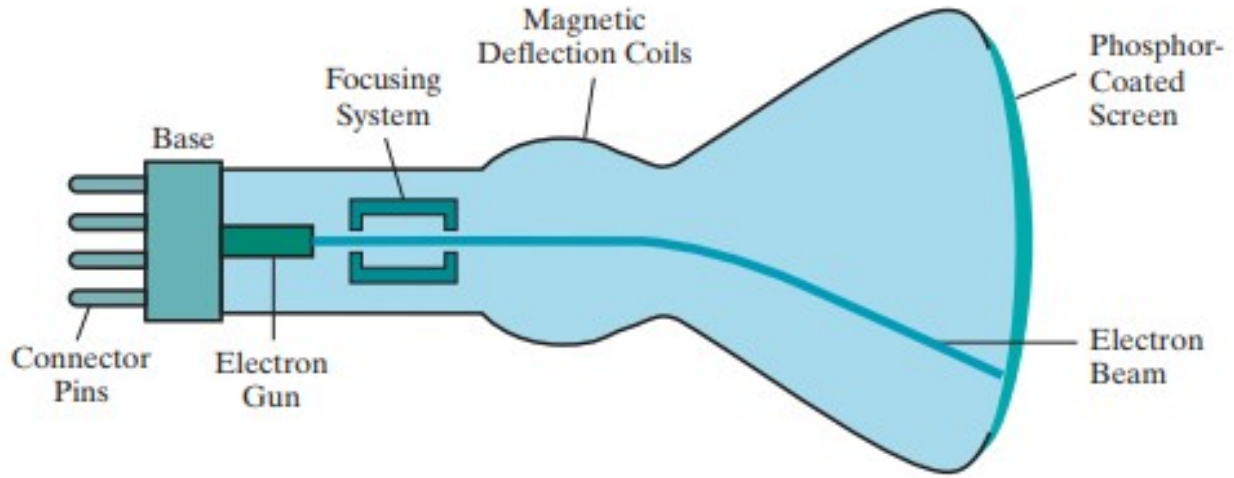
Video Controller

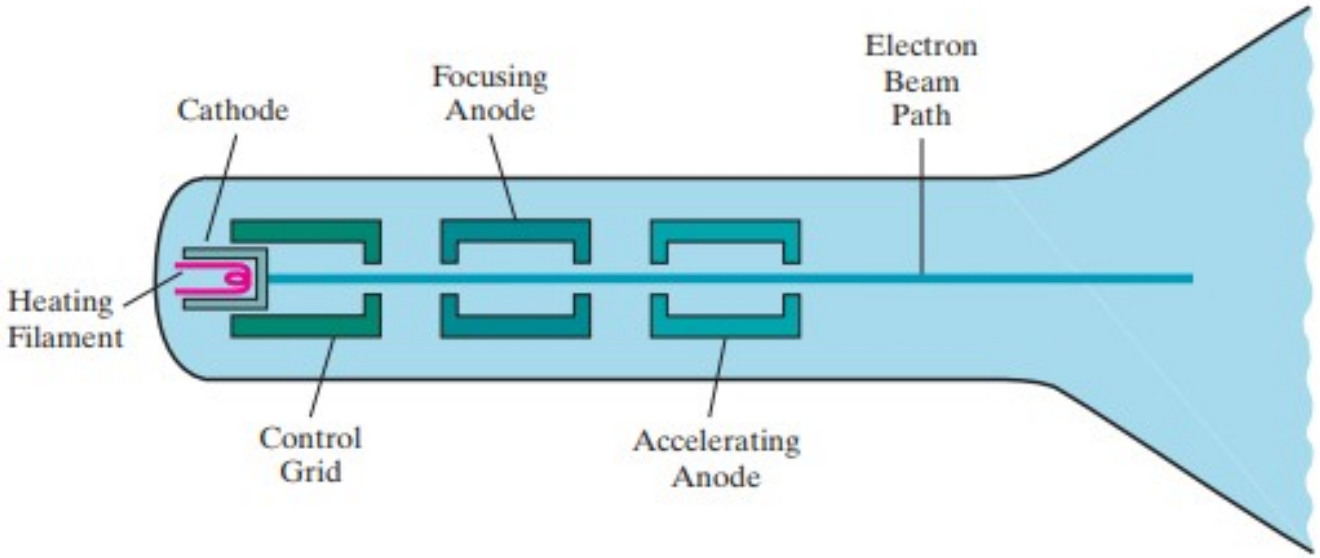
- It converts digital image into analog voltage.
- Screen needs analog voltage to display images.
- Voltage is generated according to 0’s and 1’s stored in video memory.
- It means it activates suitable electro-mechanical mechanism so that pixels on screen emit light.

