# Lecture 21

Computer Graphics

Why Computer Graphics?

- To understand and communicate, to deal with complexity
  - *"The Purpose of Computing is Insight, not Numbers"* – Richard Hamming

- We are innately visual creatures
  - visual channel is dominant and parallel
    - >50% of neurons are in visual cortex

- Making best use of the visual channel is vital, whether for entertainment, scientific understanding, or communication

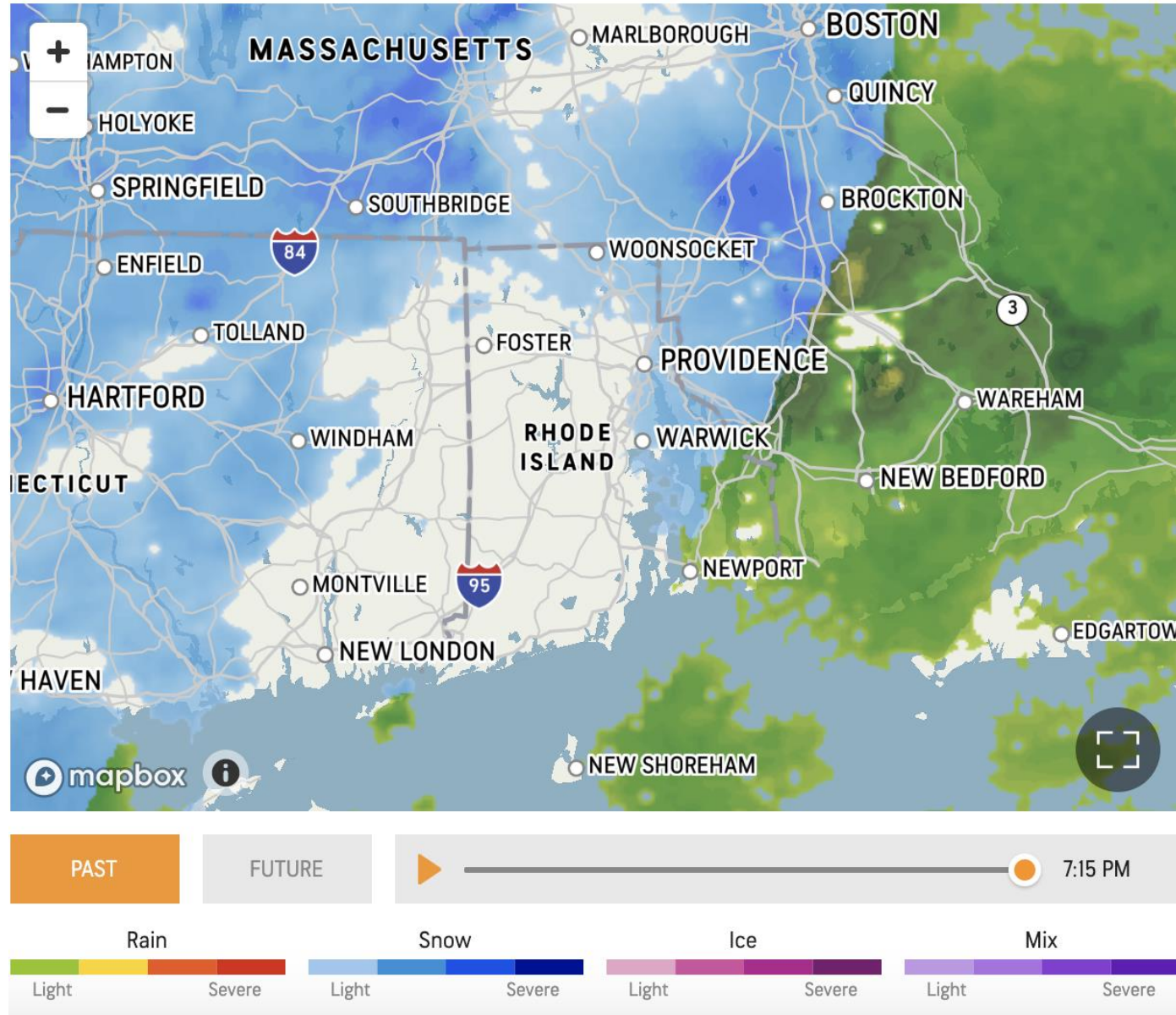Green indicates the pathway from the eyes to the visual cortex
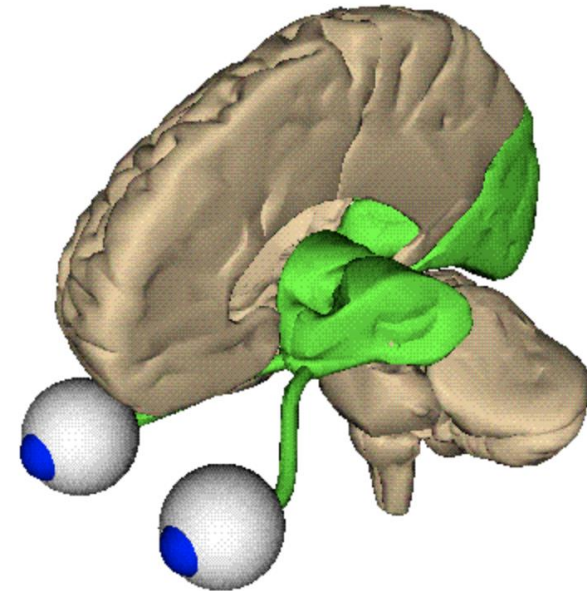
Source: Office of Teaching Resources in Psychology
http://topix.teachpsych.org/w/file/23172665/visual.gif

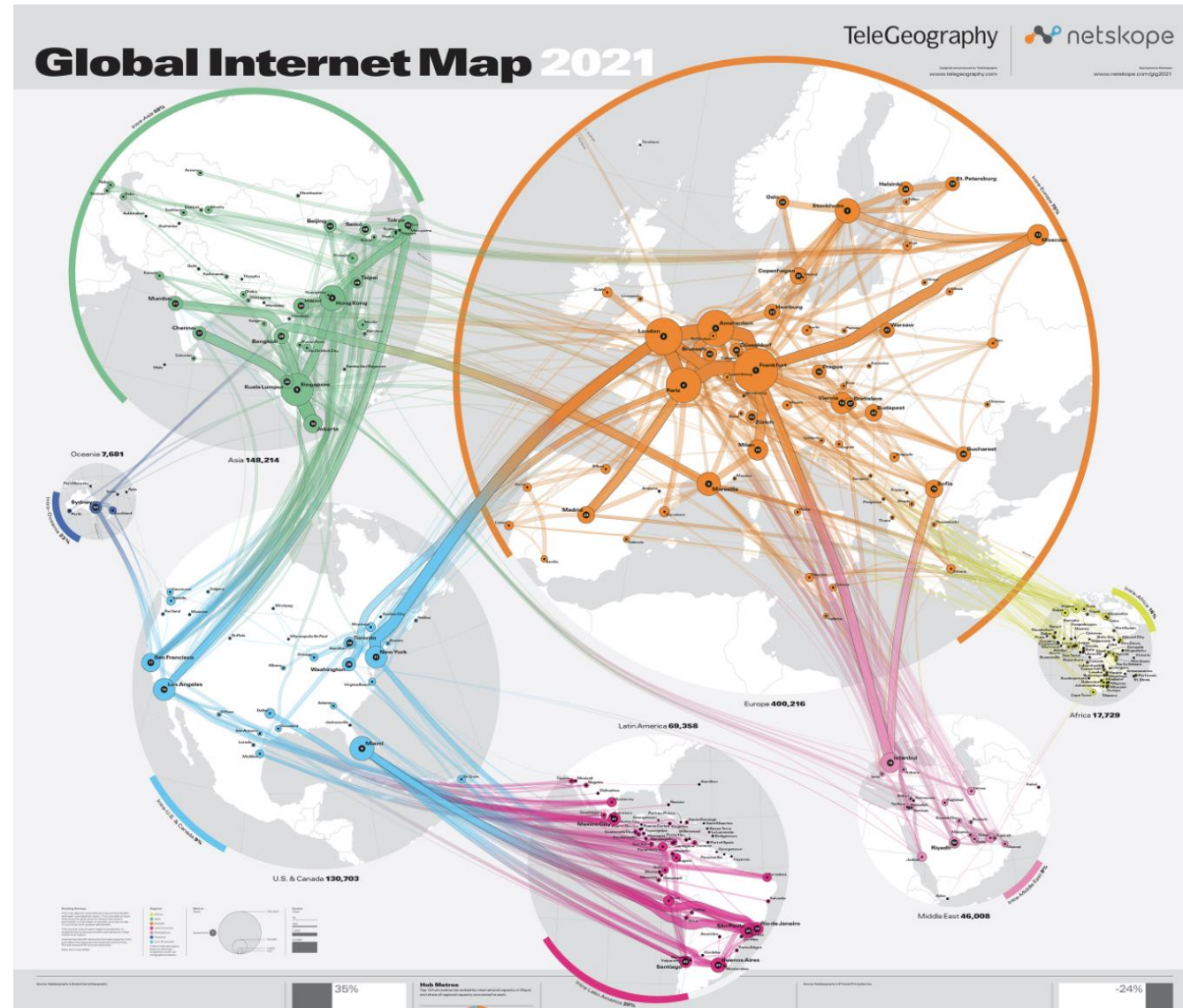# Data/Information Visualization: Organization Chart
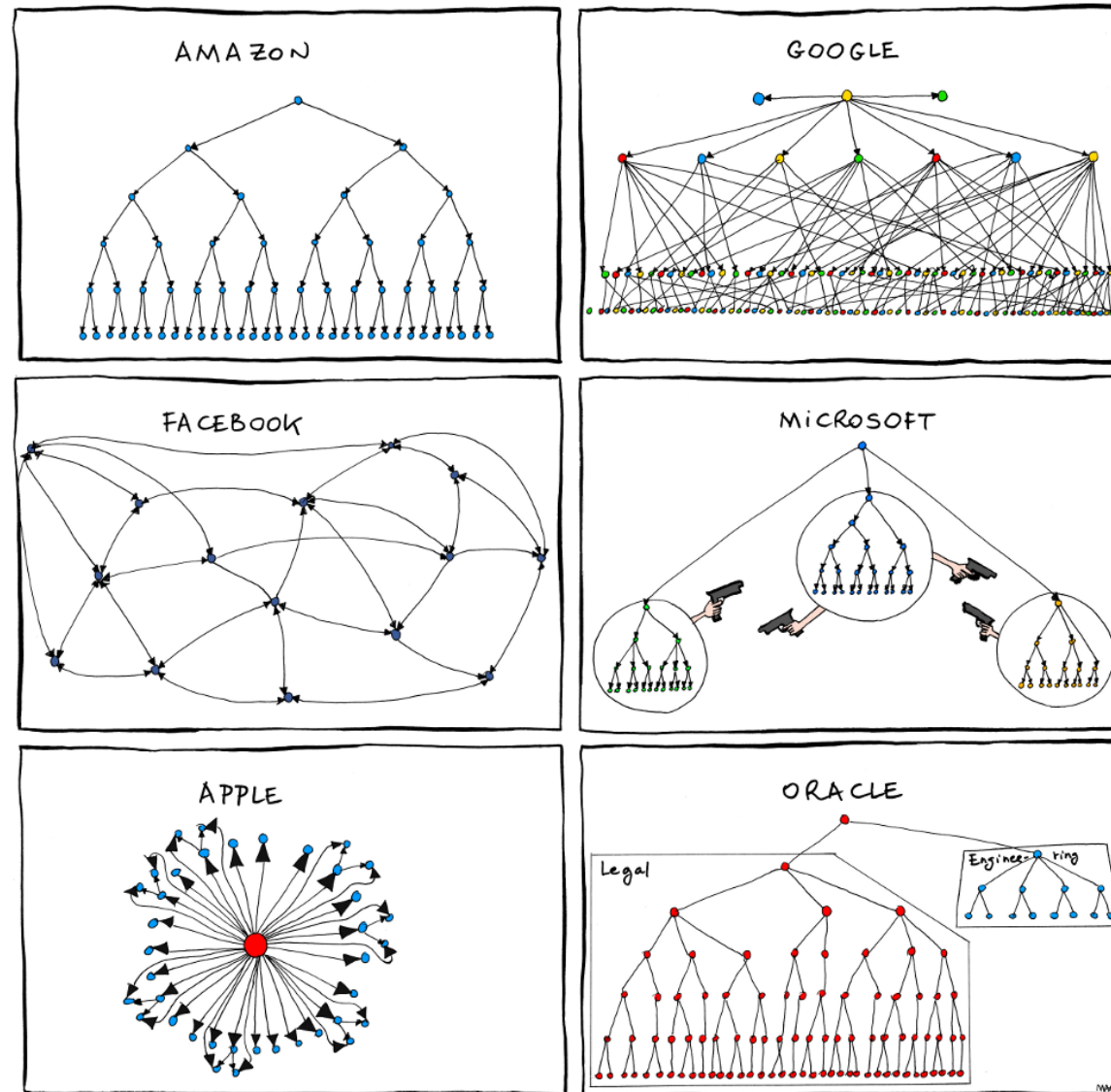
Data/Information Visualization: Providence Snowstorm Map

Andries van Dam © 2023 11/30/23

Data/Information Visualization: Global Internet Map 2018

New York Times COVID-19 Map

Andries van Dam © 2023 11/30/23
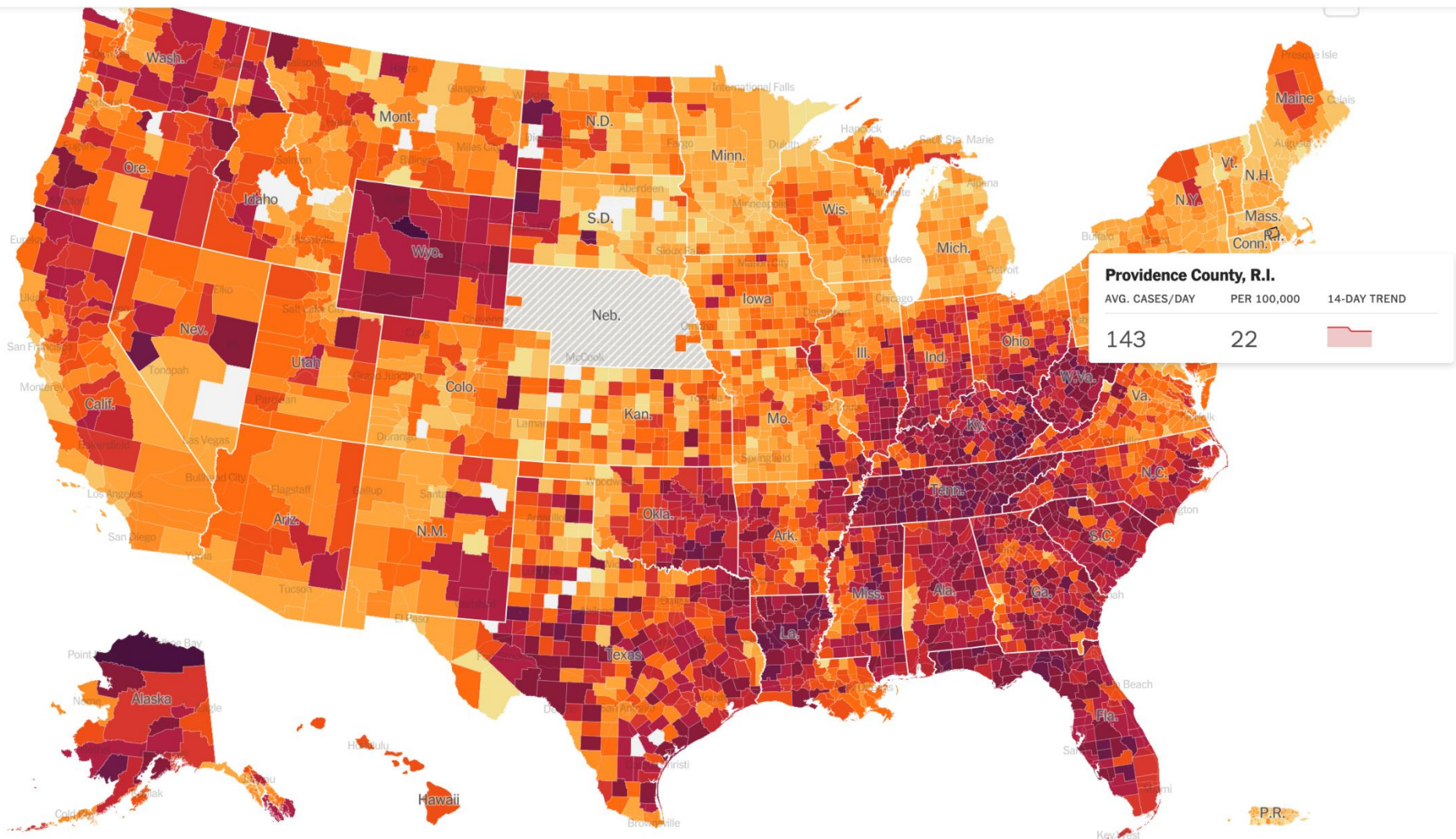
Ed Stem/GPTA Graph

