A View of Graphics History

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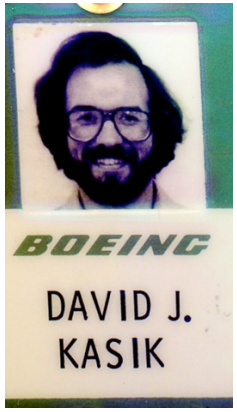
A Bit About Me

- Involved in computer graphics since 1969
- Retired Boeing Senior Technical Fellow
- ACM Fellow
- General curmudgeon about over-promising and under-delivering
- Stand-in on starship bridges



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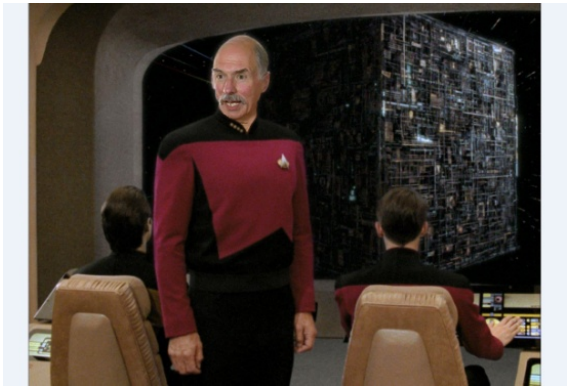
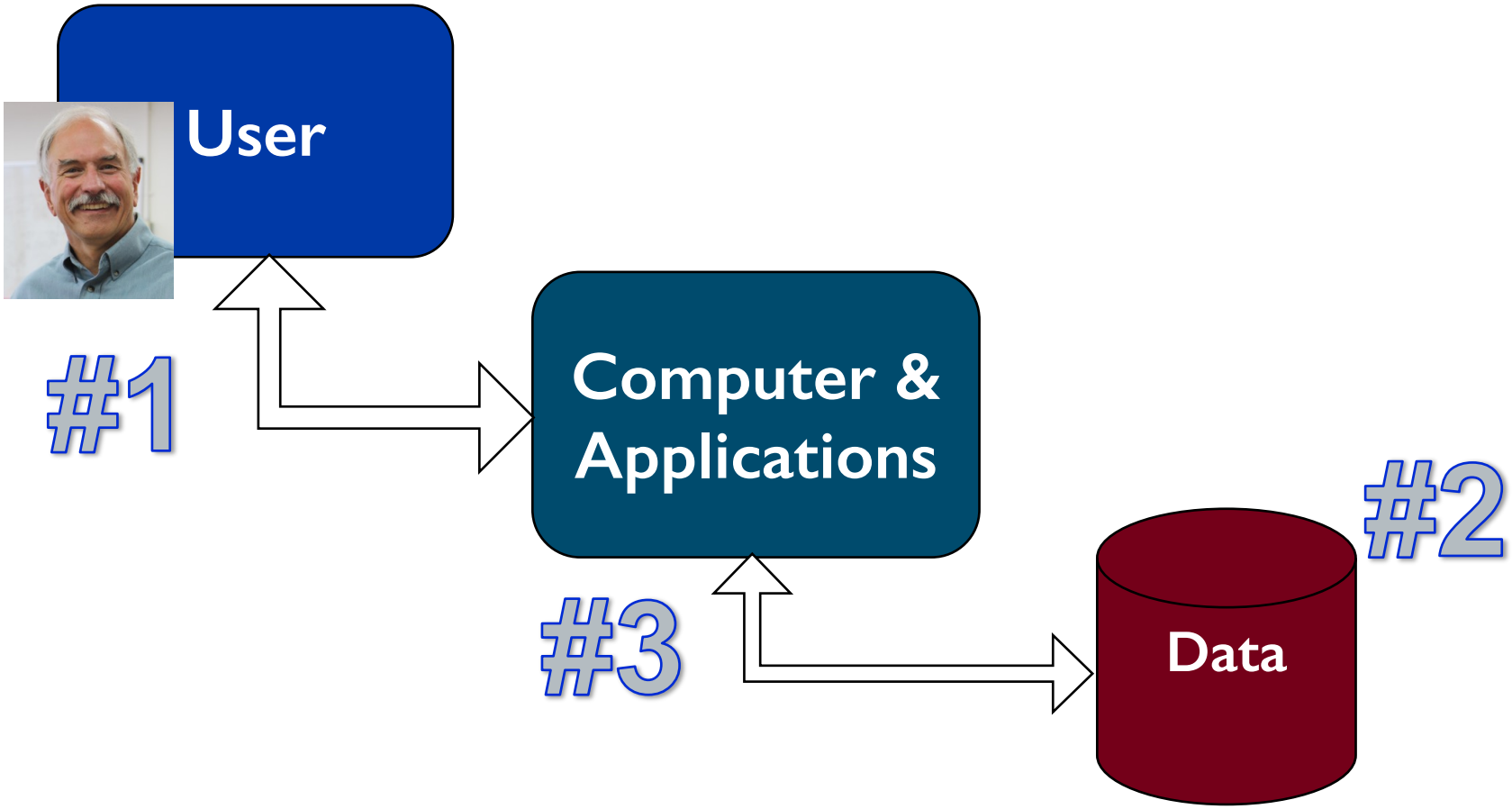


Now

Main Topics

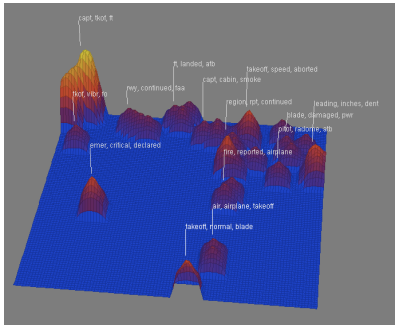
- **Set context**
- **Tracking graphics history**
- **What's next?**
- **Next week: a view from Boeing**
- **Caveat: This is not an exhaustive history. Intended as an introduction.**
  - I've either seen or had hands on with most hardware and software
- **Interested in class participation.**

