CS354P

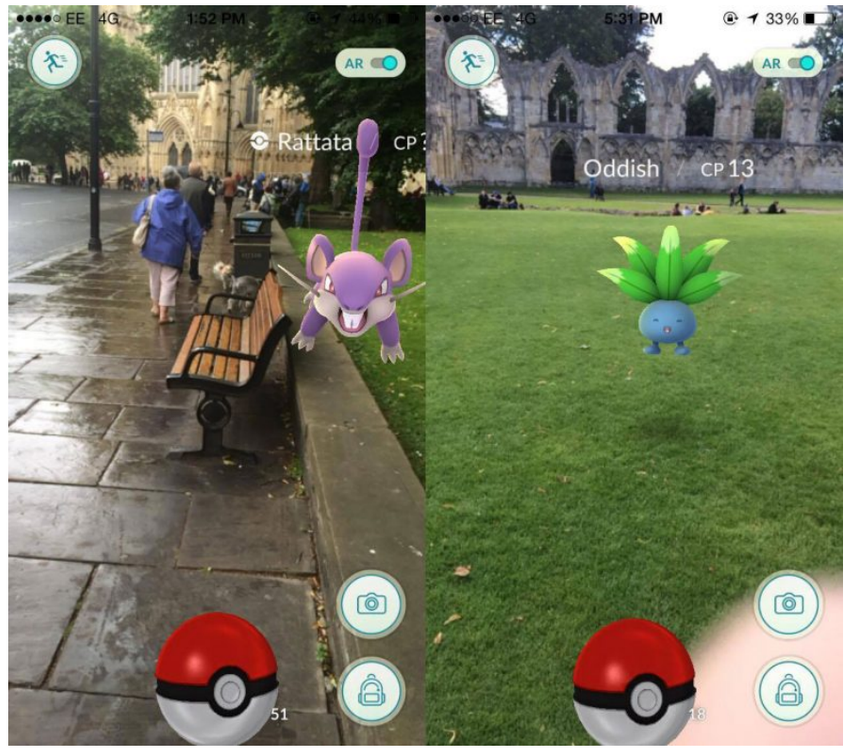
DR SARAH ABRAHAM

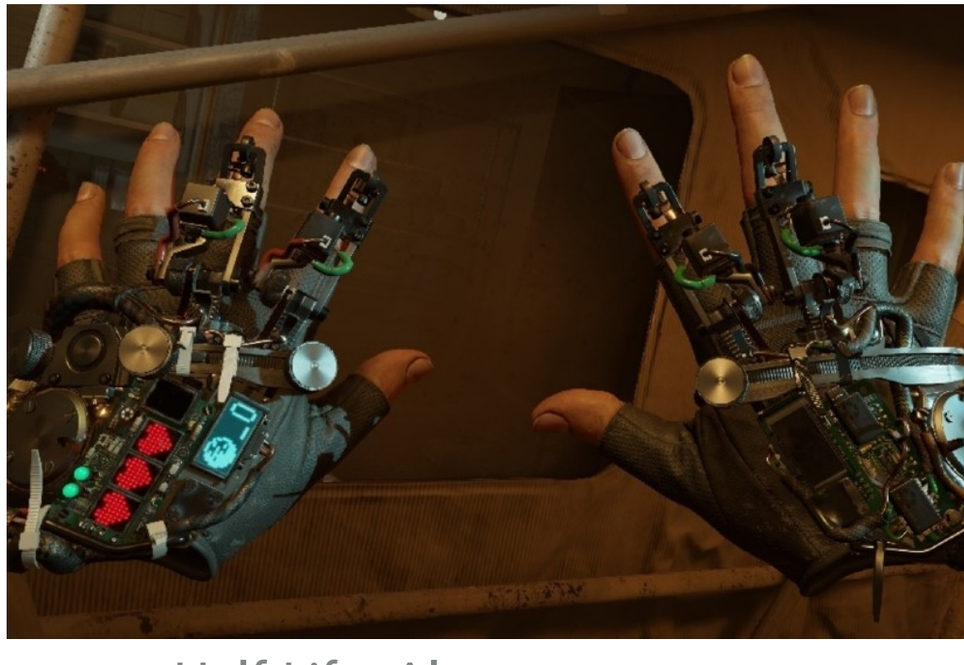
# AR/VR

# WHAT IS AR/VR?

- Augmented Reality
  - Human vision “augmented” with additional information such as visual overlays
  - Practical and game applications?
- Virtual Reality
  - Creation of a fully immersive environment including stereoscopic vision and haptic feedback
  - Practical and game applications?
- We will mostly talk about VR today