Legend

Blue Line
Ed Usage

Green Line
GPTA Usage

Red Lines
Project Deadlines

Andries van Dam © 2023 11/30/23
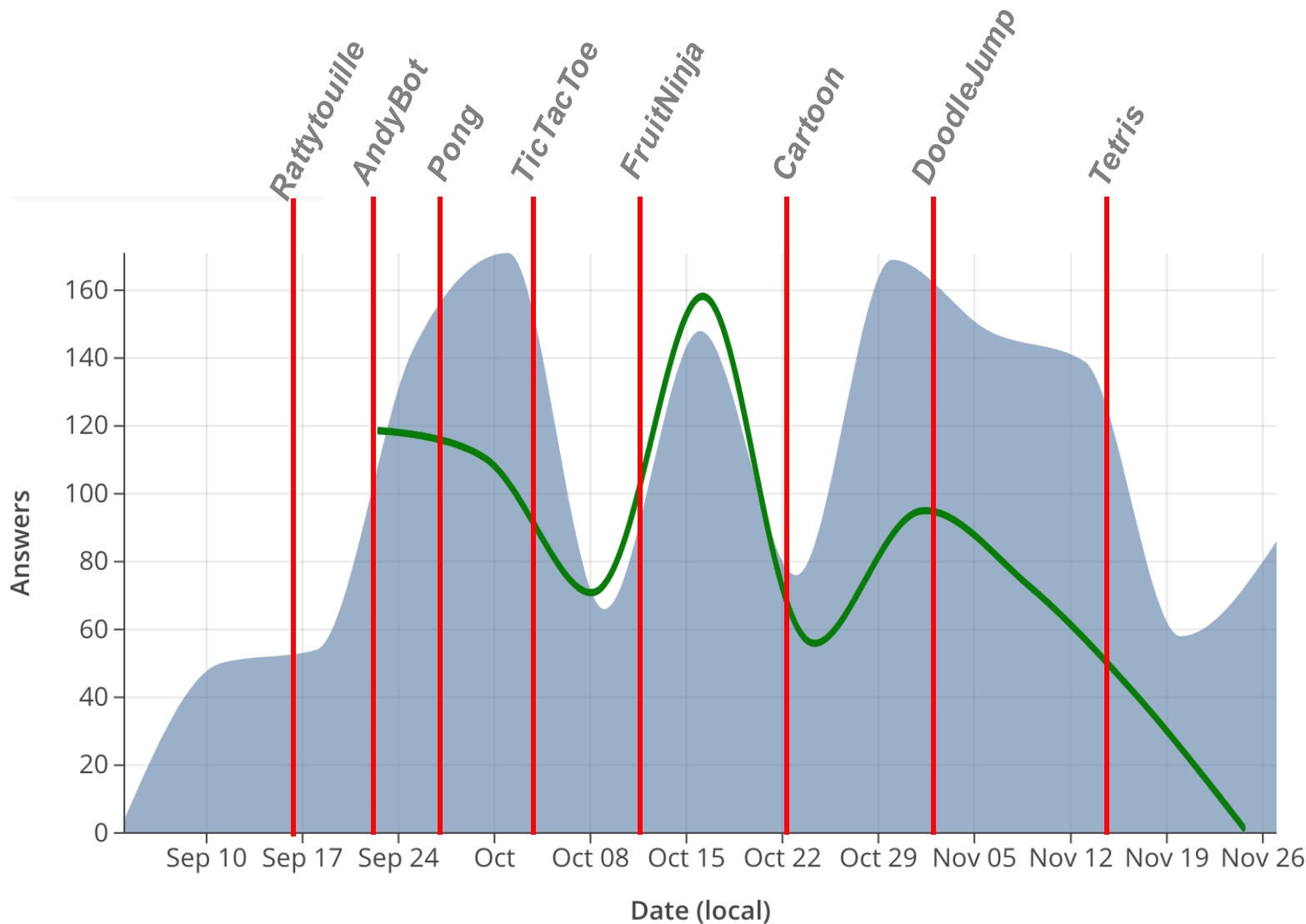
Cave Paintings – Early Form of Visual Expression

Roots of Visual Communication

Computer Graphics: A 100,000 ft view

- CG: tool for visual communication, based on:
  - technology
    - hardware, software, algorithms and data structures, math, physics…
  - art and design disciplines
    - graphic design, UI/UX design, story telling
  - human studies
    - perceptual and cognitive psychology, social sciences (teamwork, online communities, social networking…)
- Major topics (covered in CS123 and other courses):
  - modeling: creating the world
  - rendering: viewing the world
  - animation (geometry and behavior)

Geometric Modeling

- How do we represent real world objects?

- Divide and Conquer to deal with complexity (many parallels to OOD/P)

- Hierarchy of geometrical components, each at appropriate size (scale), rotation and position

- Reduction to "geometric primitives"
  - Platonic solids such as spheres, cubes, polyhedral
  - triangle and quadrilateral meshes, curved surfaces
  - 3D attributes are material properties/appearance attributes

3D Primitives

Head
Shaft
Point

composition   decomposition
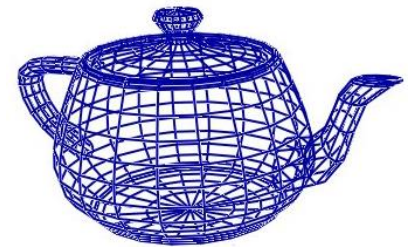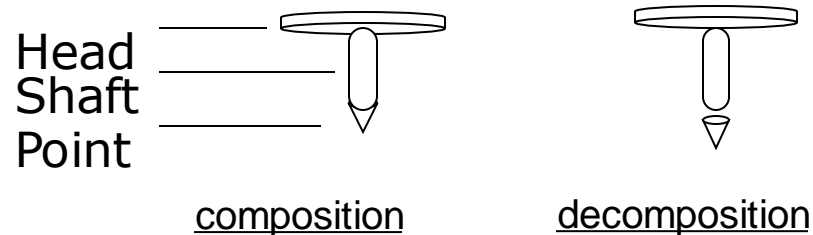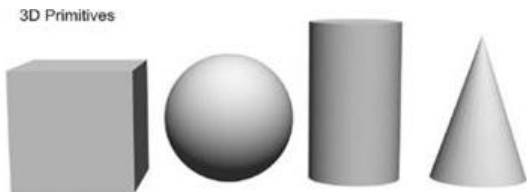
Polygonal mesh representation of the "Utah Teapot"

- Modeling geometry of simple nail vs. complex geometry of screw

Andries van Dam © 2023 11/30/23

Scene Graphs: Model Component Hierarchy

ROBOT

5. To get final scene

4. Transform subgroups

3. To make sub-groups

2. We transform them
(scale, rotate, translate)

upper body

lower body

head   trunk

arm

stanchion

base

1. Leaves of tree are standard size object primitives

Andries van Dam © 20223 11/29/23
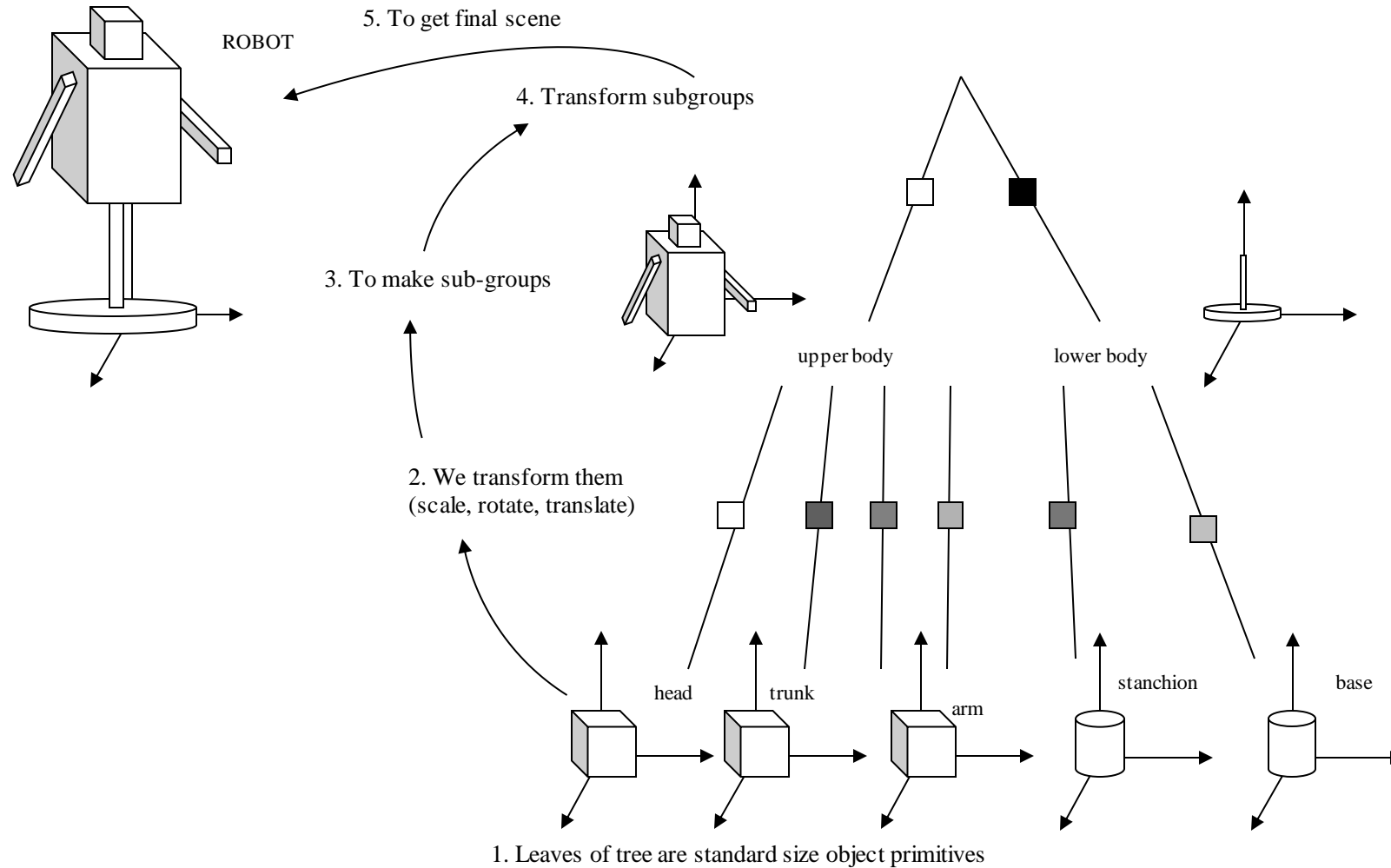
Other Modeling Techniques

Selection Box Editing Mode
Max coordinates: (0.47053, 0.148309, 0.366711)
Min coordinates: (−0.250932, −0.810572, 0.138992)

Stanford bunny is a computer graphics 3D test model developed by Greg Turk and Marc Levoy in 1994

- Point clouds
  - a collection of many small data points which exist in 3D
- Procedural modeling
  - algorithmic generation with parameters
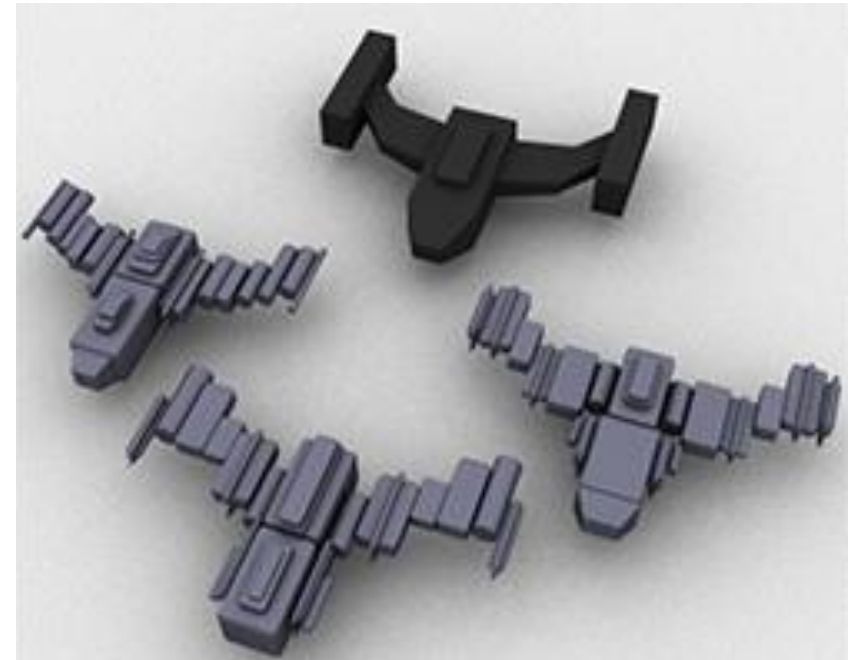- Generative AI models driven by prompts, mostly image-based (related to computational photography) – see slide 20

From Prof. Daniel Ritchie paper, **Controlling Procedural Modeling Programs with Stochastically-Ordered Sequential Monte Carlo**

Photo-Realistic Rendering 1/5

- Making scenes look realistic is an immensely complex subject drawing from physics, physiology, perceptual psychology, art, and graphic design
- Want to approximate how light energy (photons) bounces around
  - from light sources to and between objects
  - to reach the eye, and subsequent brain interpretation
    - we create our own (virtual or real) reality from two slightly different perspective projections: binocular disparity → stereopsis, depth perception
    - many other depth cues: perspective foreshortening, shape from shading, motion parallax…
- Objects **reflect** light (wall, desk, paper), others also **transmit** light subject to refraction (cellophane, glass, water), and some do **sub-surface scattering** (skin, hair, milk)
  - surface that reflects only pure blue light illuminated with pure red light appears black
  - pure green light viewed through glass that transmits only pure red also appears black
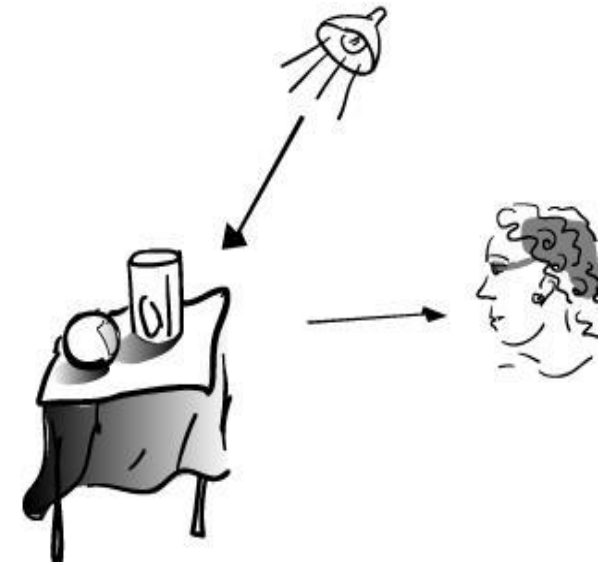
Photo-Realistic Rendering 2/5 – 1970s

Pixar "Shutterbug" images

Flat or Faceted Shading: Constant intensity over each face
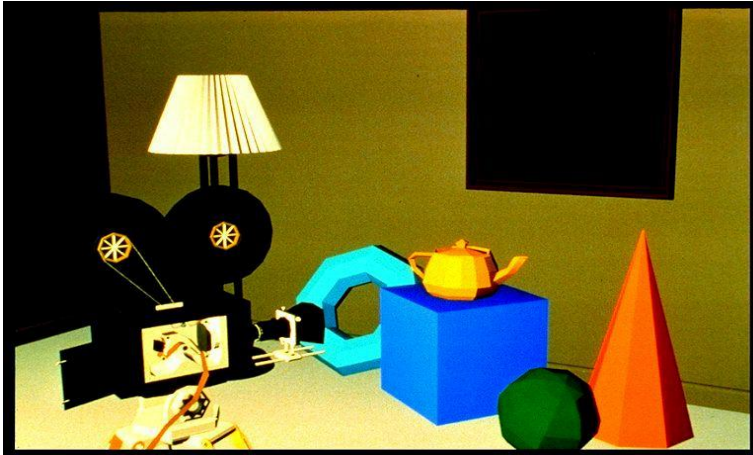
Gouraud Shading: Interpolation of intensity

Phong Shading: Interpolation of surface normals. Note the specular highlights
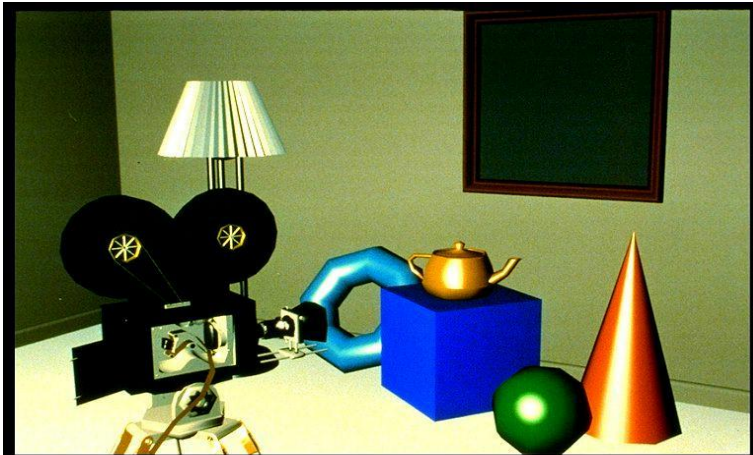
Global Illumination: Inter-object reflections, shadows, and texture mapping
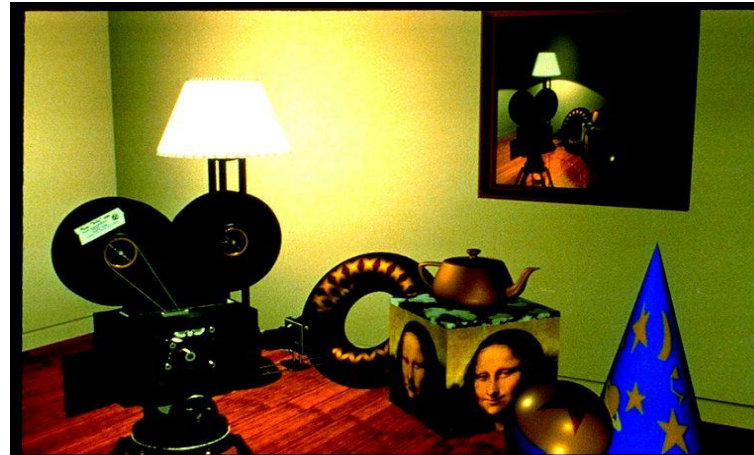
Photo-Realistic Rendering 3/5 – 2000s