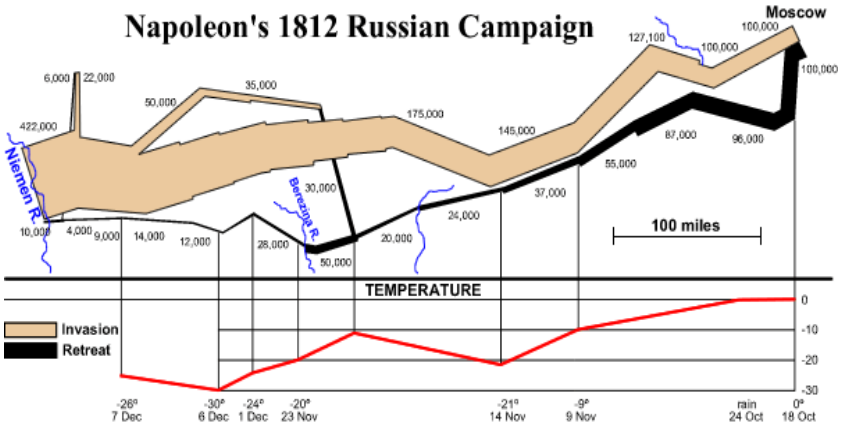
Context



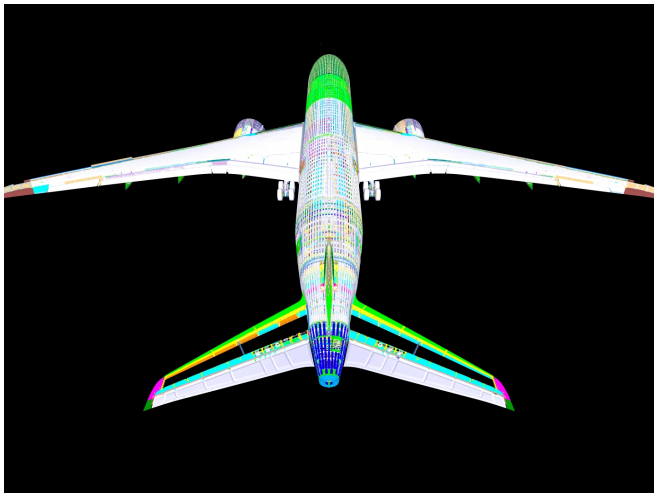
Types of Source Data

- **Non-geometric**





- **Geometric/realistic**



- **Graphics independent of source data type**

Types of Databases

- **Relational/Structured**
- **Unstructured**

Unstructured

Relational Model

Activity Code	Activity Name
23	Patching
24	Overlay
25	Crack Sealing

Key = 24

Activity Code	Date	Route No.
24	01/12/01	I-95
24	02/08/01	I-66

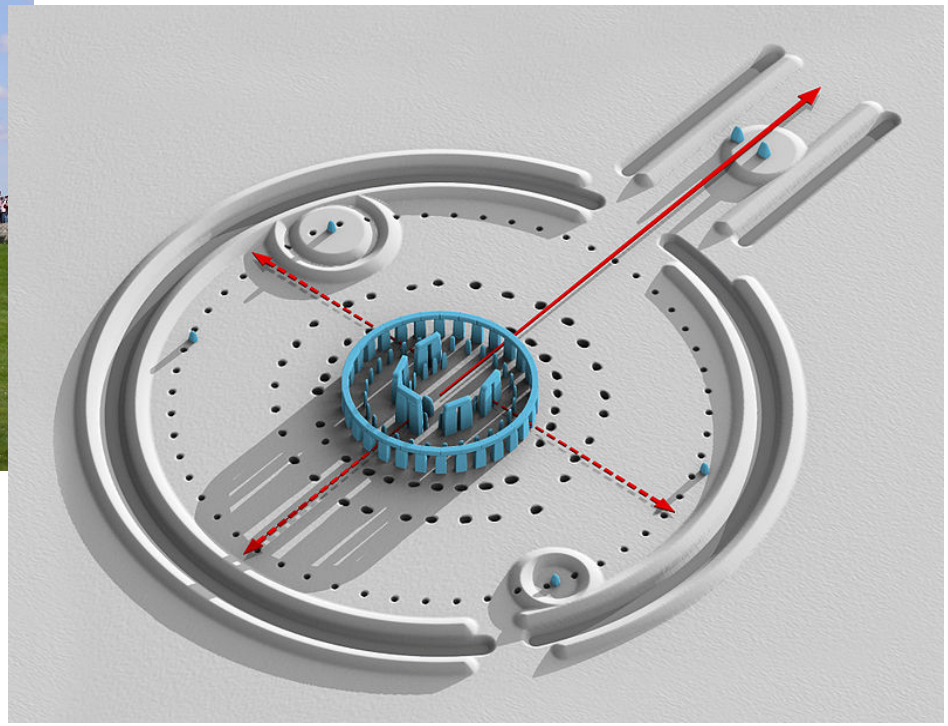
Date	Activity Code	Route No.
01/12/01	24	I-95
01/15/01	23	I-495
02/08/01	24	I-66