Pokemon Go



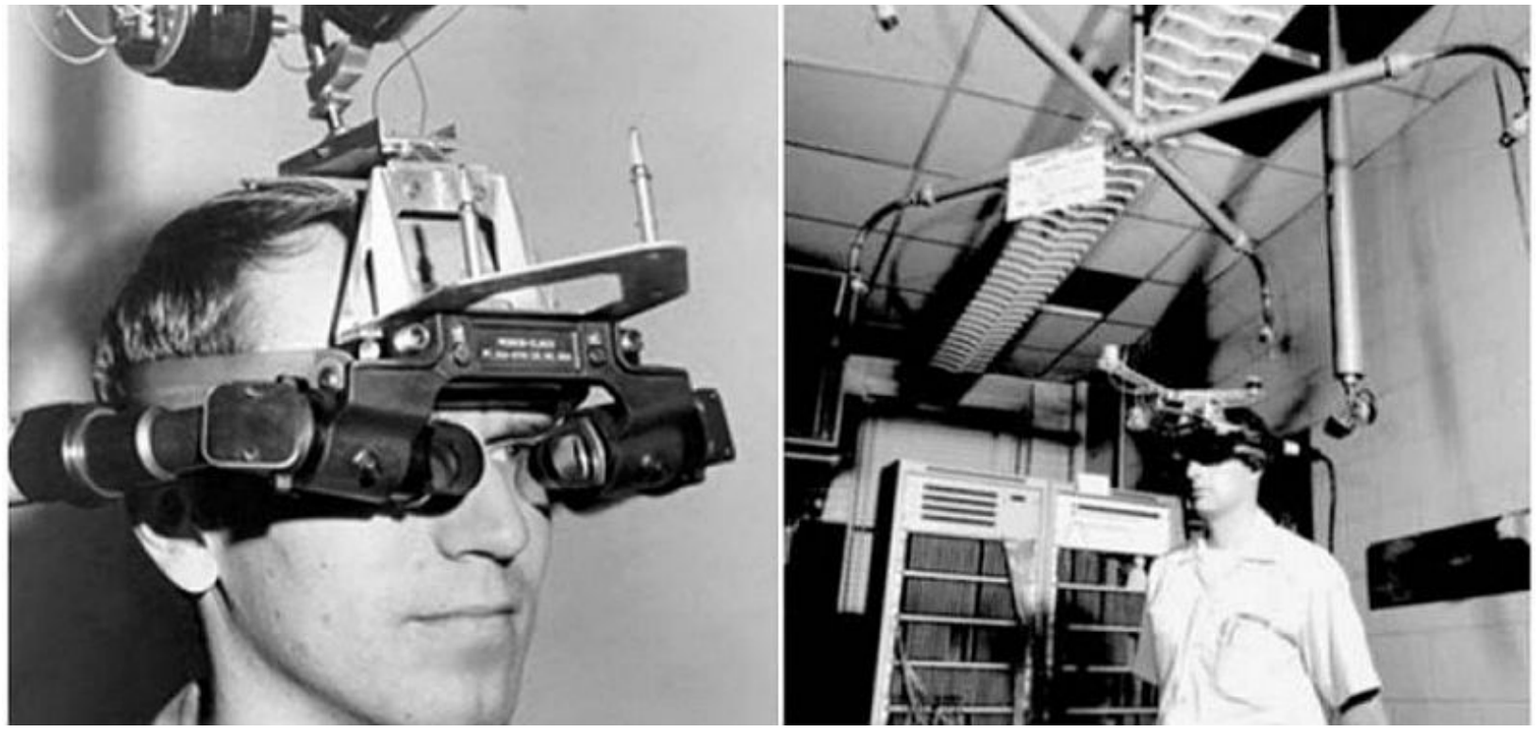



Half-Life: Alyx

# VIRTUAL REALITY

# VR CHALLENGES

- Rendering
  - Need for low latency
  - Need for high resolution
  - Hardware limitations
- Physiological
  - Eye strain
  - Helmet weight
  - Player balance
- World Interaction
  - Movement
  - Haptics



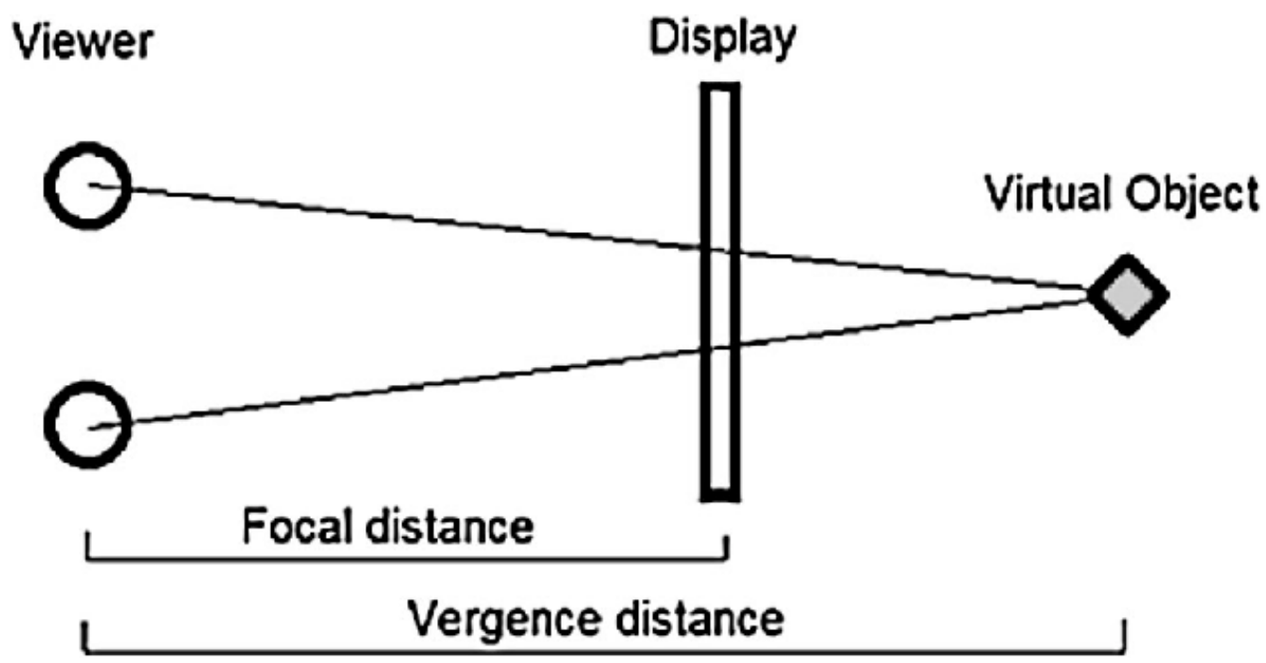
Sword of Damocles (1968)

# ACCOMMODATION AND VERGENCE

- Accommodation is the process where the eye changes optical power to maintain focus at multiple distances
- Vergence is the simultaneous movement of eyes to maintain binocular vision
- Accommodation-vergence reflex allows eyes to automatically adjust focus on objects based on distance

# ACCOMMODATION-VERGENCE CONFLICT

- Brain receives mismatching cues between distance to the object and focal distance of the screen
- Results in conflicting depth cues
- Blurry image, nausea, fatigue, etc...