Output Device : CRT

- Primary output devices in graphics system is monitor.
- CRT is one of the output devices.

Output Device : CRT





CRT

- CRT screen contains pixels of phosphorus.
- Phosphorus can be excited to generate light of different intensities.
- That is different shades of gray.
- CRT consists of heating filament, control grid, focusing anode and accelerating anode.

CRT

- Control grid is negative charged that controls the generation of electrons.
- Focusing anode is positively charged that is used to focus on pixel.
- Accelerating anode is positively charge that is used to accelerate the electronic beam.
- Heating filament heats cathode to generate electrons

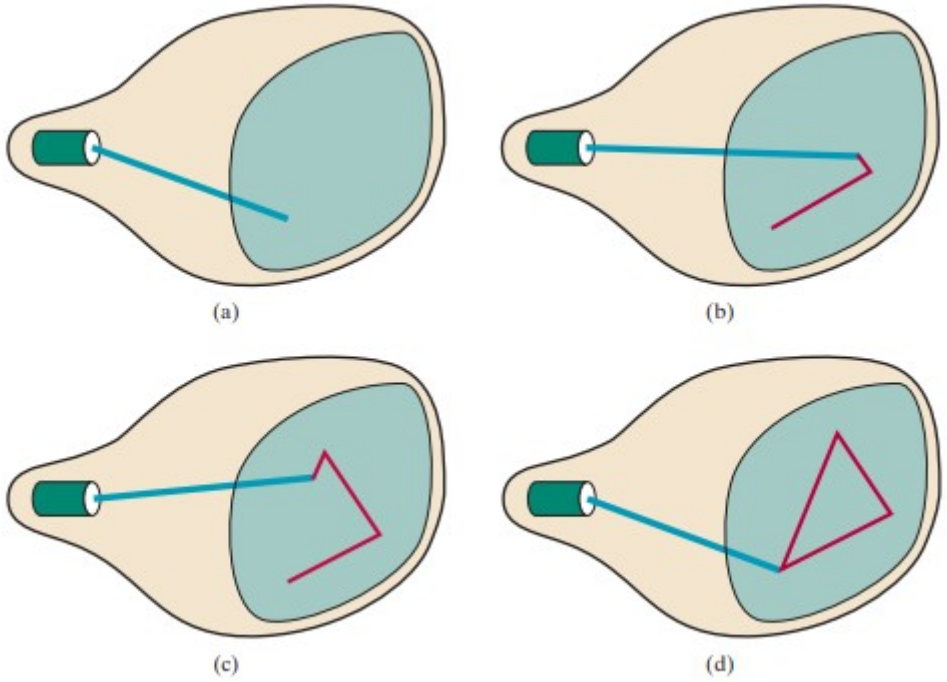
Types of Graphics System

- Based on the method used for excitation of pixels.
- Vector Scan
- Raster Scan

Vector Scan

- Image is composed of continuous geometric primitives such as lines and curves.
- Image is rendered by rendering these primitives.
- A vector scan device excites only those pixels of the grid that are part of these primitives.