Relational/structured

- **Graphics independent of DB type**

Photos vs. Virtual

Stonehenge photo

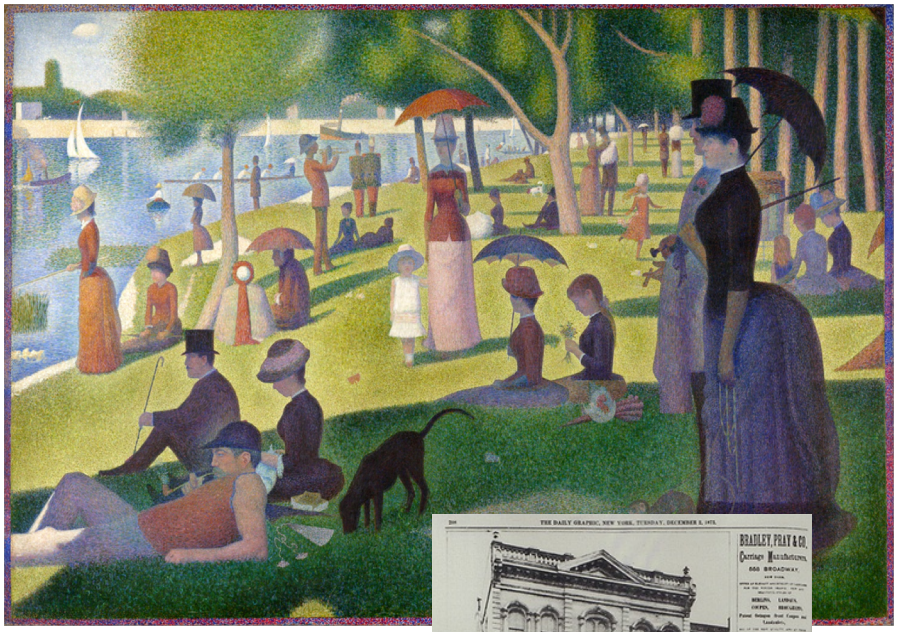


Stonehenge virtual

- **Graphics depends on primitives (point, 2D, 3D)**

Evolution of Images

Continuous fill and lines, pre-historic

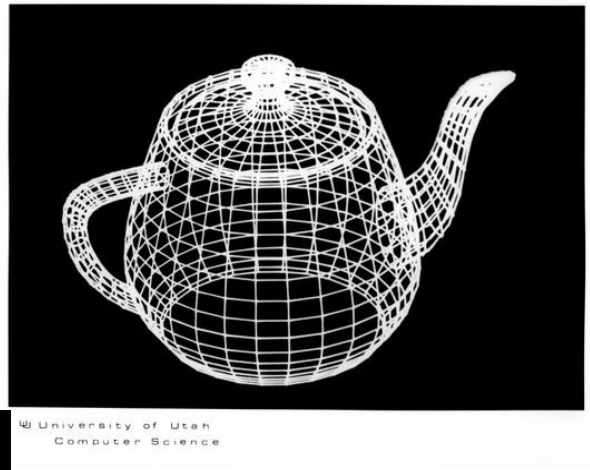


Pointilism, 1884

Half tone, 1852

Graphic Displays

- **Random Scan**
  - Essentially continuous stroke
- **Raster Scan**
  - Essentially pointilism and half-toning/dithering
- **Graphics devices:**
  - Interactive
  - Passive
    - Hardcopy
    - Film

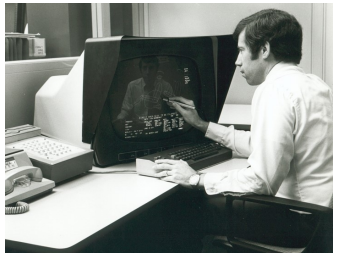


Random scan

Raster scan

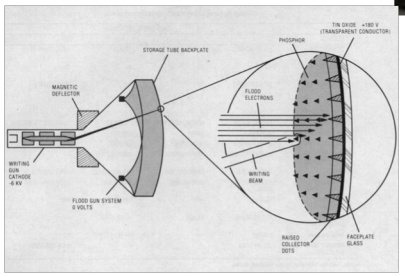
2D Random Scan (Calligraphic)

- **Addressable unit is a vector**
- **Screen is memory**
- **Based on cathode ray tubes dating from late 1890's**
- **Vector refresh, *1970's***
- **Oscilloscope, *1930's***
- **Direct view storage tube, 1960's**
- **Indirect storage tube, 1970's**
- **Problems**
  - Slow to erase DVST
  - Limited capacity vector refresh
  - COLOR

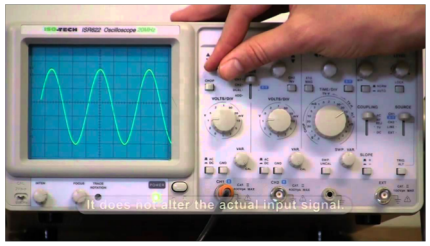


Refresh
•IBM, DEC, CDC
•Adage, VG, etc.

Direct View
•Tek
•Computek



Indirect View
•Hughes
•Princeton



Oscilloscope

2D Raster Scan

- **Addressable unit is a point**
- **Frame buffer memory**
  - Based on cathode ray tubes, LEDs, etc.
- **Television, *1920's***
- **Raster Computer Monitor, *1970's***
- **Plasma panel (Plato terminal), 1970's**
- **Problems**
  - Need frame buffer to store image in full color
    - Ubiquitous starting in 1970's (Ikonas, Raster Tech, Ramtek, Lexidata, etc.
  - Early TV's required interlace to cope with communication performance
  - Aliasing

Monitor

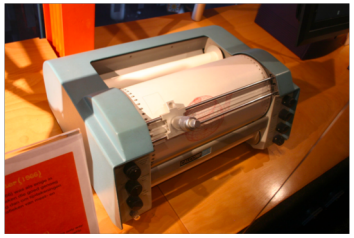
IBM 5080

Plato terminal

1940's TV

Plotters/Printers/Projectors

- **Random scan**
- **Pen random movement**
  - Calcomp, 1960's
  - Bresenham algorithm, 1962
- **Raster scan**
  - Electrostatic, *1960's*
  - Laser, *1969*
  - Ink jet, *1967*
  - Projector, *1980's*
  - Virtual retina, *1986 & 1991*
- **Problems**
  - All the problems of paper
  - Special paper

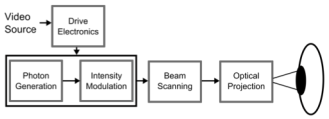


Calcomp plotter

HP plotter

HP laser

Epson inkjet



Virtual Retina Display

Early projector

Image Recorders

- **Fast-decay cathode ray tube**
- **Film camera, *1816* in France, Kodak box *1888***
- **Digital Camera, concept in *1961* at JPL, patented by Kodak in mid-*1970's***
- **Microfilm recorder, 1960's**
- **Video, *1970's***
- **Problems**
  - Recording time

Daguerreotype, 1839

Brownie Box, 1910

Minolta Digital, 1995

Sony Video recorder, 1995

SC4020, 1969

• Dicomed, etc.