Travis Fischer's Ray Tracing, CS123
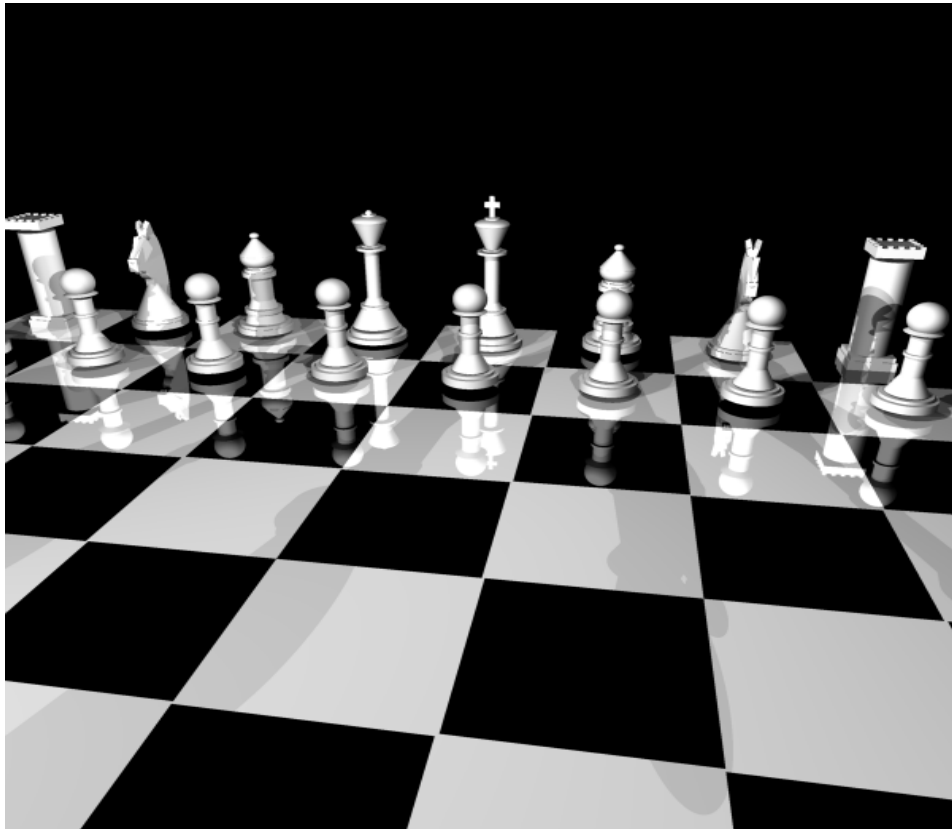
Photon Mapping from CS224
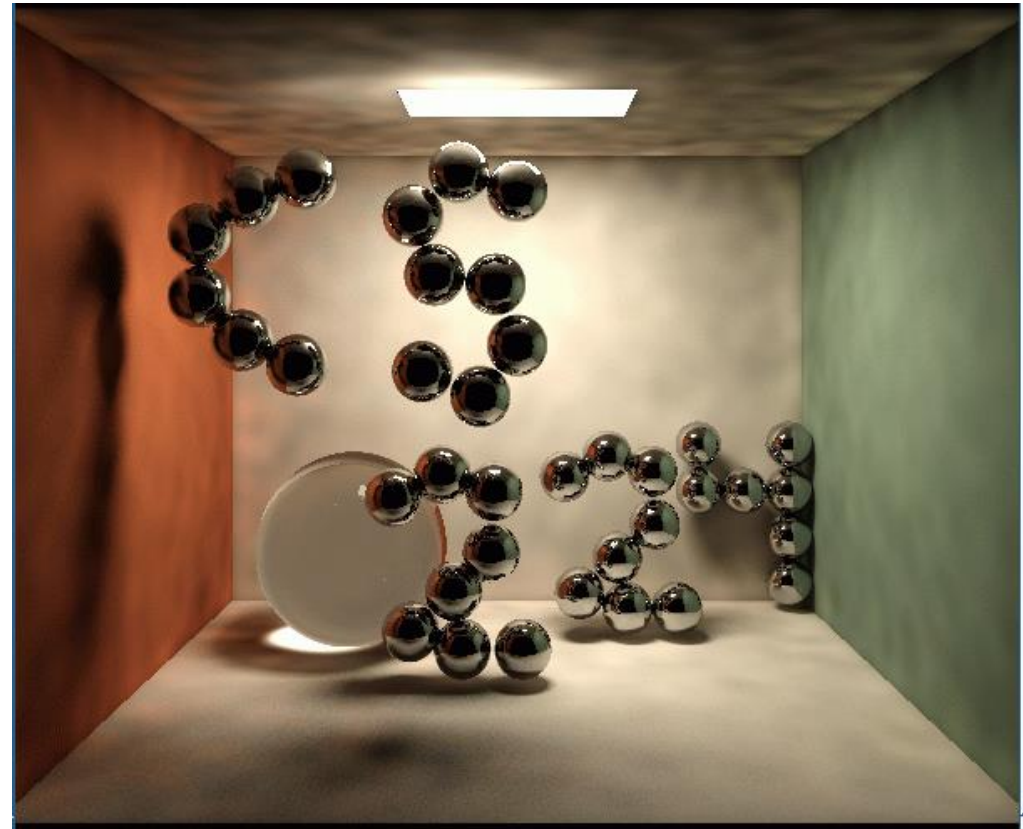
© Bernie Gordon, 2006

Photo-Realistic Rendering 4/5

Took over 500 hours to render in '90s
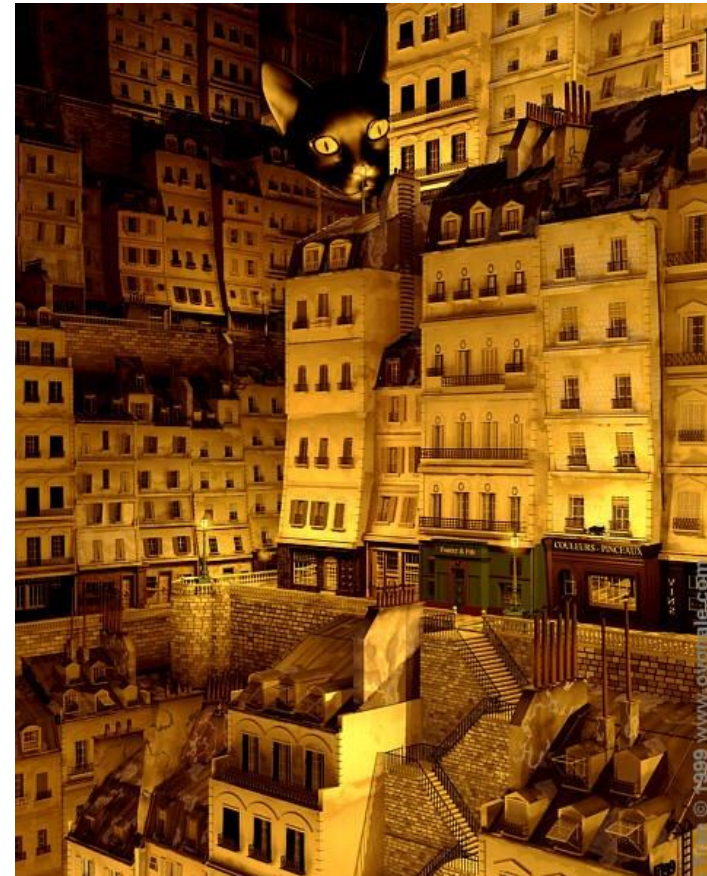
Photo-Realistic Rendering 5/5 – 1990s to 2020

Light Refraction

Digital Actors (The Matrix Reloaded)

Soft Shadows

Hair (Colette from Ratatouille, Merida from Brave)

Depth of Field

Snow effect (Frozen)

NPR: Non-Photo Realistic Rendering

Painterly
Rendering
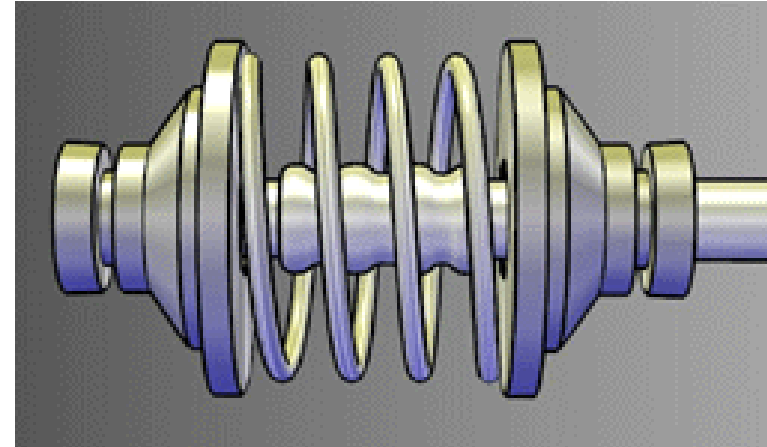
Toon
Shading

Stylized
Representation

Brown's
Contribution

AI-Generated Imagery (1/5)

- ## What is AI-generated imagery?

  - Includes all images and videos produced by computers using algorithms
  - Used in computer graphics, computer vision, and image processing to generate realistic or stylized visual content
  - Applications: video game design, film production, medical imaging, and virtual reality

- ## Implications

  - Issues regarding copyright, compensation, biases in training data, and spreading of misinformation

- DALL·E, Stable Diffusion, and Midjourney are all examples of tech that produce AI-generated images

ACTUAL VIDEO   AI RENDERED VIDEO
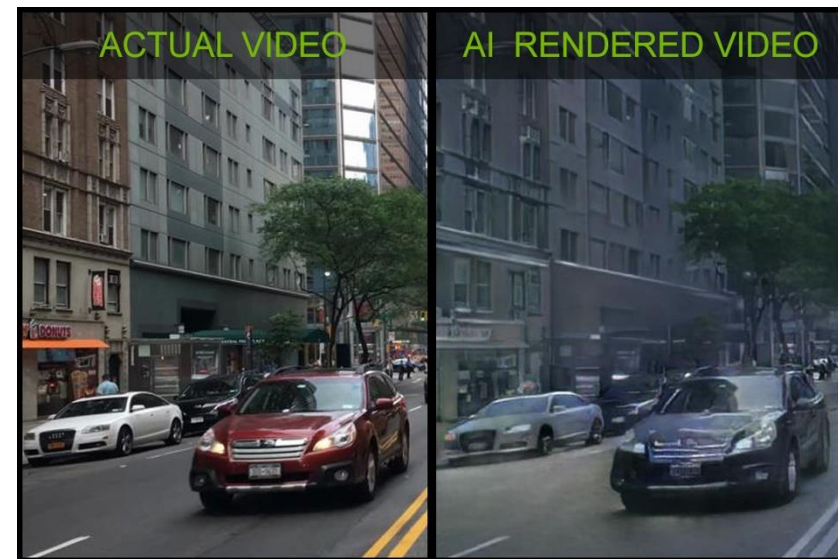
Nvidia has created the first video game demo using AI-generated

Original —

GANs
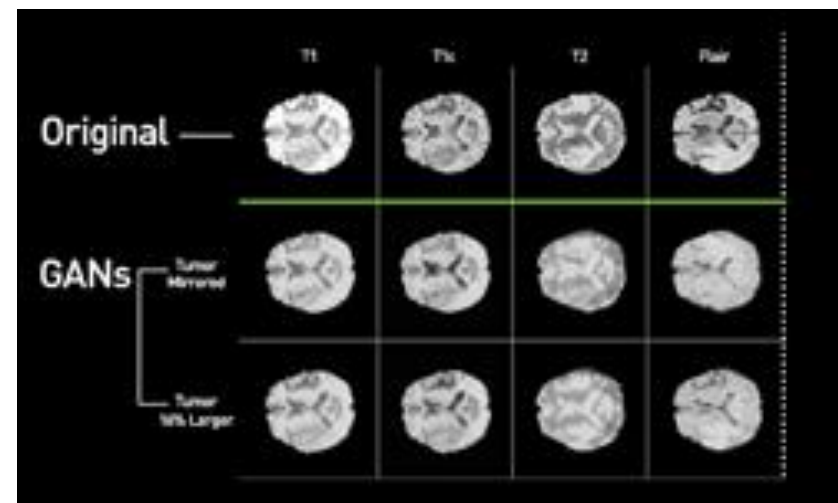
reliable generation of synthetic images to train AI systems that interpret medical images

AI-Generated Imagery (2/5)

- AI-generated imagery and machine learning
  - A prompt (text input or sketch) is required for generative AI
  - "Huge datasets are scraped together to train the AI, and through a technical process the AI is able to devise new content that resembles the training data but isn't identical" (from The Guardian)
  - AI-generated imagery typically employs machine learning, such as neural networks
  - A neural network is a set of algorithms that, in this case, creates images by:
    - taking in a prompt
    - finding images online that relate to the prompt
    - understanding the defining characteristics of these images
    - and producing an image that retains these characteristics while still being representative of the prompt
  - Learn more about machine learning and neural networks in CS1420 and CS1470!

AI-Generated Art (3/5)

- Subcategory of AI-Generated Imagery
  - AI-generated art focuses specifically on the creative output produced by artificial intelligence algorithms
  - Paintings, drawings, sculptures, and other forms of artistic expression
- Prompt engineering has now become widespread in the digital art community
  - Crafting prompts with positive or negative terms to produce specific content and style

AI-generation creates several drafts to iterate on in any style with each prompt

PROMPT: 3D Vivid [handpainted:photograph:0.5] by **Norman Rockwell** and **John Singer Sargent** of pretty expressive santa-workshop woman warrior elf, volumetric light, ornate leather dress, fearful, dark fantasy, chaotic, intricately detailed, Symmetry, snowy, wet, Winter, Hyper-Realistic, Ultra Resolution, Dark, desolate, southern gothic, 8K, christmas, masterpiece [oil painting:hyperrealism:0.5] in the style of **Ruan Jia** (from this article, created with Stable Diffusion)

PROMPT: painting of a fox sitting in a field at sunrise in the style of Claude Monet (created with DALL·E)

PROMPT: One of DALL·E's variations of *Girl With a Pearl Earring*

11/30/23

AI-Generated Imagery (4/5)

- News headlines

AI-generated images not being labeled as such on Adobe Stock

- Photorealistic AI-generated image of an explosion in Gaza appeared on websites without indication that it was fake
- Adobe Stock to crack down on AI-generated images that seem to depict real events and take steps to prevent its images from being used in misleading ways

Agency creates an AI model to replace influencers

- Could help small companies that can't afford big advertising campaigns
- Designer's goal was to "make a better living and not be dependent on other people who have egos"
- Concerns of unrealistic standards of perfection

AI-Generated Imagery (5/5)

- <u>Disney poster generator</u>
  - Recent TikTok trend of AI generating Disney-style movie posters sparked copyright concerns when users posted results displaying Disney's logo to social media
  - Bing Image Creator algorithm tweaked to generate a jumbled but still recognizable version of the logo

- Fake trailer for supposed Pixar movie

How have I never heard of this before??

TikTok
@ tony.aube
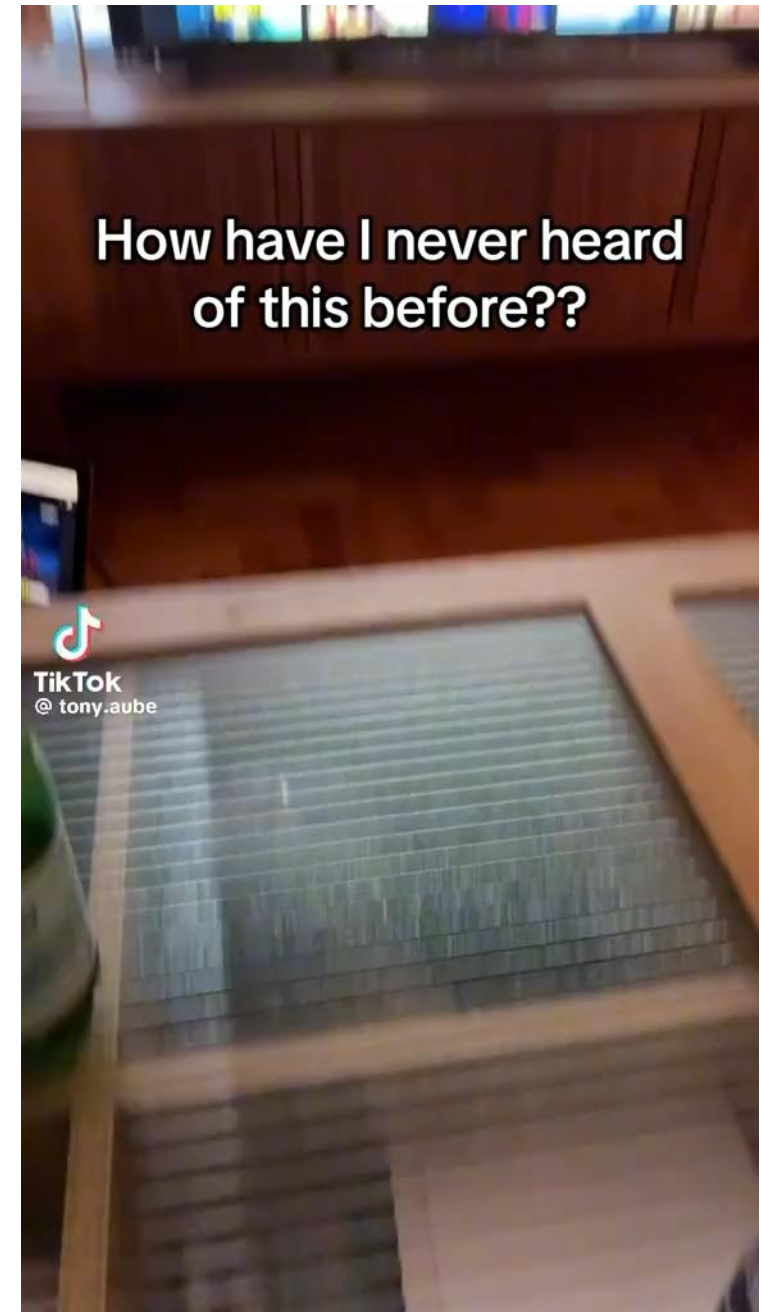
Animation

- Animate: **an·i·mate** from the Latin *animus* meaning to give life to
- Sequence of images (film is 24 frames/second) seen as continuous (persistence of vision)
- Early examples:
  - Flipbooks – see this video
  - zootropes
- Traditional Animation Process – Disney factory model
  - storyboard
  - key frames drawn
  - intermediate frames filled in (*inbetweening*)
  - trial film is made (pencil test)
  - pencil test frames transferred to celluloid cels, in layers

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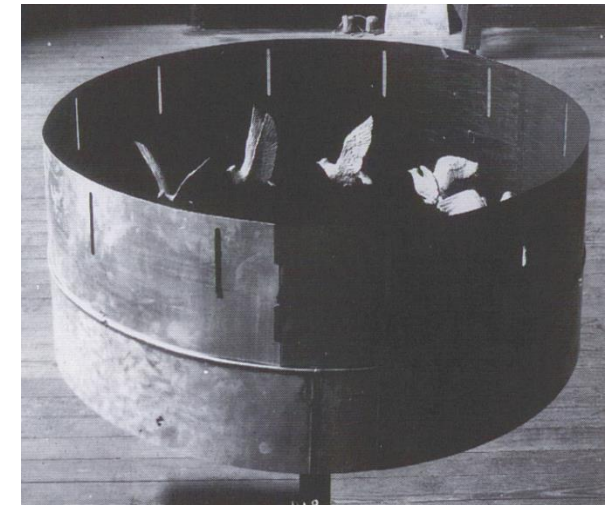
Examples

Pixar: "Elemental", "Inside Out", "Finding Dory"

Performance animation and motion capture

Andy Serkis

3D Keyframing (Luxo Jr.)