# HOW TO RESOLVE THIS?

- Hardware solutions
  - Mechanically adjustable focus using additional relay lenses
  - Deformable mirrors to project low-laser light beam into pupil
  - Liquid crystal lens for adjusting optical power based on focal plane
  - Microlens arrays, parallax barriers, pinlight displays, etc…
- Design choices
  - Pick long distance focal cues
  - Move objects at pace that allows for eye adjustment
  - Map simulated distance to focal distance, create reliable depth cues, etc…

# A FUNDAMENTAL ISSUE WITH THE TECHNOLOGY

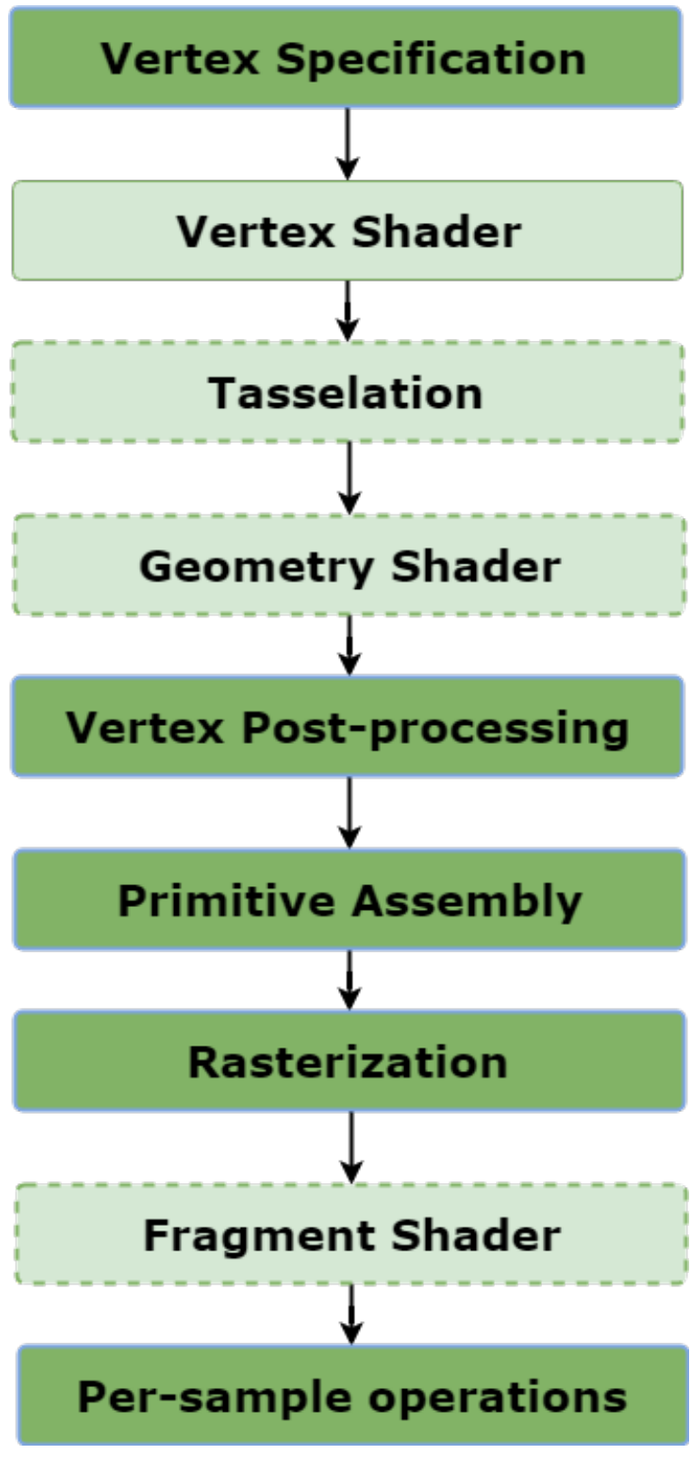
- Still an open problem in VR/AR space!
- Fundamentally, modern VR has not changed since the 60s
  - Faster, lighter hardware, but same principles of rendering from two cameras to create a stereoscopic image
- **Light fields** describe the amount of light at any point in space (holographs)
  - Results in an image that is autostereoscopic and more similar to viewing the actual scene
  - Ideal for VR but requires **a lot** more camera data (i.e. need still better hardware!)