Understanding 3D

- **Showing 3D on 2D media part of art since drawing started**
- **Giotto tried in 1200's with algebraic method**
- **In 1400's Italians Brunelleschi and Alberti used a geometrical method based on similar triangles for apparent height**

Peruggino Sistine Chapel fresco

- **References:**
  - Manfredo Massironi, *The Psychology of Graphic Images*, 2001
  - JJ Gibson, *The Perception of the Visual World,* 1950
  - Edward Tufte, *The Visual Display of Quantitative Information,* 2001
  - Peter Stevens, *Patterns in Nature,* 1974

Creating the Illusion of 3D

- Interactive manipulation
- Synthetic stereo
- Rendering style

Interactive Manipulation

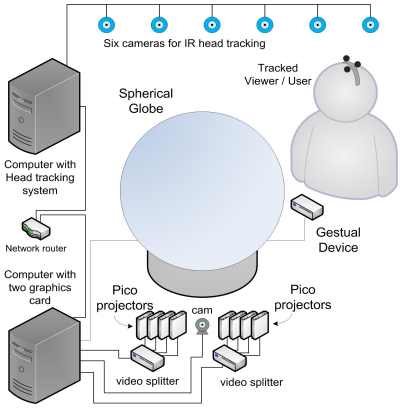
- **Accelerators increase interactive performance**
  - Target: Exceed human flicker-fusion threshold: 16 to 24 Hz
  - Target for games : 60 Hz
- **Integrated into *1970's* random-scan systems**
  - Evans & Sutherland, VG, Adage, etc.
- **Integrated into 1980's raster-scan terminals**
  - IBM 5080, Silicon Graphics, E&S, etc.
- **Add-on PC board 1990's (nVidia, ATI)**
- **Problems**
  - Too many polygons or vectors in scene

SGI

E&S

3D Devices

- **Come in a wide variety of shapes and sizes.**
- **Examples, starting in 1968:**
  - Flat screens in glasses (Oculus Rift)
  - Holographic flat screens (Holografika)
  - Multi-channel holograms (Zebra Imaging)
  - Parallel flat screens (Zspace, Lightspace, CAVE, CUBEe)
  - Single curved cylindrical segment screen (IMAX)
  - Single curved truncated cylinder (Panoscope360)
  - Single curved truncated cylinder + floor (RPI)
  - Spherical segment (Elumens)
  - Spherical projection into air (Actuality)
  - Intersecting lasers into air (Burton-Japan)
  - Intersecting lasers into special plastic (3D Technology Labs)
- **No real commercial success except stereo**

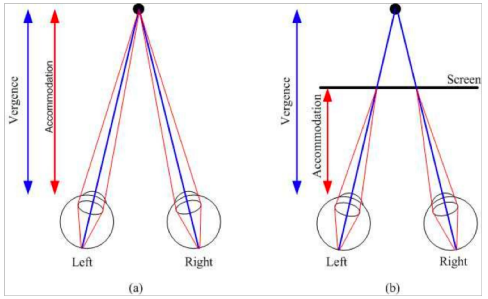


Spheree

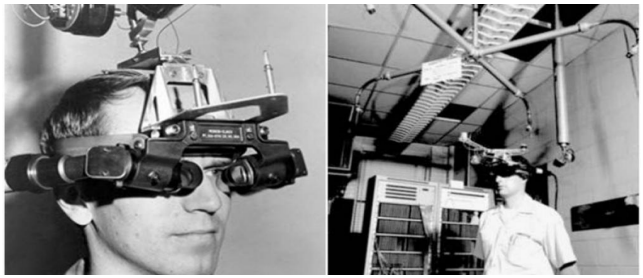

Panoscope360

A Bit More on AR/VR/Stereo

- **Sword of Damocles, Ivan Sutherland, Harvard, 1968**
- **CAVE, Carolina Cruz-Neira, UIUC, 1992**
  - Part of Jaron Lanier VR reboot in late 1980's
- **Oculus Rift, Palmer Luckey, 2011**
- **Problems**
  - Vergence-Accommodation (stereo sickness)
  - Interactive input (like pointing and typing)
  - Goggles inhibit mobility & field of view
  - Performance, performance, performance



Vergence Accommodation



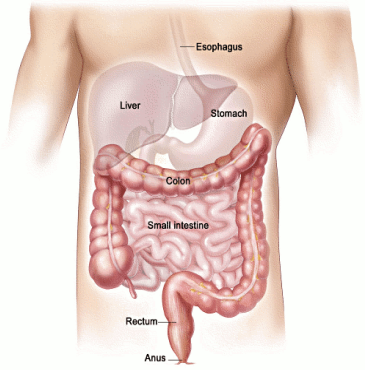
Sword of Damocles

StarVR Goggles

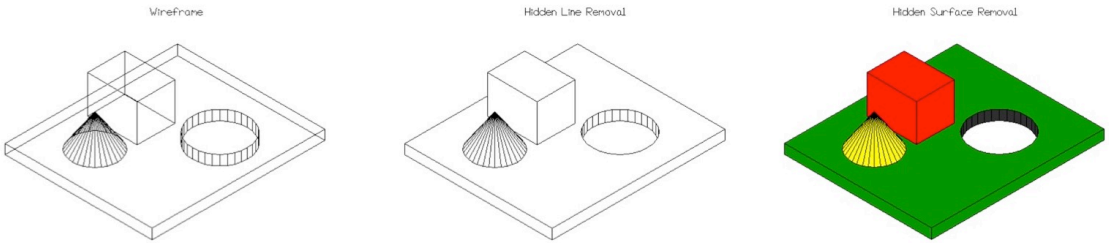
Rendering Styles

- **So many to choose from!**
  - Photorealism
  - Material characteristics
  - Hidden line/hidden surface
  - Shadows
  - Stylized
- **All result from rendering approach**
  - Rasterization
  - Ray-tracing