Walt Disney Studios

Zoe Saldana
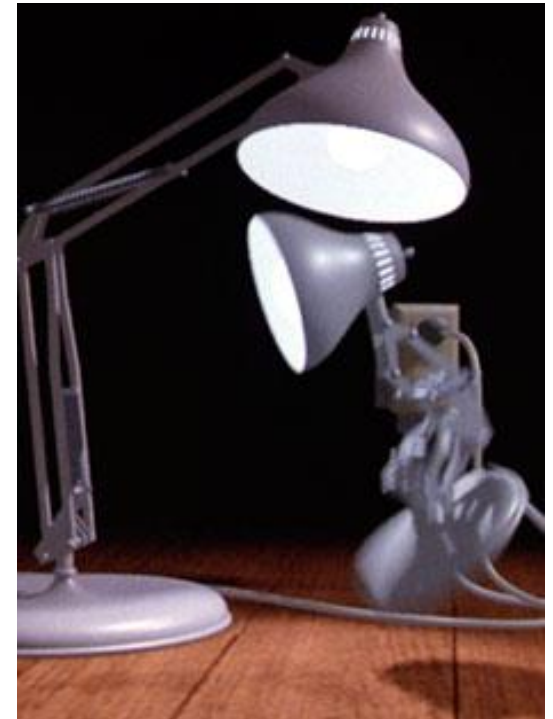
Some Shorts!

Monsters University Trailer:

Soul Trailer:

Luxo Jr.

Geri's Game

For the Birds

Piper

Physically-Based Animation

Cartoon Physics

• Roadrunner's anticipation

• Squash and Stretch

Physics Simulation

• Clothing (Geri's Game)

• Balloons (Up)

• Water (Finding Nemo)

• Hair (The Incredibles)

• "Rigid" body physics (crashing space pods in Phantom Menace)

Animator-Assisted Inverse Kinematics

• "Optimal" motion

• User specifies keyframes

• User specifies constraints

• System searches for minimum energy motion to accomplish goals
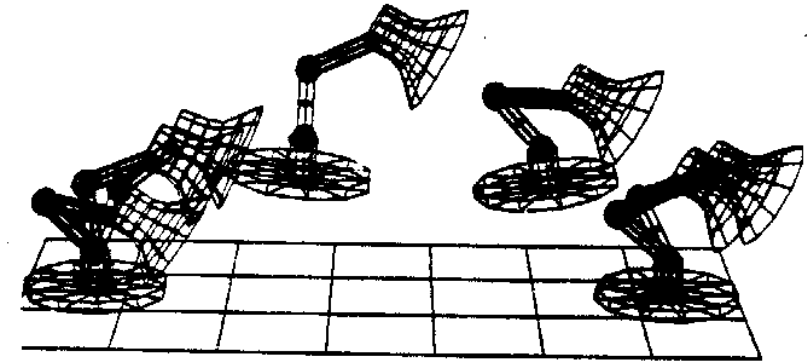
State of the Art in Rendering: Realtime Ray Tracing

Forza Horizon 5

Real-time Interaction, Animation, and Rendering: Marvel's Spider-Man 2

https://youtu.be/ayeQ3CTLIMU?feature=shared&t=24

GPU Based Game Engines

- Unreal Engine

- Unity

https://youtu.be/-n58sQqdmA0?feature=shared&t=26

https://youtu.be/KpPx_lvthBQ?feature=shared&t=4

UI/UX Key to Productivity and Enjoyment

- Many apps have reached point of diminishing returns on functionality and features. Aesthetics and usability have become a differentiating factor – Pareto's 80/20 principle applies to number of features!

- Ease of use and fluidity, aesthetics and enjoyment, are dominant criteria now

- Multiple faculty and courses including the intro **CS 1300** ***has CS0200 and CS0320 as prerequisites.***

Design is not just what it looks like and feels like. Design is how it works.
-Steve Jobs

User Interface – WIMP

- ### WIMP: Windows, icons, menus, and point-and-click interfaces

- ### Microsoft Word worst case ;)

- ### WIMP GUIs work well, but…

  - o no gestures

  - o no speech

  - o no 3D

  - o limited audio

  - o limited tactile
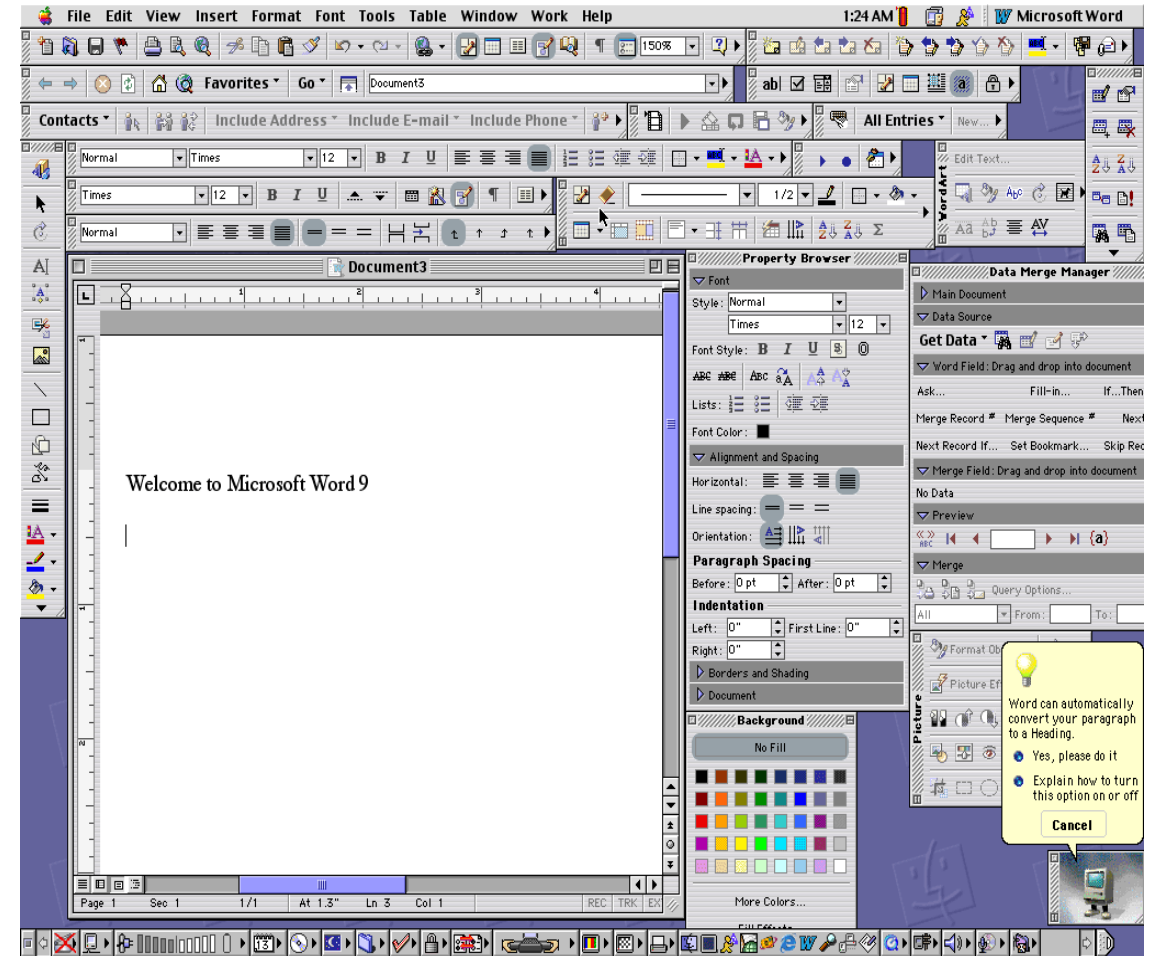
Computer power vs. brain power

Compute → Graphics → UI

Computing Capacity "Moore's Law"

Human Capacity
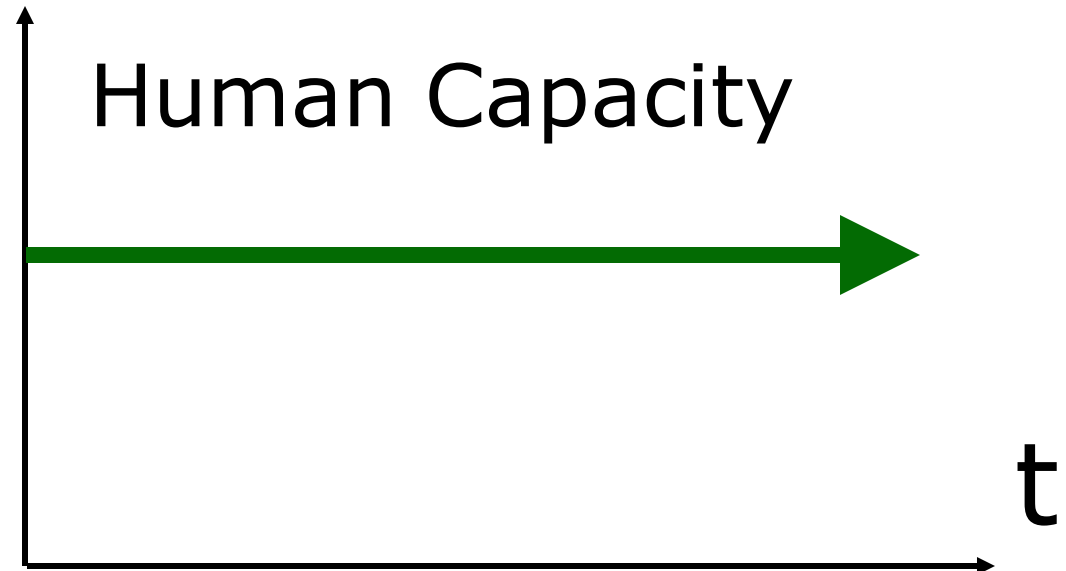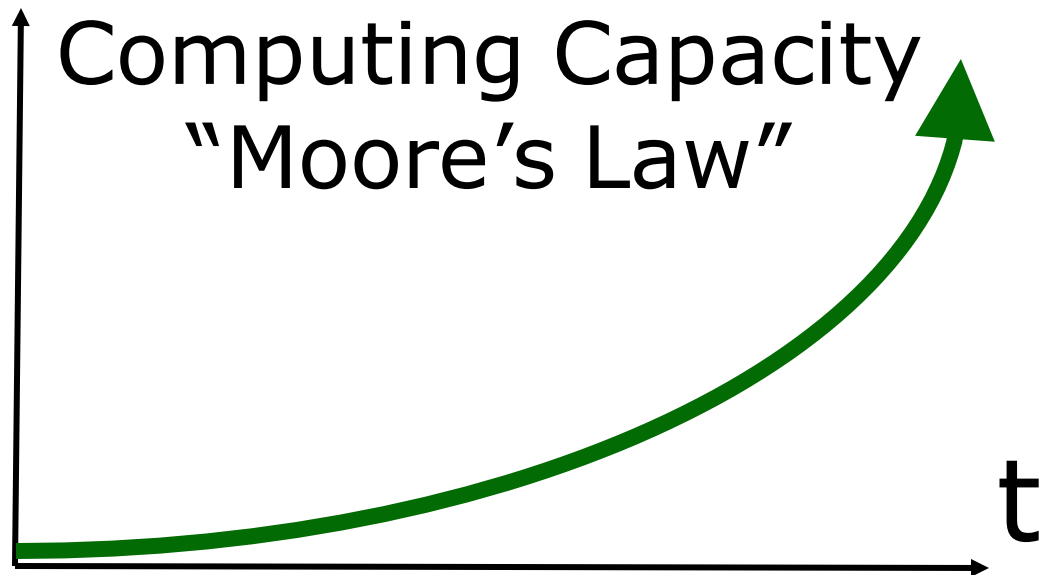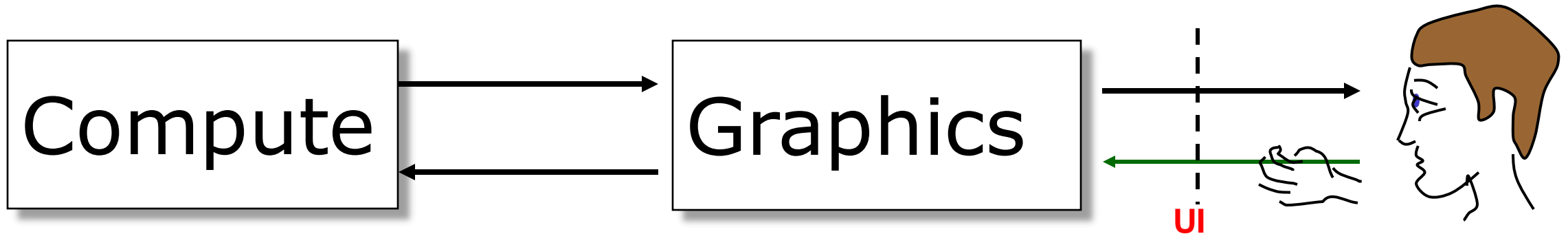
Use compute power in UI to increase b/w to the brain

Courtesy of Bill Buxton

Post-WIMP Multi-Modal UIs: gestures via pen, touch; audio in/out; haptics (force feedback,…), game controllers…

WIMP UI ⟶ Post-WIMP UIs
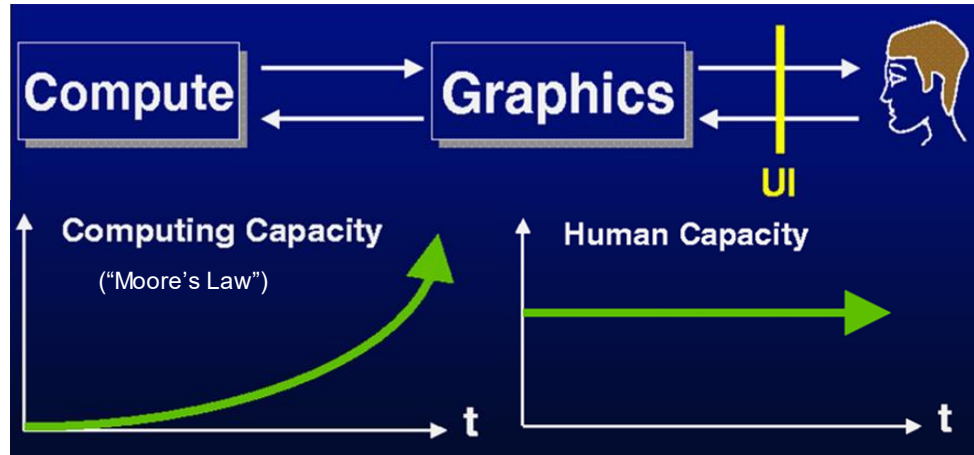
Goal: Increase B/W to the brain

Ubiquitous Computing

- Sensors everywhere
- Storage & computation in the cloud
- Internet of Things (IoT)

Multi-touch displays: smart phones, tablets, whiteboards,…WIMP augmented by post-WIMP pen and touch gestures

The AIDS Quilt in Touch Art Gallery (TAG)

- 54-ton, 1.3 million-square-foot, 22 acres patchwork quilt made as a memorial to and celebration of the lives of people who have died of AIDS-related causes

- Early version of TAG used to display the quilt in Summer 2012 at the National Mall, Washington D.C.
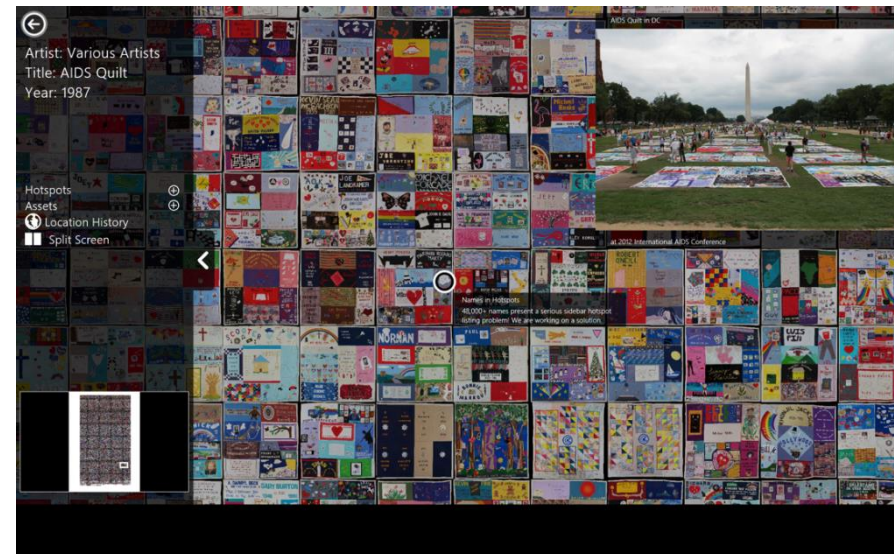
Computational Photography: Intersection of Computer Graphics, Image Processing, Computer Vision, and ML

- Beautifying images by eliminating distractions, selectively enhancing, filling in missing detail, and other tricks we used to do in the dark room with real film: "Photoshopping", machine learning from millions of images
  - https://youtu.be/gg0F5JjKmhA?t=4
- Image composition is popular in art world, as well as in tabloid news
- Takes parts of several images and creates single image
  - hard part is making all images fit together naturally
- Artists can use it to create amazing collages and multi-layered effects
- Tabloid newspaper artists can use it to create "News Photos" of things that never happened – "Fauxtography". Worse, "deep fakes"
  - Trump is right about at least one thing: you can't believe what you see. There is no absolute visual truth in media => use trusted sources (and even then, be cautious!)