# VR LATENCY

- Need as low latency as possible to avoid **simulator sickness**
  - Aiming for 10ms latency
  - Must account for both software and hardware needs (i.e. head-tracking, rendering, display)
- **Judder** is the smearing/strobing that occurs when the display changes quickly
  - Caused by low refresh rate and high persistence of display
  - Need high refresh rates (120Hz in practice -- ideally 1000Hz) and low persistence (pixel only lit for 2ms)

# UNDERSTANDING RENDERING

- Forward shading pipeline:
  - Processes all scene vertices
  - Creates all necessary primitives
  - Rasterizes the primitives to a screen based on depth information
  - Colors the pixels based on the fragment shader



# FORWARD SHADING ISSUES

- Considers each object in relation to each scene light
  - Performance issues with increasing light complexity
- Objects processed regardless of whether they are visible to viewer
  - Performance issues with increasing depth complexity

# RENDERING FOR VR

- Forward rendering is fast but cannot handle large amounts of dynamic lighting or scene geometry
- Works with MSAA (multi-sample anti aliasing)
- Does not require full-screen passes
- Use of culling and LODs (level of detail) to reduce scene size
- Emulation of lighting with as few lights as possible
  - Directional lights are cheap and provide good coverage

# HOW TO MAKE RENDERING FASTER?

- Many fast rendering “hacks” such as billboarding and normal mapping don’t work in VR so already require more expensive techniques
- With good eye-tracking, can better spend rendering budget on **foveated** region
  - Humans can only focus on a small region at any given time
- Use of re-projection to take lower frame rate rendering and synthesize new frames at a higher frame rate to match head movement

# DESIGNING GAMES AROUND VR

- Good game design is just as important as good technology!
  - Short gameplay loops to facilitate short play sessions
  - Relatively simple objectives and tasks
  - Limited player movement for mechanics
  - Art direction for performance
  - Level design that reduces eye strain

# AR

# AR DISPLAYS

- Two primary methods of display in AR:
  - Optical see-through
  - Video see-through
- Optical see-through displays allow light to propagate from real-world
  - Use beam splitters to combine with virtual imagery
- Video see-through displays capture video of real world and combine it with virtual imagery before redisplaying it to viewer

# COMPUTER VISION AND AR

- Relies heavily on computer vision techniques to understand scene information and correctly project and order augmented data
- Need for image segmentation, image recognition, and depth reconstruction

NVidia Digits 5

# RECONSTRUCTING SCENES IN AR

- Need to map between the real world and the scene being displayed
- World-to-scene must be consistent through application interaction
- Requires linear transforms and some knowledge of the environment


Kinect

# UNREAL AND EXTENDED REALITY

- XR (extended reality) is superset of VR, AR and MR (mixed reality)
- Unreal use the OpenXR standard for all XR development
  - https://dev.epicgames.com/documentation/en-us/unreal-engine/developing-for-xr-experiences-in-unreal-engine
  - Currently only supports head-mounted devices
- Some examples: https://www.unrealengine.com/en-US/xr

# RESOURCES

- https://medium.com/vrinflux-dot-com/vergence-accommodation-conflict-is-a-bitch-here-s-how-to-design-around-it-87dab1a7d9ba
- https://www.cs.umd.edu/sites/default/files/scholarly_papers/Kramidarev.pdf