Utah teapot with reflection



Stylized

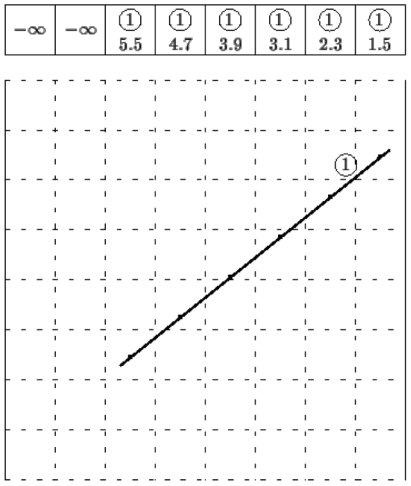


Wireframe, hidden line, hidden surface

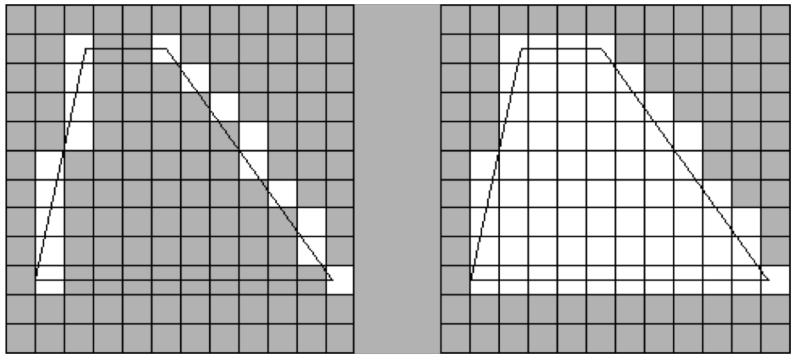
Do Shadows Help?

Rasterization

- **Scan line, Utah, late 1960's**
- **Z-Buffer, W. Strasser, Germany, *1974***
- **Problems:**
  - Requires two passes for transparency and translucency
  - Uses a hidden buffer (a-buffer) to help with photorealism
  - Material characteristics are approximations
  - Multiple light source modeling approximations



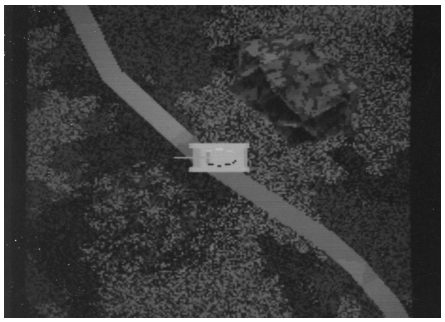
Basic z-buffer algorithm



Polygon Rasterization

Ray-Tracing

- **Used for scientific analysis (1900's)**
- **Appel visualization in *1968* (AFIPS)**
- **Production at MAGI in early 1970's**
- **Popularized by Whitted in *1979***
- **Radiosity (1950, basics, visualization, Cornell, *1984*) improved photorealism**
- **Problems:**
  - Parallel compute power
  - Performance



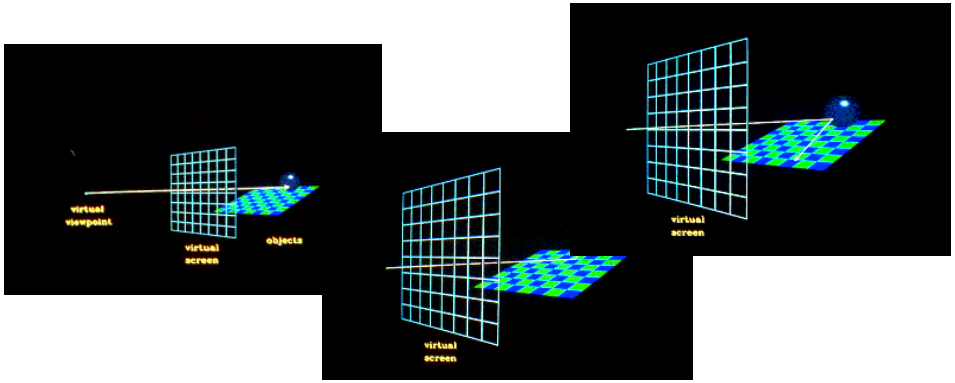
MAGI Trees & Tank

Whitted

Radiosity Effect

Exercise

- Work in pairs
- Both rendering and rasterization can benefit from parallel processing. Discuss how you would address ray-tracing and rasterization using parallel processing.
- Be prepared to provide a 30-second summary



Ray Tracing Single Ray

- For rasterization inspiration, consider this demo

Input Sources

- Interactive Devices
- Scanning Devices
- Applications
- Sensors

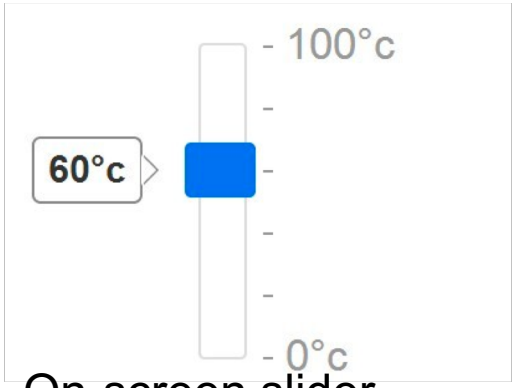
Interactive Devices

- Single Value
- Locator (multiple values simultaneously)
- Alphanumeric

Single Value

- **All have been around since the 1950's and 1960's**
  - Buttons
  - Knobs
  - Dials
  - On-screen controls
- **Problems**
  - Numeric precision (non-binary)