Image Composition — Frankenface (1/2)

Aseem Agarwala, Mira Dontcheva, Maneesh Agrawala, Steven Drucker, Alex Colburn, Brian Curless, David Salesin, Michael Cohen. **Interactive Digital Photomontage**. *ACM Transactions on Graphics (Proceedings of SIGGRAPH 2004)*, 2004.
http://grail.cs.washington.edu/projects/photomontage/

Image Composition — Frankenface (2/2)

Aseem Agarwala, Mira Dontcheva, Maneesh Agrawala, Steven Drucker, Alex Colburn, Brian Curless, David Salesin, Michael Cohen. **Interactive Digital Photomontage**. *ACM Transactions on Graphics (Proceedings of SIGGRAPH 2004)*, 2004.
http://grail.cs.washington.edu/projects/photomontage/

Deepfakes (1/4)

- **Deepfakes**: AI-manipulated videos that take an existing text or video, and make it appear that it is being spoken by another person

  - These algorithms can match the appearance, mannerisms, and vocal patterns of the target

- There are many applications of this technology, some of which are not malicious

  - A company called Synthesia worked with David Beckham to create a deepfake video to spread Malaria awareness in 9 different languages

Deepfake Tom Cruise (TikTok)

https://youtu.be/QiiSAvKJIHo?feature=shared&t=5

Deepfakes (2/4)

- However, many worry that **deepfakes** will contribute to the ongoing spread of misinformation and fake news.

https://youtu.be/oxXpB9pSETo?feature=shared

https://youtu.be/X17yrEV5sl4?feature=shared

The threat of **deepfakes** is of growing concern with the upcoming 2024 election cycle:

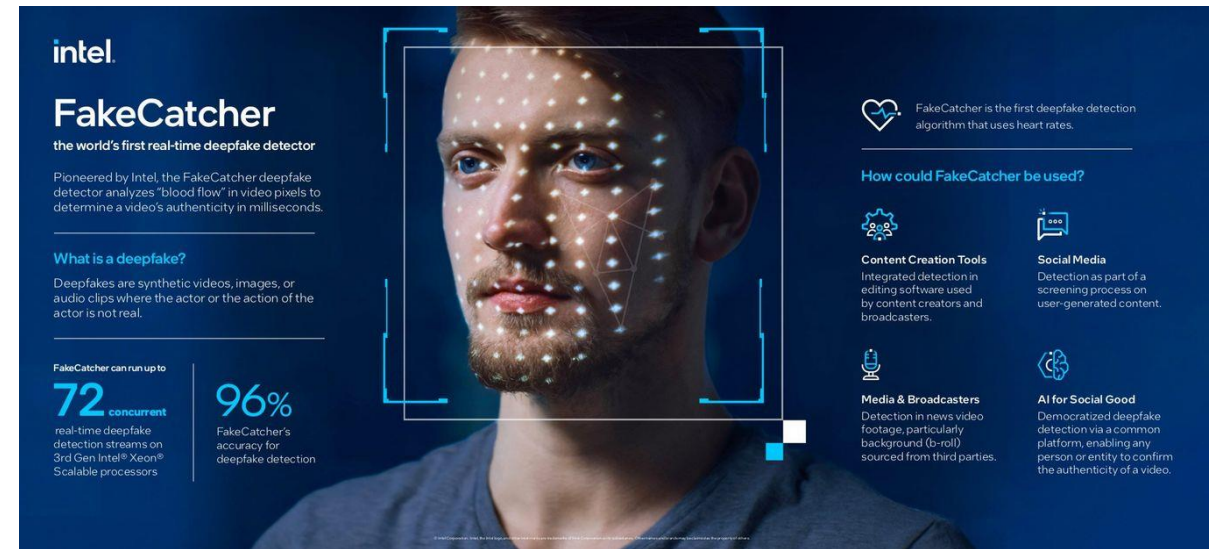 o The Federal Election Committee recently proposed a ban on deepfakes and AI generated imagery in campaign ads, and members of congress sent a letter to the CEOs of Meta and X, expressing "serious concerns" about the emergence of AI-generated political ads on their platforms.

Source: https://apnews.com/article/election-deepfakes-ai-x-twitter-facebook-meta-instagram-d52e8703a9e47936061bf2c8bbc94bb5

Deepfakes (3/4)

Deepfake detection software developed by Intel

- Companies like Intel and Microsoft are developing software to catch deepfakes with comparisons to real videos using features such as lighting, blinking patterns, blood flow, etc.

Source: https://spectrum.ieee.org/deepfake

- Lawmakers have also started to respond to this rising threat

  - U.S. Representative Yvette Clark introduced the **Deepfakes Accountability Act**, that would require creators to label all deepfakes uploaded online and disclose any alterations made to a video or other type of content.
    - This bill was first introduced in 2019 and reintroduced in 2023 but has yet to pass.

  - California, New York, and Virginia have all passed state laws prohibiting the distribution of non-consensual, sexually explicit deepfakes online.

Source: https://www.responsible.ai/post/a-look-at-global-deepfake-regulation-approaches

Deepfakes (4/4)

- It is easy to create Deepfakes

  o Lucy Reyes (former HTA) created a model that generated fake images of celebrities

    ▪ model is trained on 202,599 images of celebrities

    ▪ learns to generate "fake" images of celebrities until discriminator can't tell whether image is real or fake

      – model generates low resolution images

  o Online software allows people to make deepfakes

    ▪ Zao, Chinese App able to create Deepfakes in seconds.
      – user chooses a video clip from app's library
      – app creates a seemingly authentic deepfake video, indistinguishable from original video

    ▪ Deepfakes Web requires just two videos (and optional images) for training
      – Generates a video where the subjects' faces are swapped
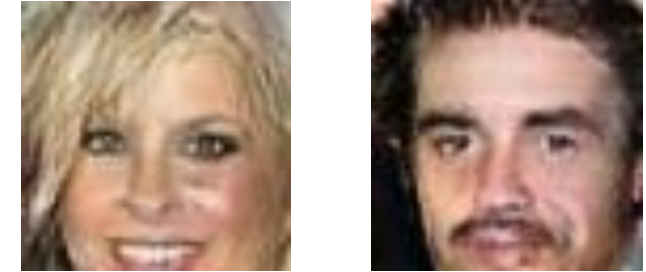
Augmented and Virtual Reality: Computer Generated Sensory Experiences

- Virtual Reality: purely 3D computer-generated environment in which the user is immersed
- Augmented Reality: superimposed computer generated imagery on 3D real environment
- Computer-generated **head-tracked stereo** image updated in real-time in response to the user's viewpoint
- Spatial 3D sound enhances the experience of **immersion** (being "in" the scene) and **presence** ("being there")
- We're wired for 3D, and the visceral feeling overrides cognitive processing

https://youtu.be/nX-FpMARbvs?t=40

IVR (Immersive Virtual Reality), Potential Benefits

- Leverages human pattern recognition ability

- Provides:
  - global context through peripheral vision
  - qualitative difference between 'looking at' (through a small display window) and 'being in the scene

- Easier to see 3D spatial relations: body-centered judgments
  - kinesthesia and proprioceptive actions enhances ability to grok 3D environments
  - navigate by moving body (not mouse), walking, + grappling hooks, teleporting, and other magic
  - size, distance, and angle judgments easier, more like in real world
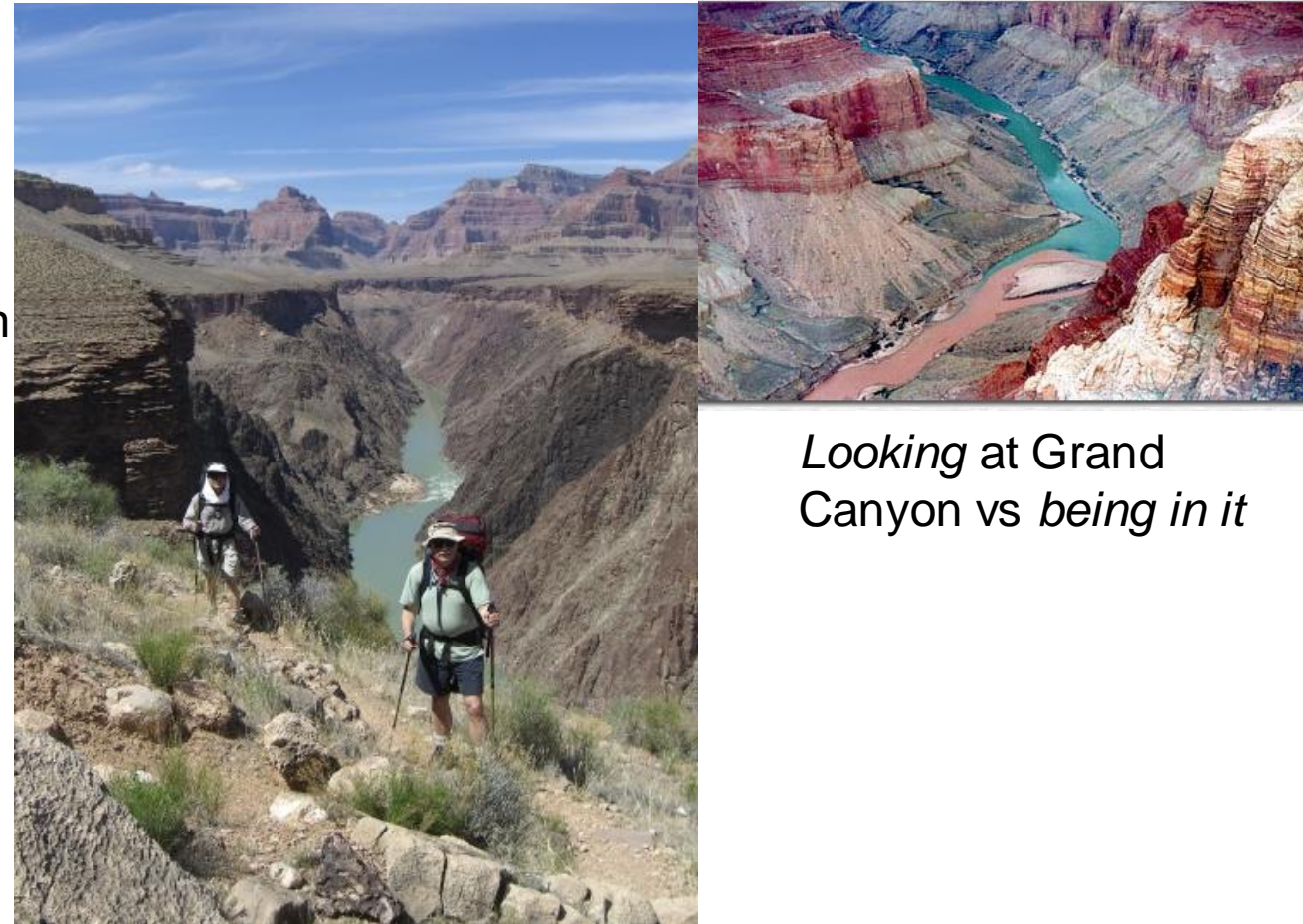
Looking at Grand Canyon vs *being in it*

Augmented Reality – computer generated overlay on the real world, via Smart Phone or Headset
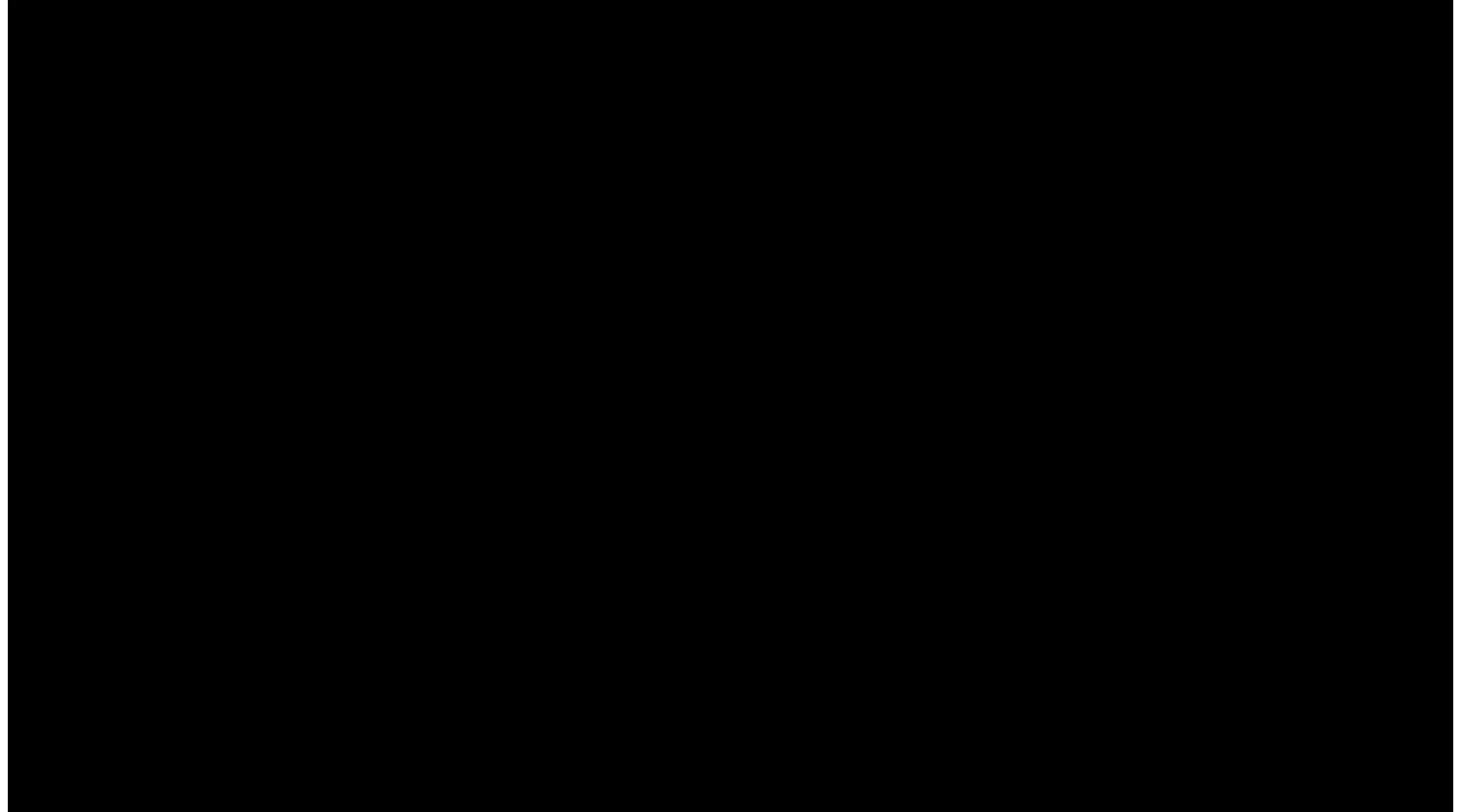
Virtual Reality – illusion of immersion via head tracked stereo, wands and other interaction devices

- We are currently witnessing the rebirth of Virtual and Augmented Reality, mostly for games
- Many offerings from many companies, e.g.,
  - VR: mostly HMD's (head mounted displays)
    - e.g., Meta Quest 4, Apple Vision Pro (coming 2024)
    - headgear was heavy and uncomfortable, and dis-embodiment and lag/latency/swim can lead to cybersickness – vastly improved in today's gear
  - AR: not disembodied, more comfortable for most people
  - at the other end of the spectrum of AR: CAVE™s
    - used to be one at Brown

Birdly Virtual Reality Simulator

The Metaverse(1/3)

- ## What is a metaverse?