Vector Scan



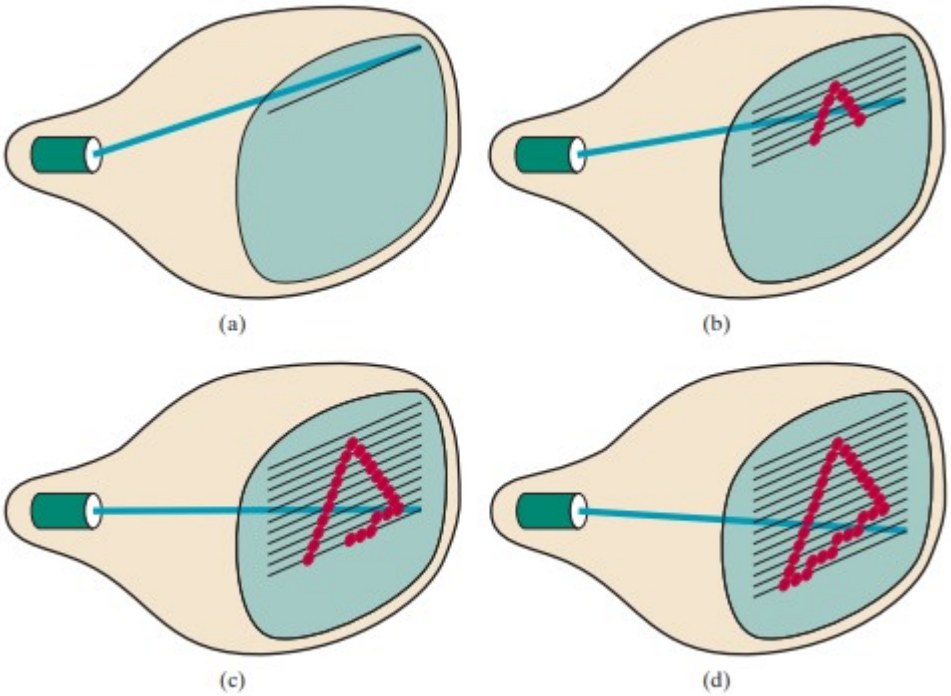
Vector Scan: Pros and Cons

- Excites selected pixels only.
- This requires high precision and complex hardware.
- So, costly.
- For complex scenes, flicker is visible as rendering involves lots of random movement.
- Good for wireframe (outline) images.

Raster Scan

- Image is whole pixel grid.
- To render a raster image, all the pixels are considered.
- All the pixels are scanned from left to right, top to bottom.
- Some pixels are excited and some are left according to image.
- Each row in the pixel grid is called scanning line.

Raster Scan



Raster Scan : Frame Buffer

- Video memory is called frame buffer in case of raster scan.
- Contains pixels equal to the screen resolution.
- Display processor works at the speed of CPU (nanosecond).
- Video controller is much slower (millisecond)
- Mismatch in speed.
- Image may distorted if directely output.
- To synchronize operation, frame buffer is used.

Raster Scan : Frame Buffer

- At least two buffers used.
- Primary buffer and secondary buffer.
- Initially, display controller fills secondary buffer.
- Then primary buffer is filled.
- Video controller takes input from primary buffer.
- Then role reversed.

Screen Refreshing

- Light due to pixel excitement starts decaying over time.
- This lead to fading of the scene.
- Moreover, pixels get excited at different point of time.
- This lead to image distortion.
- So pixels are kept excited periodically called refreshing.
- Typical refresh rate is 60hz.

Raster Scan : Pros and Cons

- Simple hardware to implement.
- Good for generating complex images.

Graphics Software

- Graphics library
- Application programs

Graphics library

- High level programming language usable graphics library provides function to work with graphics.
- These function can be used to generate picture components such as straight lines, polygons, circles.
- Some function can be used to set color, intensity values and applying transformation.

Graphics Application Software

- Application programs to manipulate graphics without programming.
- Paint, CAD are some examples.

Graphics Standard

- Standardized software determines its portability, reliable, and efficiency.
- It means can be executed in most of hardware system.
- It also maintains quality.

Graphics Standard

- GKS (Graphical Kernel System):
- First standard by international standard organization.
- Software for synthesis and visualization for 2D graphics.
- Text, fill color, lines, polygon.

Graphics Standard

- PHIGS
- Programmers’ Hierarchical Interactive Graphics Standard.
- A 3D extension of GKS
- Increased capabilities for object modeling, color filling, surface rendering.