IBM 5080 with buttons and knobs



On-screen slider

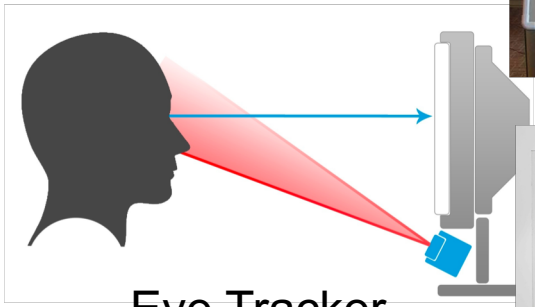
Locator

- **Devices enter x,y or x,y,z:**
  - Lightpen, *1955*, MIT
  - Mouse, *1965*, Xerox PARC
  - Joystick, early *1900's*, France
  - Trackball, *1940's*, UK
  - Thumbwheel, 1960's, Tektronix
  - Tablet,*1957*, RAND
  - Touch, *1967*, CERN
  - Eyes, *1920's*, Chicago
- **Problems**
  - Limited to screen accuracy
  - Fingers even less accurate
  - Eye tracking tends to be slow
  - No standard gesture vocabulary

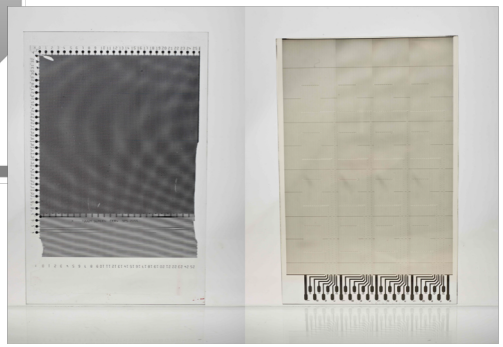
Wacom Tablet

Tektronix Thumbwheels

Summagraphics Digitizer



Eye Tracker



CERN Touchscreen

Alphanumeric

- **QWERTY keyboard, 1874**
  - Keypunch, 1890's
  - Teletype, 1930's
  - On-screen, 1970's
- **Voice, 1960's**
- **Brain, 1960's**
- **Problems**
  - Speed/accuracy
  - Voice often ambiguous
  - Ambient noise
  - Extra equipment, esp. for mobile

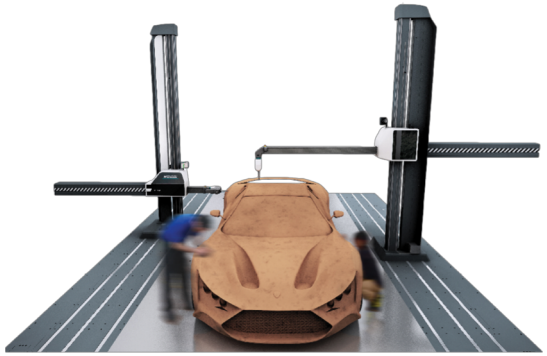
IBM 026 Keypunch

ASR 33

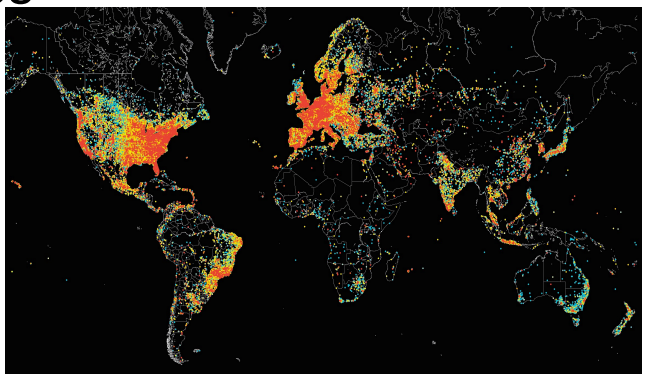
Paras Kaul, BrainWave Chick

Scanning/Monitoring Devices

- **Digitizers**
  - 2D and 3D Scanners
  - 2D and 3D Coordinate Measurement Machines
- **Cameras**
  - Gestures
  - Images/videos
- **Internet of Things**
- **Problems**
  - Speed/accuracy
  - Gestural vocabulary
  - Error correction
  - Data volume