    ○ term coined by Neil Stephenson in his sci-fi novel **Snow Crash** (1992)

    ○ a shared, persistent, immersive 3D virtual environment or network of environments in which users can interact with computer-generated objects, other users and AI agents
    – laws of physics need not be obeyed (gravity, space-time, causality, …)

    ○ a user interface typically will be multi-modal (controllers, gestures, speech, gaze, …)

    ○ decentralized in nature; may be aided technology such as blockchain

    ○ use cases that simulate activities such as sports, commerce, social gatherings, movies, …

    ○ early desktop examples: MMORPGs (WoW,…), Linden Lab's Second Life (2003)

    ○ And lots of sci-fi: Gibson's cyberpunk **Neuromancer** (1984), The **Matrix** films, …

    ○ There is no current example of a Metaverse satisfying these criteria–still working on the technology and GAI has overtaken it as the "Next Big Thing"

The Metaverse(2/3)

- current versions of them
  - Roblox
    - Brown Ph.D. Morgan McGuire is Chief Scientist
    - online game platform and game creation system
    - 3D non-stereo (non-immersive)
    - Allows users to create communities and interact within them
    - Now available on the Meta Quest 3 headset
  - The Sandbox
    - virtual world where players can build, own, and monetize their gaming experiences
    - in the Ethereum blockchain and created by the same people

Roblox (released 2004)
Gained popularity for its engaging online community

The Sandbox (released 2018)
Utilizes NFTs as virtual tokens

The Metaverse(3/3)

- Dominant use-case is still games
- [Fake Demo](#) of how Meta's Metaverse is supposed to look in the future
  - The Comment Section:
    - "This is inspiring. I'm breaking my computer and going out doors."
    - "This feels like the beginning of a Black Mirror episode"
    - "This world would be better if Mark just learned to talk to girls in high school"
- Problems with normal 2D and 3D virtual spaces are exacerbated in in VR
  - interactions with objects, navigation…
  - cybersickness
  - privacy and security in social interactions
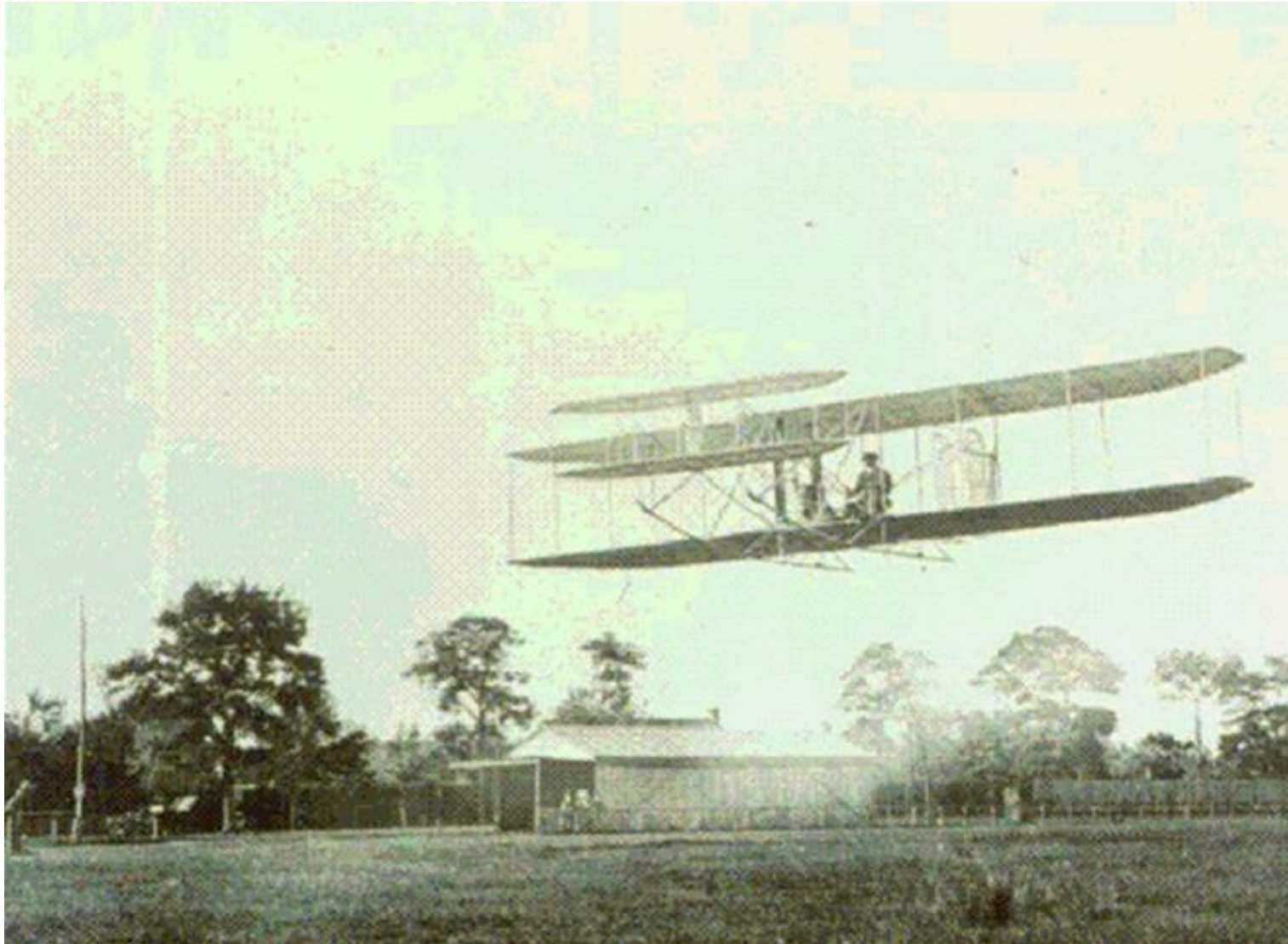 - age appropriateness
  - addiction

Meta Horizon (released 2021)

Rec Room
free online multiplayer game on the Meta Quest

Where Are We Today?

Opportunities in Graphics/Visual Computing (1/2)

- CS123 Graphics with Daniel Ritchie Fall 2024 to learn the basics of graphics technology
  - write ray tracer in C++, Final Projects typically use "shader programming" on the GPU
  - CS224 Interactive Computer Graphics with Daniel Ritchie Spring 2024
- CS1300 User Interfaces and User Experience with Vannessa Cho and Talie Massachi (Spring 2024)
  - requires cs0320 (Fall 2024)
- CSCI 1430 Computer Vision with Srinath Sridhar
  - (Spring 2024) and TBD (Fall 2024)

Daniel Ritchie

Talie Massachi

Vannessa Cho

Srinath Sridhar

Opportunities in Graphics/Visual Computing (2/2)

- Apply for internships at Brown and Beyond

  o [my Dash hypermedia Group for independent studies](#)

  o David Laidlaw's Visualization and VR Group

  o James Tompkin's VR/AR group

  o Jeff Huang's Human Computer Interaction Group

  o Daniel Ritchie's Machine Learning-Based and Procedural Modeling and Rendering group

  o Professors Sridhar and Sun have their own Computer Vision/Machine Learning groups

  o Pixar, DreamWorks, Microsoft, Google, Adobe, Facebook…

  o Games and media companies

  o Strong resumes, transcripts (and portfolios) required
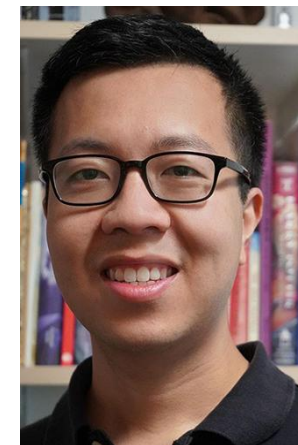
Announcements

- Final Projects
  - code checkpoint due this Sunday, December 3 at conceptual hours. See calendar for when your FP is holding hours. Get checked off early to avoid long lines
- FP Hours
  - you can only sign up for Debugging Hours for the project you specified in the FP Declaration Form
- Come to lecture on Tuesday! The HTAs want you there :)
  - each of the HTAs will present a mini-lecture on their topic of choice (and there may be other surprises as well)!
- SRC extra-credit discussions are happening this Sunday 3th + Monday 5th Dec
  - Details on Ed! Signup deadline is today after class!
    - Seats are limited and will be admitted on a first come, first served basis. (Best presentations win a lunch w/ Andy!)

Some Shorts! (End of Class)

Monsters University Trailer:

Soul Trailer:

Luxo Jr.

Geri's Game

For the Birds

Piper

Attic

Immersive Virtual Reality – the Cave, a 21st Century Holodeck

- Lightweight, head-tracked stereo glasses, various 6-DOF interaction devices

- Brown's old Cave (now in Granoff) was used primarily for scientific visualizations:
  - to explore surface of Mars, blood flow in arteries, bat flight, developmental biology, 4D geometry, etc.
  - as well as for creative arts, e.g., Cave Painting, Cave Writing

An emulation of the Martian surface on Cave of yesteryears
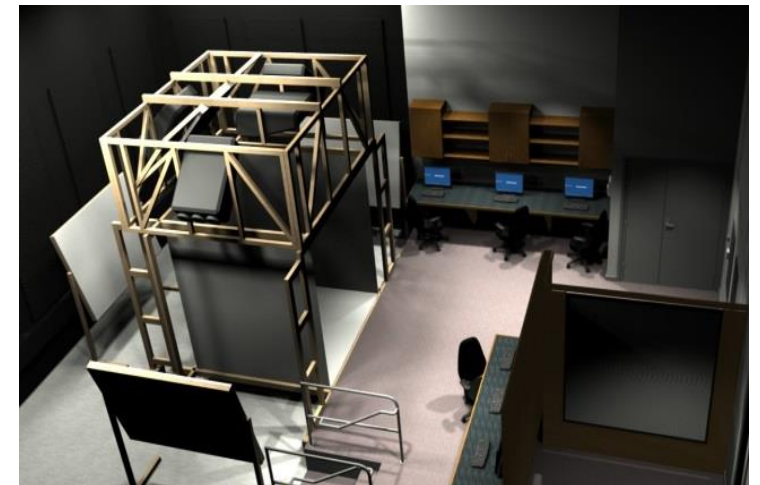
Old Cave

The Garibaldi Panorama

- Touch Art Gallery (TAG) app allows touch interaction with the Garibaldi Panorama, about 270 feet long and 4.5 feet tall, painted on both sides of wallpaper
  - interaction previously very difficult due to size and fragility of artifact – had been in storage unused by Brown for many years
  - allows for exploration, zooming / magnification, clipping, and viewing contemporary documents associated with the artifact
  - produced in conjunction with the Brown Library and Italian Studies department
- Was shown at the British Library in a 9-month exhibition on the future of scholarship and learning
- TAG used in Haffenreffer Museum, Seattle Art Museum, Massachusetts Historical Society (Jefferson exhibition) and New Bedford Whaling Museum for 1300ft x 9ft moving panorama of Whaling Around the World
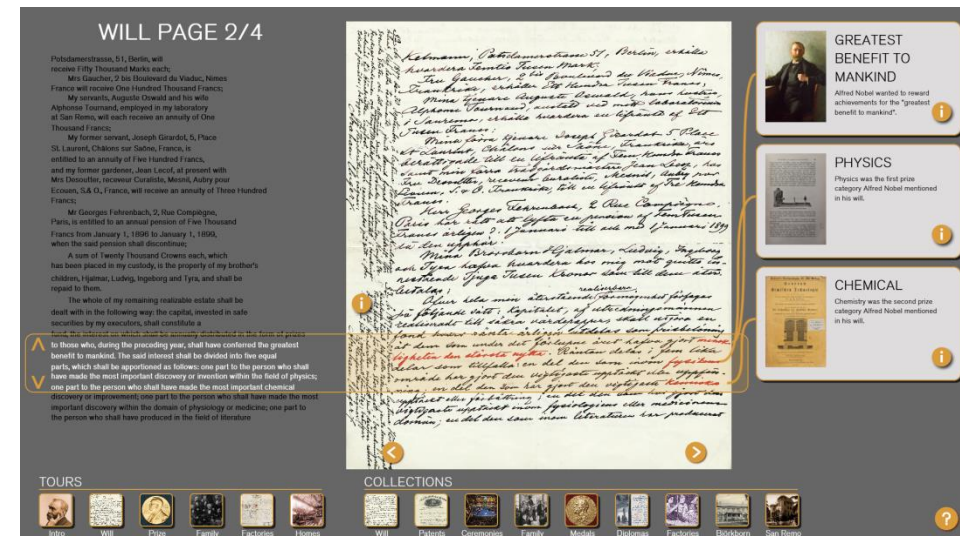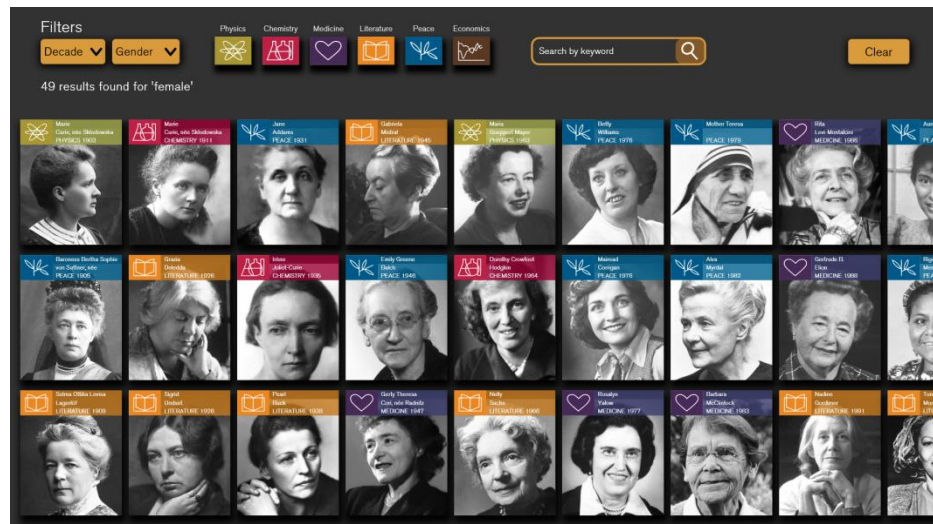

Andries van Dam © 20223 11/29/23
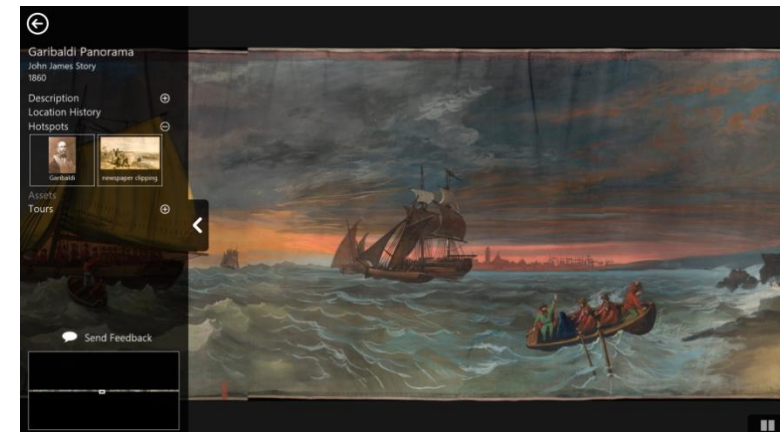
TAG used for Nobel Exhibit in Singapore

- TAG was used in Nobel Prize Exhibition at ArtScience Museum in Singapore
  - also held in Dubai, Goa, India

- Two applications:
  - Laureates Gallery
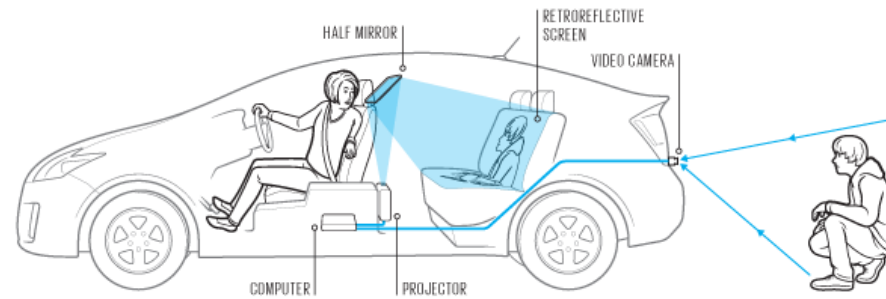 - Alfred Nobel's Will *Experience*

Facebook Computational Photography

- Michael Cohen et. al,
  - ○ Computational Photography Group at Facebook
 - ○ https://youtu.be/NO74A450-N4

# Augmented Reality Helps Drivers See Around Blind Spots

- Inner surface of car becomes window showing outside world

  - projector directs outgoing beam to a half mirror in front of observer

  - part of beam hits retro reflective screen, which reflects most of beam back into observer's eyes

    - full Article: http://spectrum.ieee.org/transportation/advanced-cars/augmented-reality-helps-drivers-see-around-blind-spots/

  - Stefanie Tellex's group using this idea to let people see a manufacturing robot's intentions to help make them safer to be around!

- Video: http://youtu.be/gDk5HdGfuVI

Andries van Dam © 20223 11/29/23

Gestural Interfaces for Tablet PC: FluidMath

- Educational Math Software

  - based on Joe LaViola's Ph.D. dissertation on MathPad^2

  - easily create, solve, graph, and animate math and physics problems

  - accurate recognition of handwritten math

  - interactive creation and exploration of graphs

  - animate hand-drawn diagrams by associating math and sketches

- Available on Tablet PC, SmartBoard, PC, etc. from Fluidity Software, a Brown spin-off

  - http://www.fluiditysoftware.com/index.php?option=com_content&view=article&id=27&Itemid=7

- Also did ChemPad, Music NotePad, SketchPad
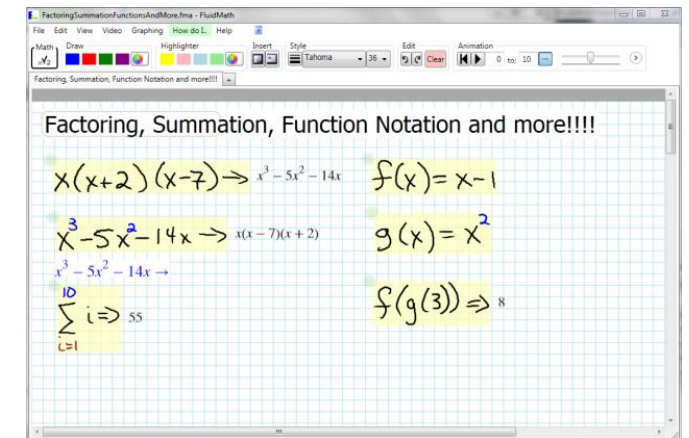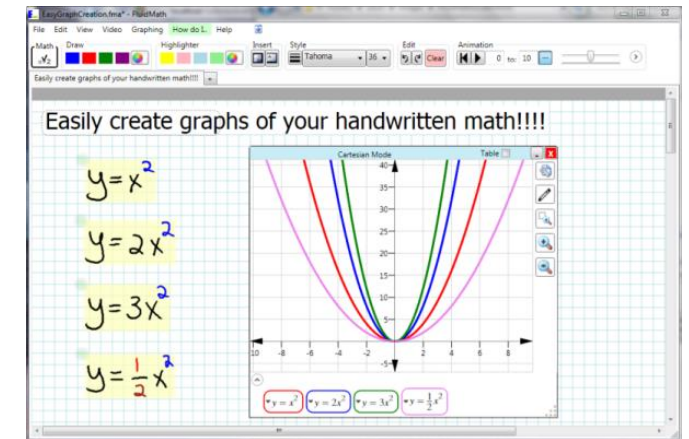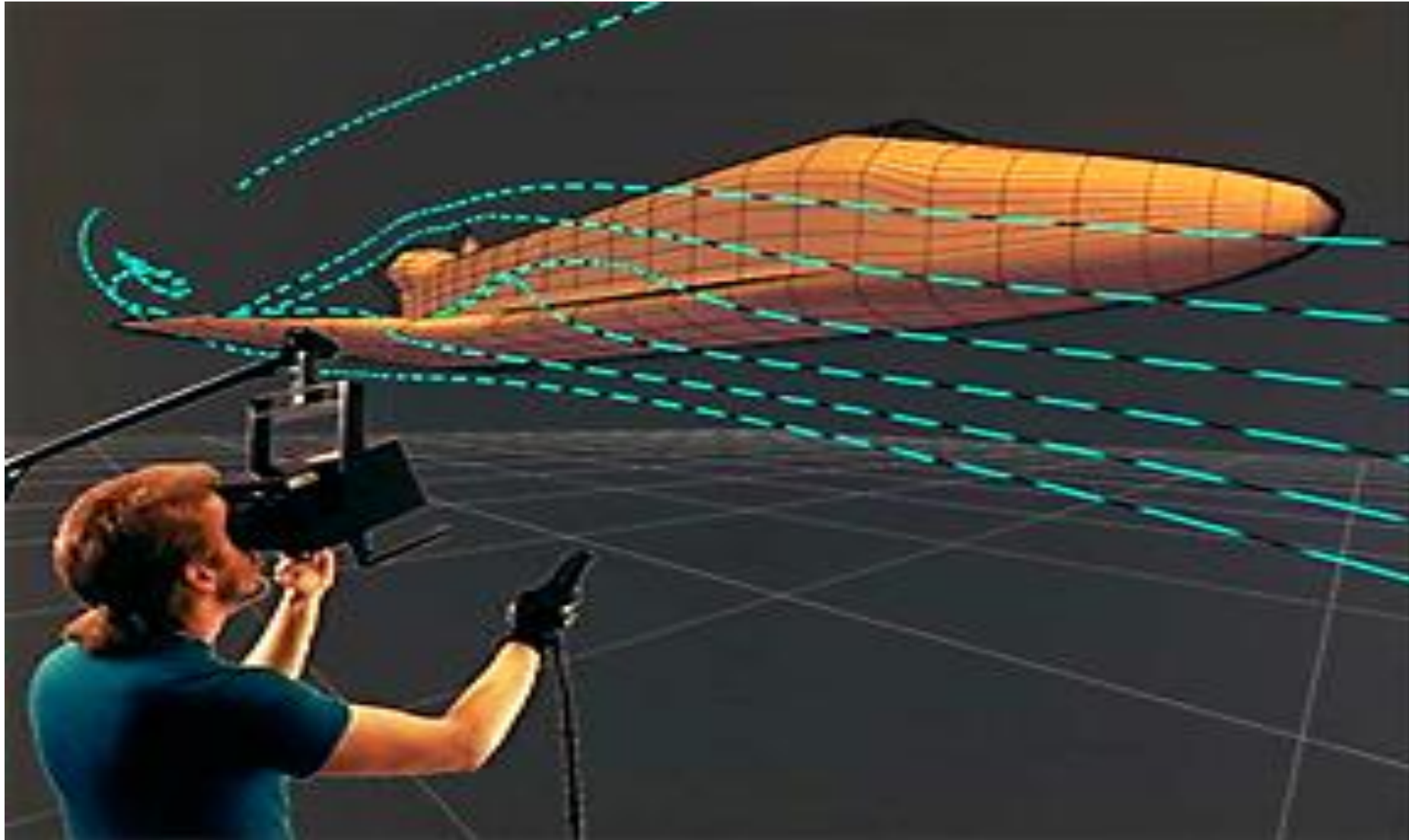
1990's Virtual Reality

Dr. Steve Bryson, NASA, using FakeSpace Boom to visualize air flow around a model of a space shuttle

The Cave's successor – the YURT (being decommissioned!)

- YURT Ultimate Reality Theatre
  180 George Street
  (Center for Computation and Visualization)

- 16' diameter hemi-cylinder, 8.5' walls, 10' doors, conical ceiling

- 69 projectors, each 1920 x 1080 resolution and ~40 dpi; at least 115,000,000 pixels in total

- 120 Hz field-sequential stereo with LCD shutter glasses

- front screen yields near 20/20 vision

- camera-based head-tracking
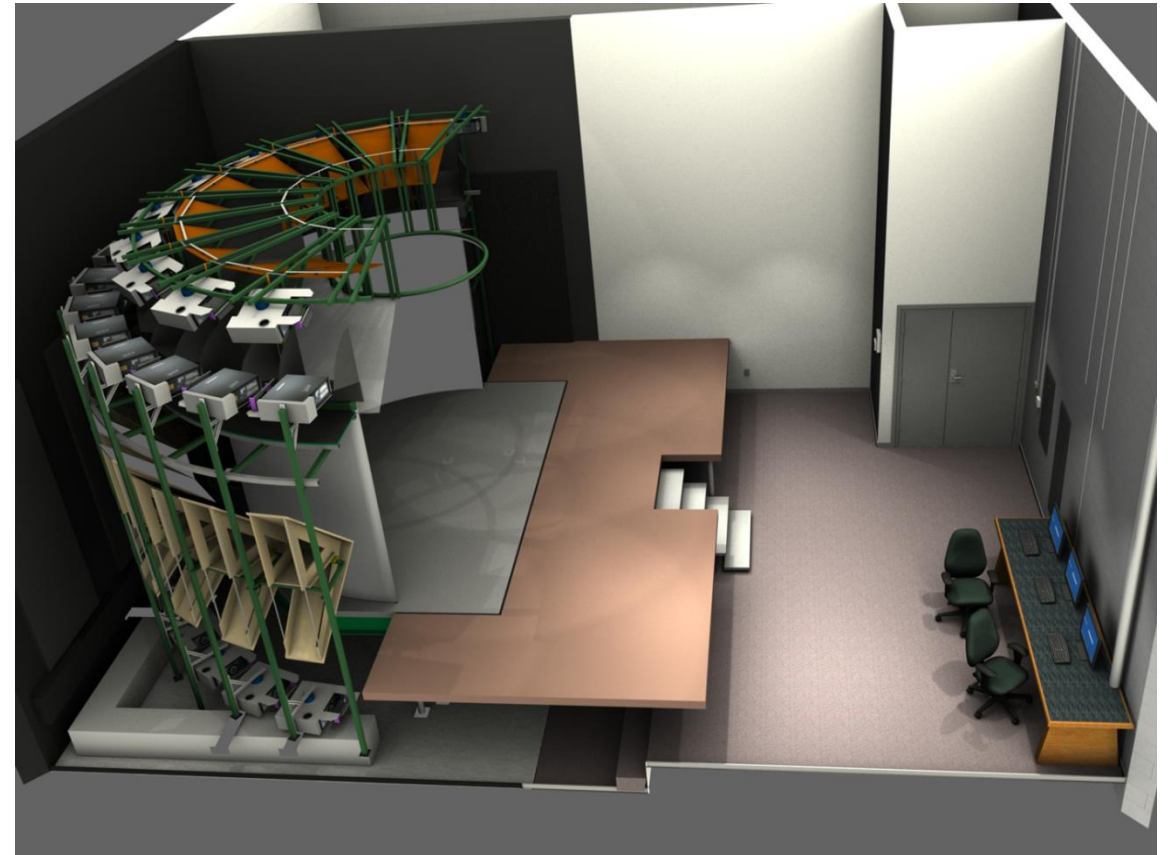
- wands as pointers and tricorders

Image from Anne Keyon's November 5, 2013 talk on the Cave.

https://www.bostonglobe.com/lifestyle/style/2015/06/19/brown-university-unveils-virtual-reality-room/QoTOOp66NpPZeGMF0bapjO/story.html

The YURT

Ben Knorlein demonstrating the Hypercube program
photographed in the Yurt
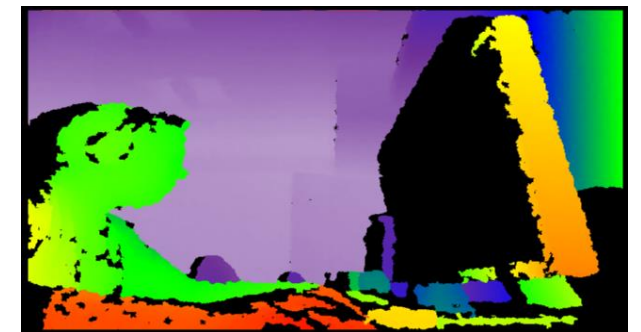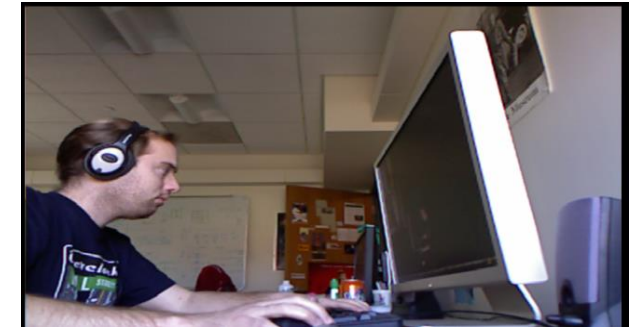by Gretchen Ertl for the Boston Globe

Prof. David Laidlaw photographed in the Yurt
by Gretchen Ertl for the Boston Globe

Kinect

- Motion sensing input device introduced by Microsoft for XBOX and Windows PCs

- Enables users to control and interact with the XBOX without the need to touch a game controller, through a natural user interface (NUI) using gestures and spoken commands

- Features an RGB camera, depth sensor, and microphone running proprietary software, which provide skeletal motion capture, facial recognition, and voice recognition capabilities

- Check out the video:
    - http://www.youtube.com/watch?v=Hi5kMNfgDS4
    - https://www.youtube.com/watch?v=IhaycgyFt2U

XBOX One Kinect

Above: Original Picture
Below: Kinect finds depth map using infrared lasers

Images from http://graphics.stanford.edu/~mdfisher/Kinect.html

Post-WIMP User Interfaces – at the limit

Haptic Devices

Neuroprosthetics (major research at Brown - BrainGate™)
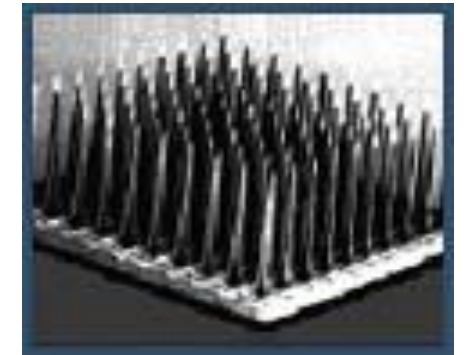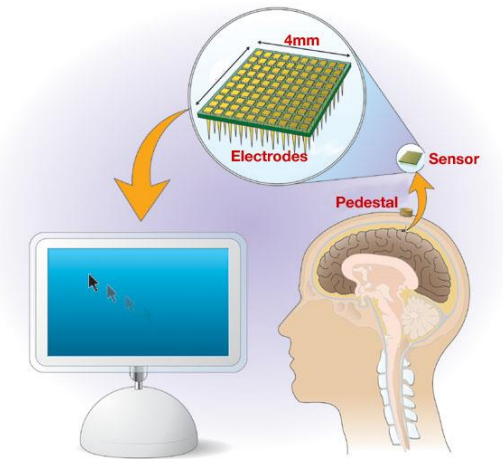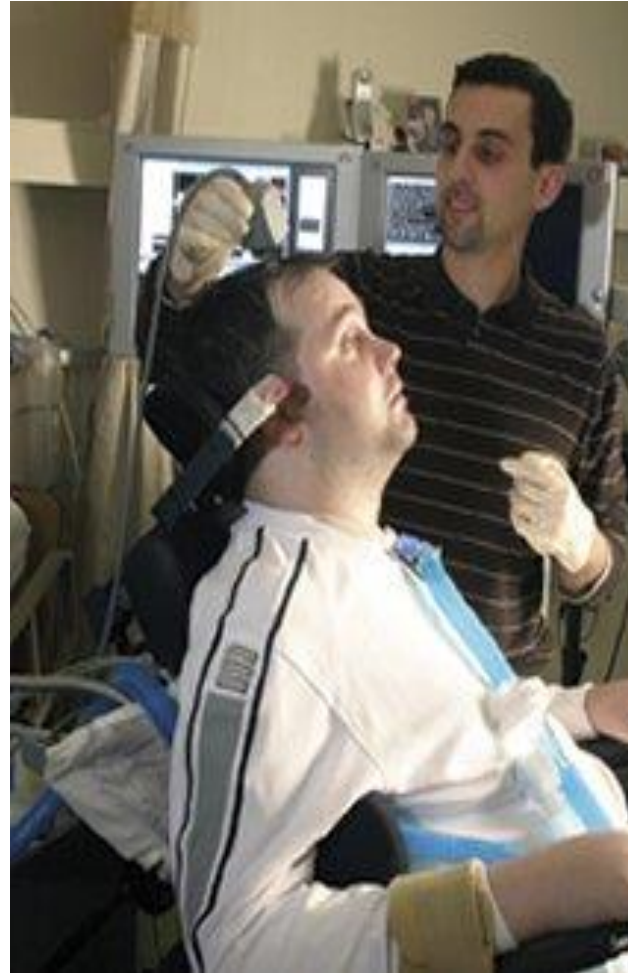
Morphing

- This year is the 27th anniversary of Barbara Meier's use of morphing
- This was a groundbreaking innovation in the field of computer science!
- Barb Meier was a major contributor to the morphing of face sequences in Michael Jackson's "Black or White" music video

Augmented Reality – Google Glass

- What it did (now discontinued)

  o fitness tracking

  o turn-by-turn navigation

  o sports data

    ▪ golf: club speed, ball position, distance

  o hands free messaging

- Features

  o voice control

  o highly customizable appearance

  o video camera

Related Article:
http://techcrunch.com/2014/11/15/as-developers-depart-google-glass-is-ready-to-become-this-eras-segway/
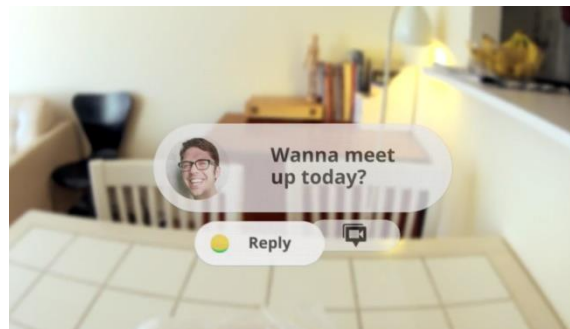
VR in Media

- The idea that reality is a computer simulation has always been popular in science fiction
- In the second half of the 20th century, the concept of virtual reality "headsets" showed up
- Literature
  - Daniel F. Galouye's Simulcron-3 (1964)
  - Neal Stephenson's Snow Crash (1992)
  - Ready Player One (2011)
- Films
  - Welt am Draht (World on a Wire) (1973) (based on Simulcron-3)
- Star Trek's Holodeck (first appeared in 1974) was inspired by work with holograms from the 60s

The Ultimate Display

The computer can easily sense the positions of almost any of our body muscles. So far only the muscles of the hands and arms have been used for computer control. There is no reason why these should be the only ones, although our dexterity with them is so high that they are a natural choice. Our eye dexterity is very high also. Machines to sense and interpret eye motion data can and will be built. It remains to be seen if we can use a language of glances to control a computer. An interesting experiment will be to make the display presentation depend on where we look.

For instance, imagine a triangle so built that whichever corner of it you look at becomes rounded. What would such a triangle look like? Such experiments will lead not only to new methods of controlling machines, but also to interesting understandings of the mechanisms of vision.

There is no reason why the objects displayed by a computer have to follow the ordinary rules of physical reality with which we are familiar. The kinesthetic display might be used to simulate the motions of a negative mass. The user of one of today's visual displays can easily make solid objects transparent - he can "see through matter!" Concepts which never before had any visual representation can be shown, for example the "constraints" in Sketchpad [2]. By working with such displays of mathematical phenomena we can learn to know them as well as we know our own natural world. Such knowledge is the major promise of computer displays.