Coordinate Measurement Machine



Global Connected Devices

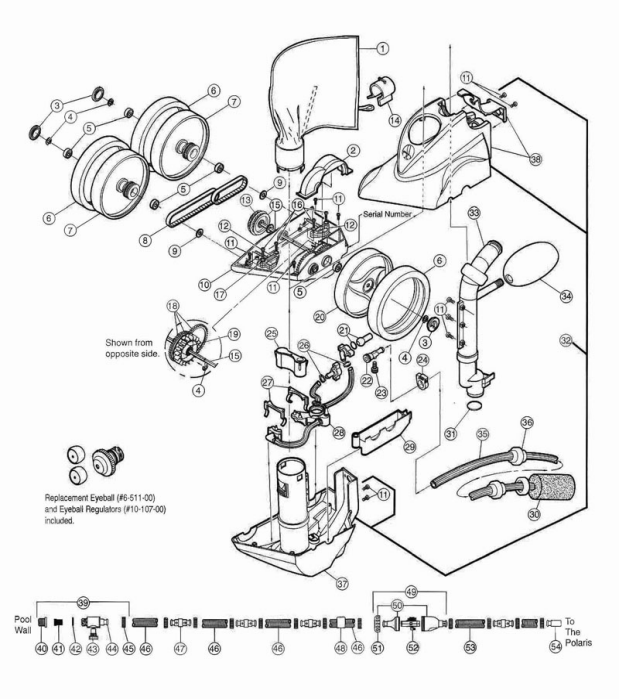
Fetus Ultrasound

Applications

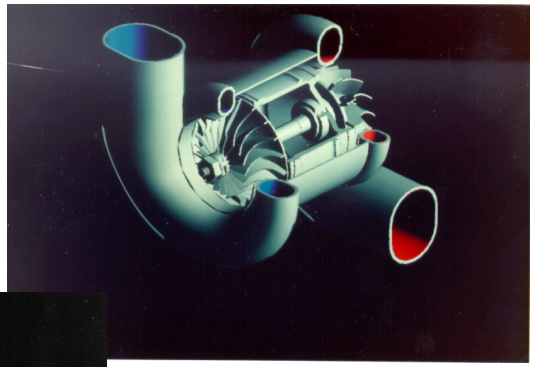
- CAD/Computational Geometry
- Animation
- Scientific Visualization
- Games

CAD/Computational Geometry

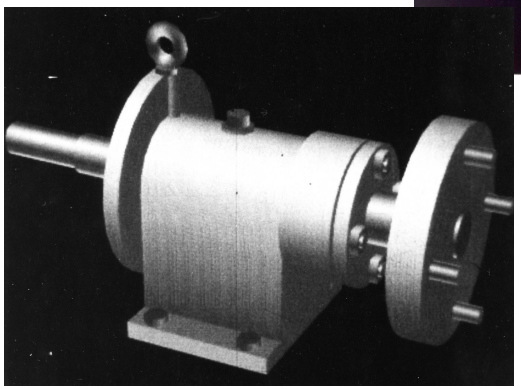
- **Derived from engineering drawings**
- **First computer-based, Sutherland's Sketchpad, *1962***
- **Picked up by GM as DAC-1**



Exploded view



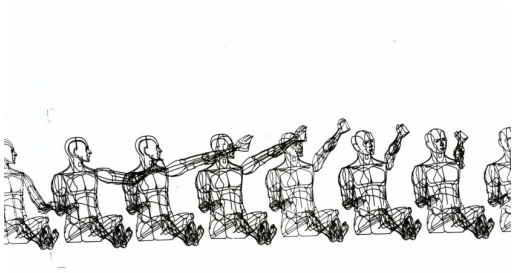
B-Rep Solid



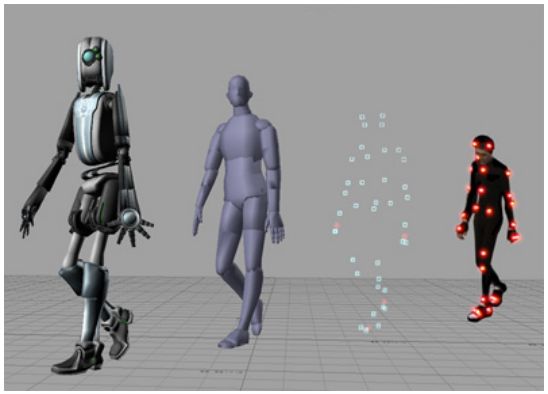
CSG Solid

Animation

- **Movement started as early 1830's with stroboscope and zoetrope**
- **Hand-drawn animation started in *1908* with Cohl's Fantasmagorie**
- **Disney did first color animation in *1932***
- **Computer animation started in *1960's* with advent of microfilm recorder**



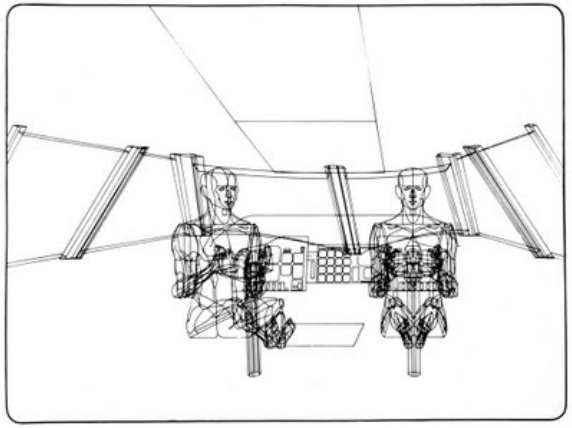
Human Model on Plotter



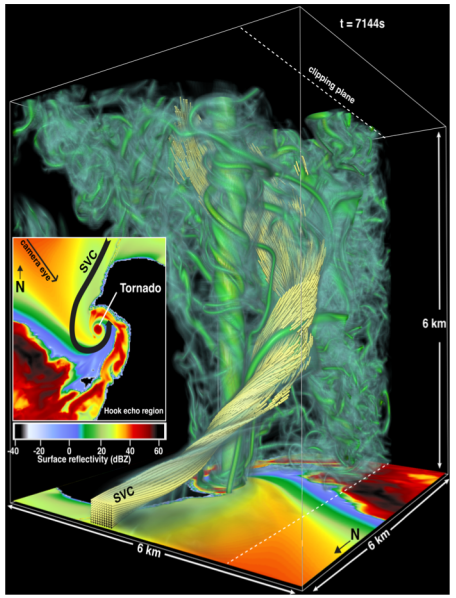
Human Mo-Cap

Engineering Analysis

- **Analysis-generated values lead to scientific visualization**
- **Applications include**
  - Weather
  - Structures
  - Aerodynamics/Fluids
  - Heat transfer
  - Reactions
  - Human model
  - And many more



Human Model

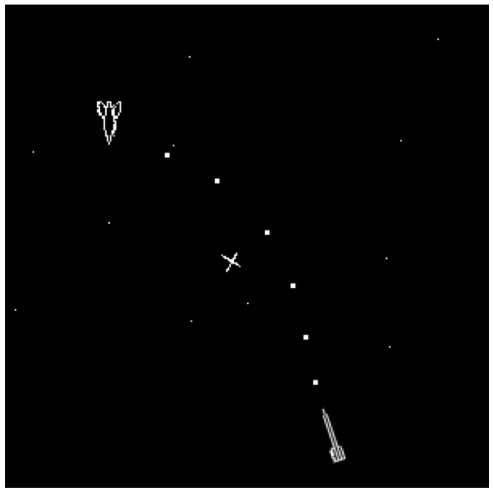


Anatomy of a Tornado

- **Started with plotters in early *1960's***
  - Moved to microfilm recorders to improve animation