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.

- Ivan Sutherland, "The Ultimate Display" (1965)
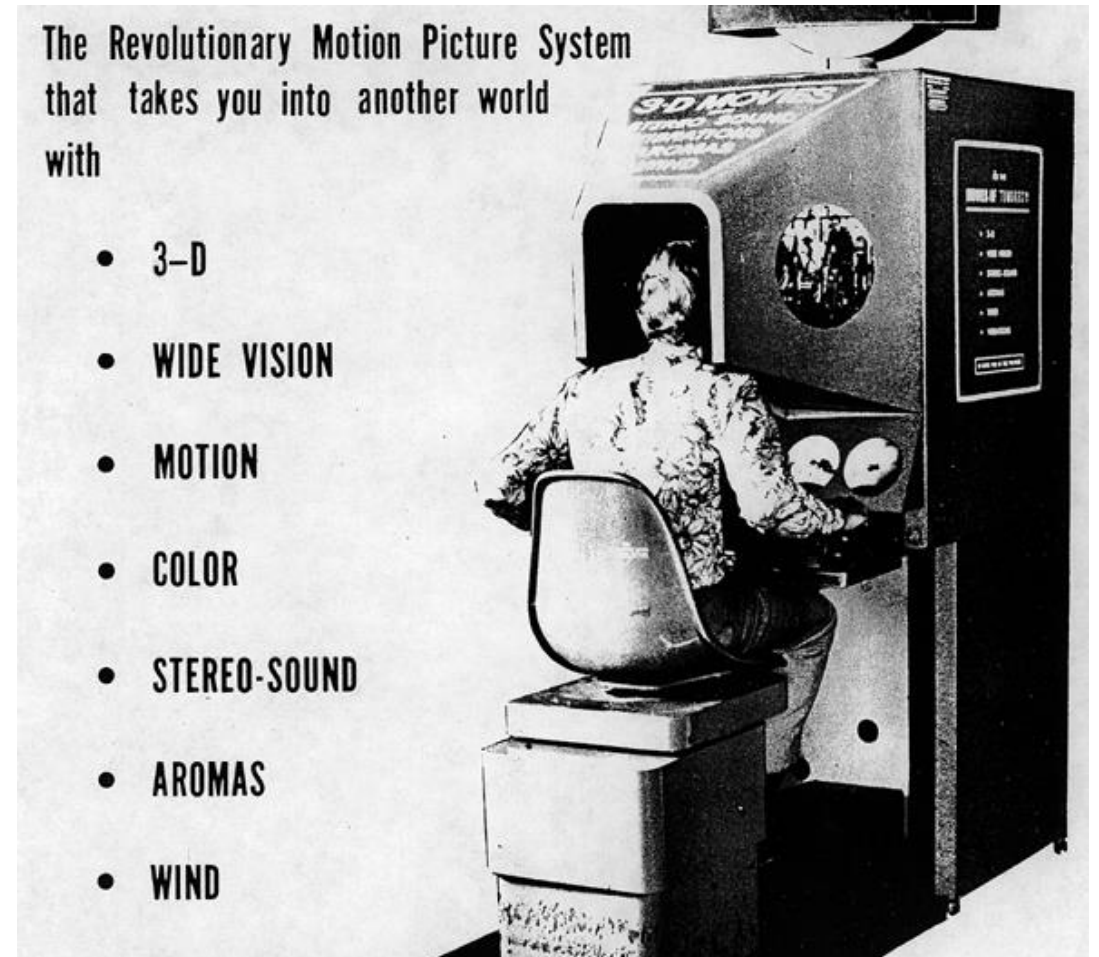
Gestural Interfaces for Tablet PC: MathPad²

- Mathematical sketching
  - combine handwritten math and freeform diagrams
  - math expression recognizer
  - graphing
  - uses MATLAB® as underlying math engine

- Diagrams animate according to associated math expression(s)

- Fully gestural interface for editing
  - expressions can be deleted, edited, and re-recognized
  - modeless operation
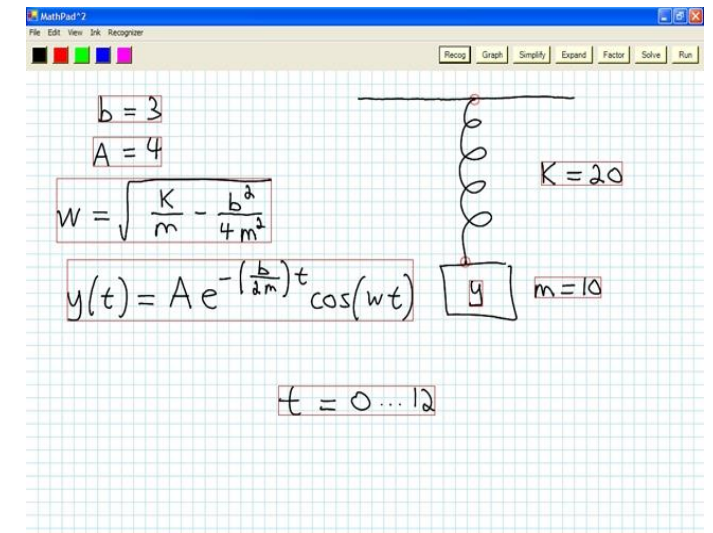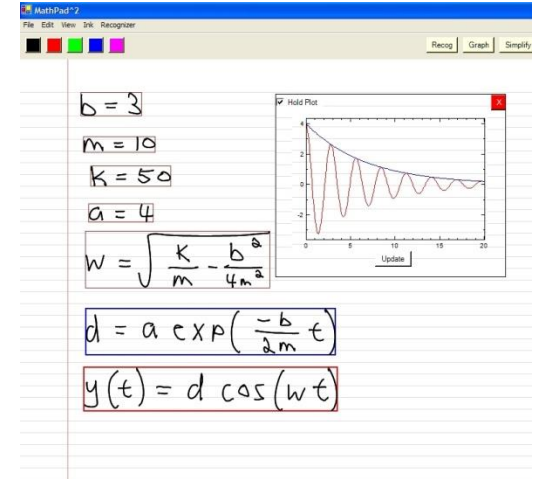
VR History (1/5)

- "Sensorama" created by Morton Heilig in the 1950s
- Provided immersive film experiences that stimulated multiple senses
  - sound
  - sight
  - smell
  - touch
- Heilig produced six short films to be experienced in the Sensorama
- Non-interactive, no motion tracking

The Revolutionary Motion Picture System that takes you into another world with

- 3-D
- WIDE VISION
- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND

VR History (2/5)

- "The Sword of Damocles" created by Ivan Sutherland (creator of "Sketchpad") in 1968

- Considered the first IVR HMD

- Rendered 3D wireframe geometry

- Tracked head motion, but had no other interactivity

- Had to be suspended from the ceiling and held up by a mechanical arm to be used
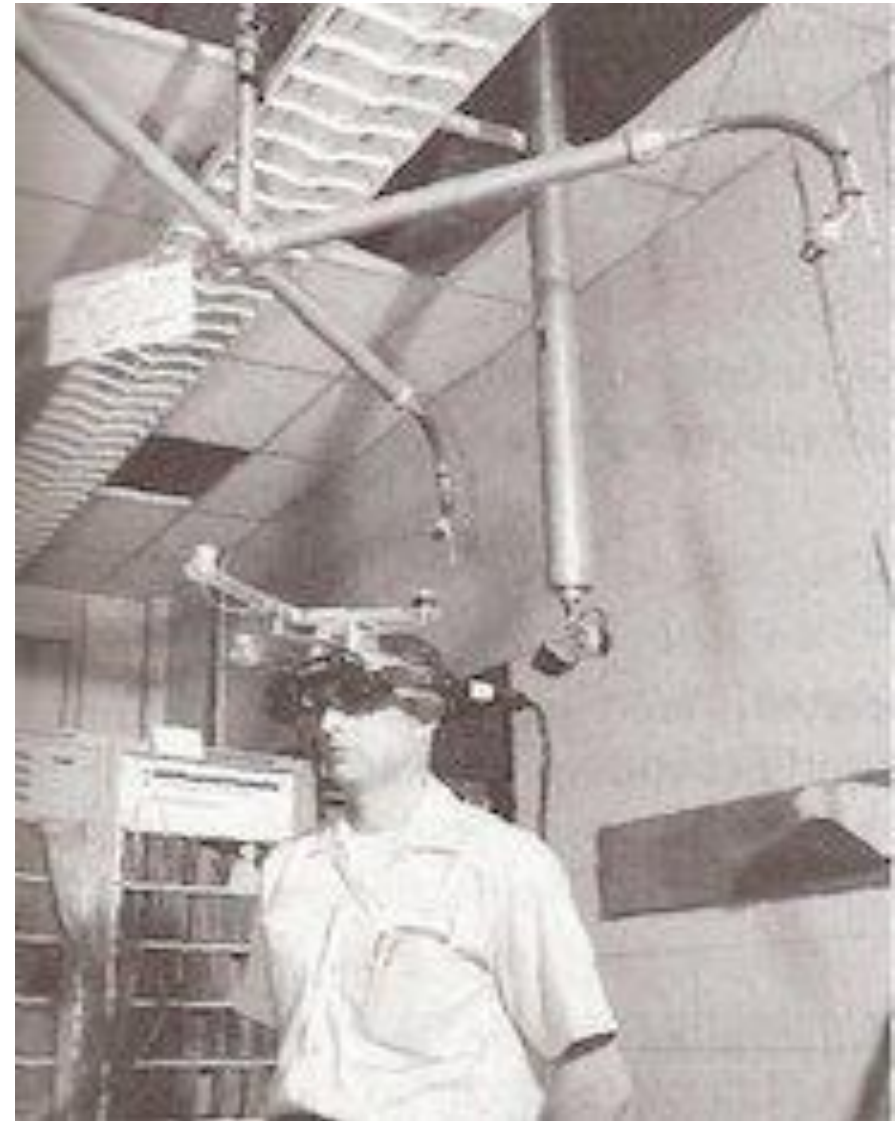
VR History (3/5)

- Jaron Lanier's EyePhone and Thomas Zimmerman's DataGlove
- They formed VPL (Visual Programming Languages) Research (1984 – 1990)
- Attempted to design a visual programming language to make programming more accessible
- Technological limitations, 5-6 FPS
- Sega VR (1993) and Nintendo Virtual Boy (1995)
- First attempts by large industries to make an IVR HMD that accompanies a console system
- Both bombed
  - technical difficulties, poor rendering
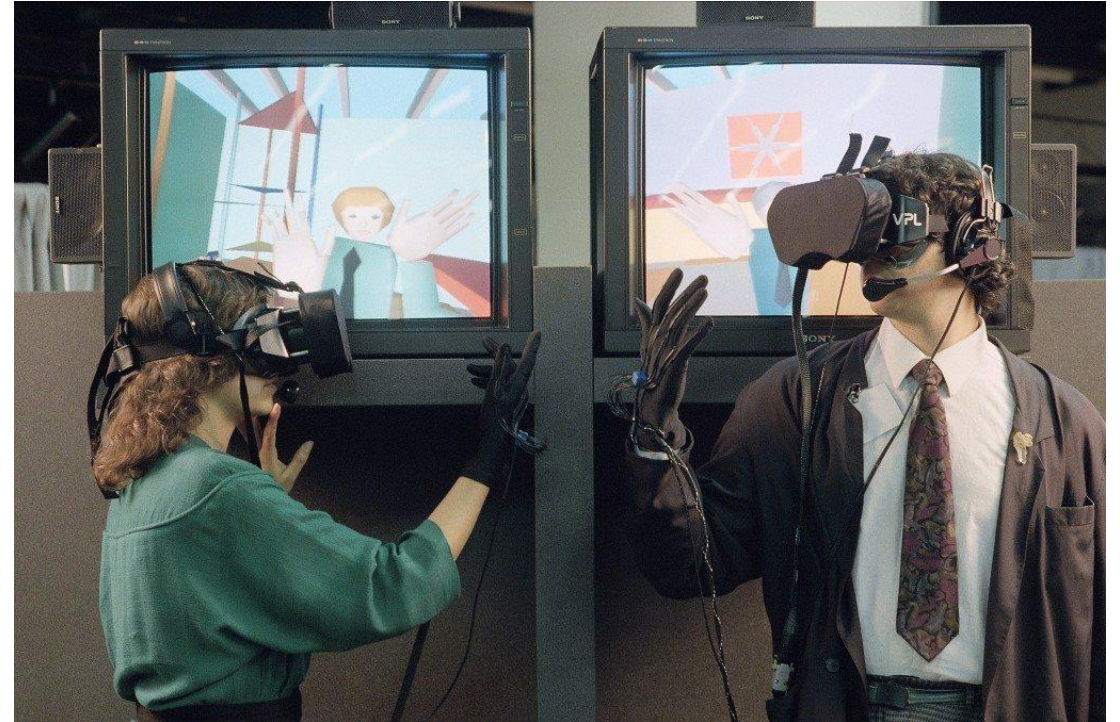
VR History (4/5)

- Google Cardboard (2014) and Gear VR (2015)

- Take advantage of smartphones to provide a relatively inexpensive VR solution

- Limited by hardware and processing power
  - exists in a different tier than modern PC and console-based VR systems
  - meant to provide an affordable taste of VR

- Speculatively about 10 million Cardboards (Mar 2017) and 5 million Gear VRs shipped (Jan 2017)

VR History (5/5)

- 2017's Premium VR HMDs: HTC Vive, Oculus Rift + Touch, PlayStation VR

- HTC Vive
  - o unveiled during HTC's Mobile World Congress keynote in March 2015
  - o partnered with Valve Corporation

- Aim to provide fully immersive experiences
  - o front facing camera to identify and alert users of real world obstacles for safety
  - o wireless controllers with multiple input methods (track pad, grip buttons, dual stage trigger)
  - o 110 degree field of view

- Speculatively about 420,000 Vives and 240,000 Rifts sold as of end of 2016

Input in VR (1/2)

- Head **orientation** tracking is the most important input in VR
  - allows you to turn your head and look around
- Head **position** tracking is a close second
  - allows you to actually move around
- What about the rest of your body?
- What about actions or devices that can trigger more complex actions?

Input in VR (2/2)

- Standard input devices (mouse, keyboard, standard game controller, etc.) are no longer sufficient
  - we need more degrees of freedom (DOF) and finer input control
  - might still need to maintain some joysticks or buttons for certain actions (e.g. moving/strafing with joysticks)
- Unlikely that there is a perfect, universal input device that will satisfy all VR needs
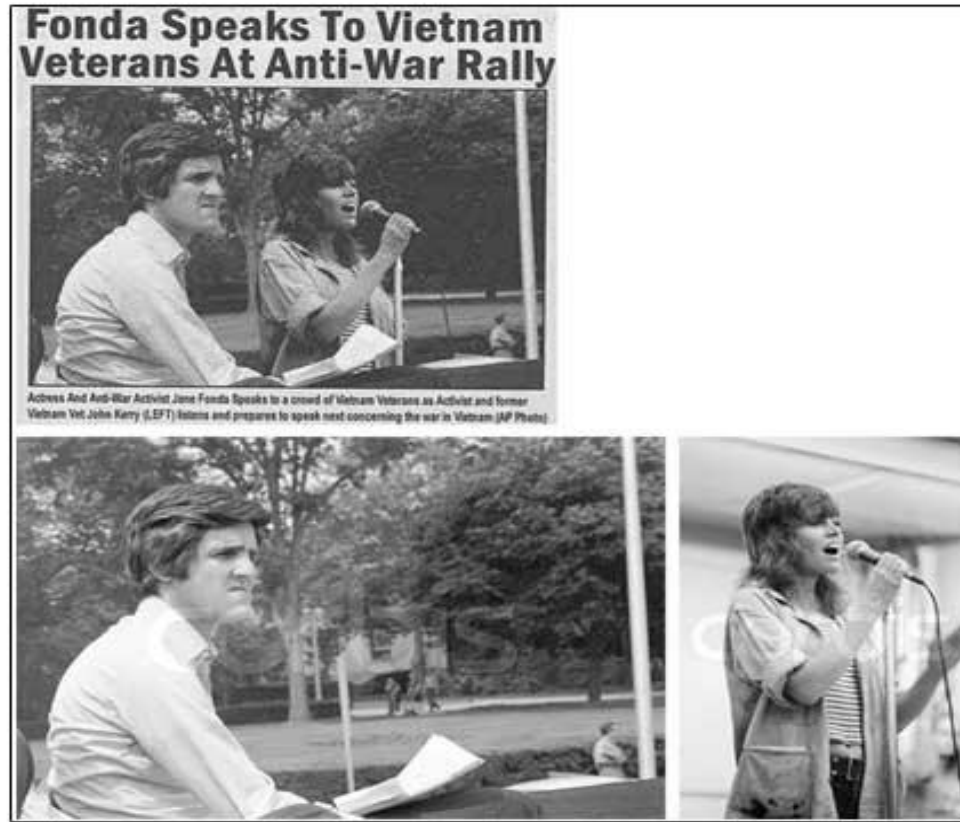 - Birdly

The Nintendo PowerGlove (1989) – based on DataGlove patent, greatly simplified to reduce cost and increase performance. Commercial failure.

Famous Faked Photos

Tom Hanks and JFK (Forrest Gump)

Fonda Speaks To Vietnam Veterans At Anti-War Rally

Actress And Anti-War Activist Jane Fonda Speaks to a crowd of Vietnam Veterans as Activist and former Vietnam Vet John Kerry (LEFT) listens and prepares to speak next concerning the war in Vietnam (AP Photo)

Infamous "dirty trick" in politics to help defeat John Kerry in 2004 (running against G. W. Bush)

Real

Fake

Iranian rocket launch press photo

Deep Nostalgia

- Tool on MyHeritage that animates old photographs of loved ones using AI-based image manipulation