Games

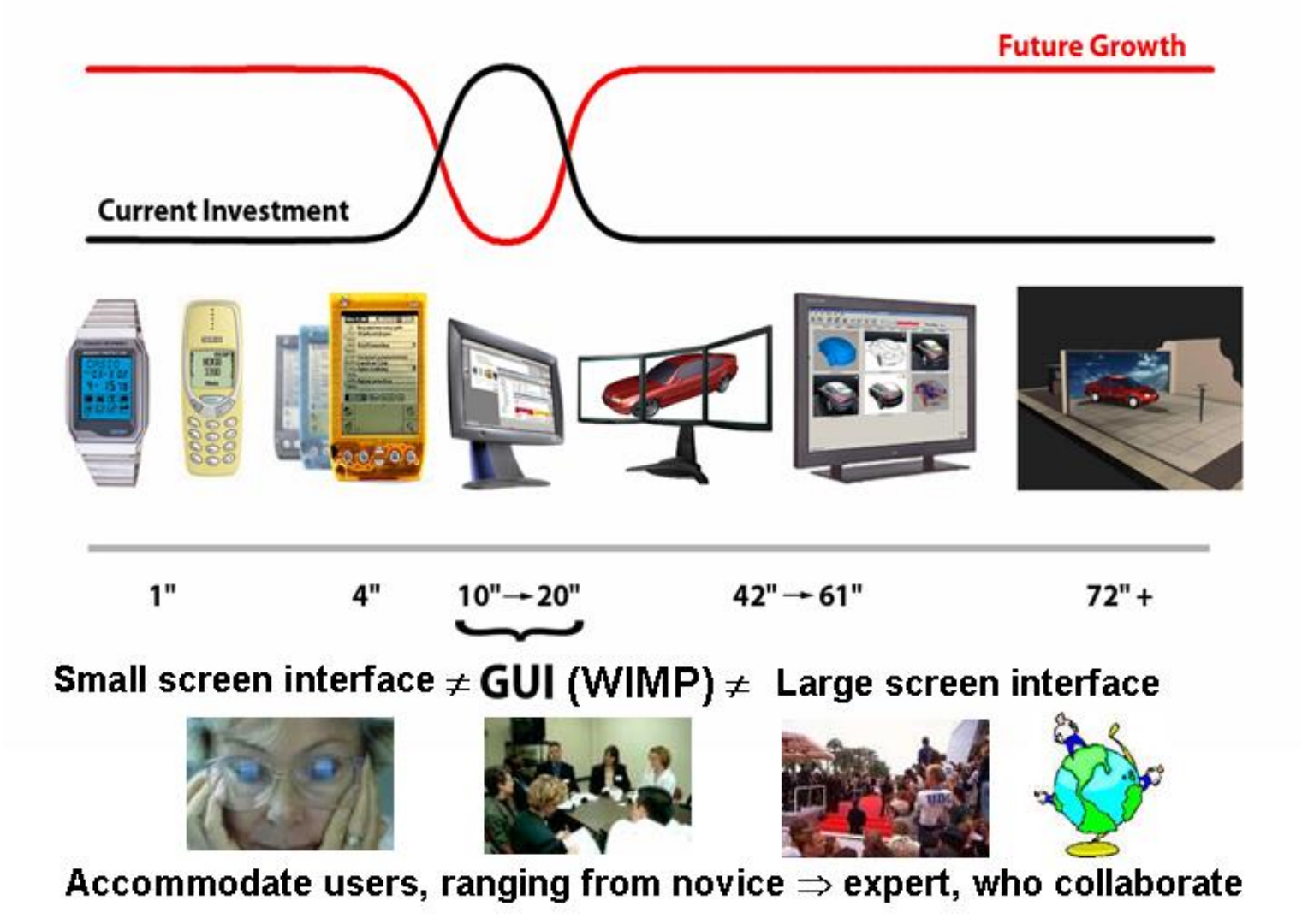
- **One of first applications dating from early *1950's***
  - Kates' Bertie the Brain early game-playing computer
  - Tic-tac-toe played on EDSAC
- **Played on operator's consoles and teletypes**



SpaceWar!

Super Mario

What's Next? The Third Wave, A Systems View



What Will Drive the Third Wave?

- **Could pixels disappear?**
  - Vector displays magically re-appear
  - Dynamic holograms became commonplace and cost effective
- **Could high order objects become graphics primitives?**
  - Objects have inherent semantics
- **What graphics systems will arise?**
  - CAD/CAM
  - Visual analytics
  - Can such systems result in publications?
- **Can a non-WIMP interface appear?**
  - Voice for text entry
  - Semantic mouse over
  - Accurate, precise gestures for pointing & selecting

Technical Challenges

- **While cost is coming down, it can always get lower**
- **Volume of data just keeps getting larger**
- **Input techniques across different screen sizes are asymmetric**
  - For small- and mid-sized screens, multi-touch and WIMP have different vocabulary
    - Affects both software and users
    - Causes problems with both thick and thin client
  - For large screens (immersive or not)
    - Wear cumbersome hardware (e.g., wands, gloves, HMDs)
    - Graphically select an object or a command
    - Enter text or numbers
    - Workaround is for a dedicated operator
- **Stereo for long sessions**
  - Stereo sensitivity can be an issue

Top Challenge

Summary

- **Lots of history in computer graphics**
  - Much started before 1985
- **Even with history, substantial research questions still exist**
- **Pick topics that make a delta improvement**

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