Multimodal User Interfaces 2019

[6] Virtual and Augmented Reality

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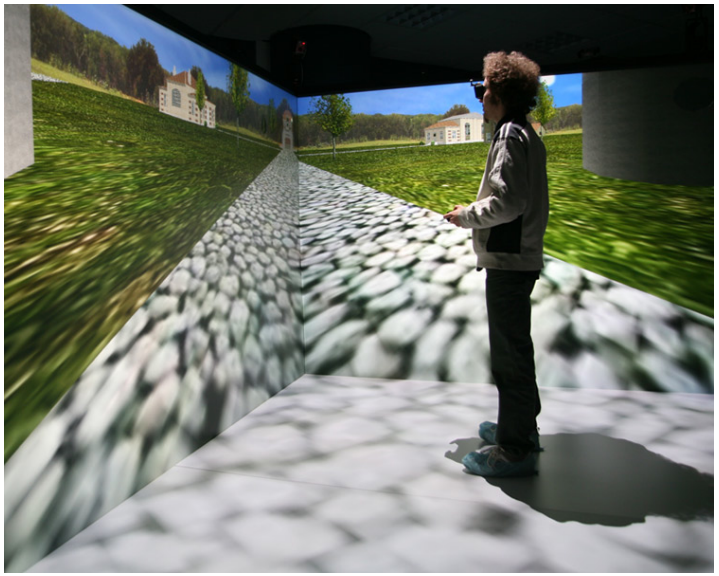
UNI FR

Program for today

- Difference between virtual and augmented reality
  - … and mixed reality
- Virtual reality
  - some examples
  - technologies
  - interaction techniques
- Augmented reality
  - some examples
  - techniques
  - tracking
- Reality-virtuality: a taxonomy

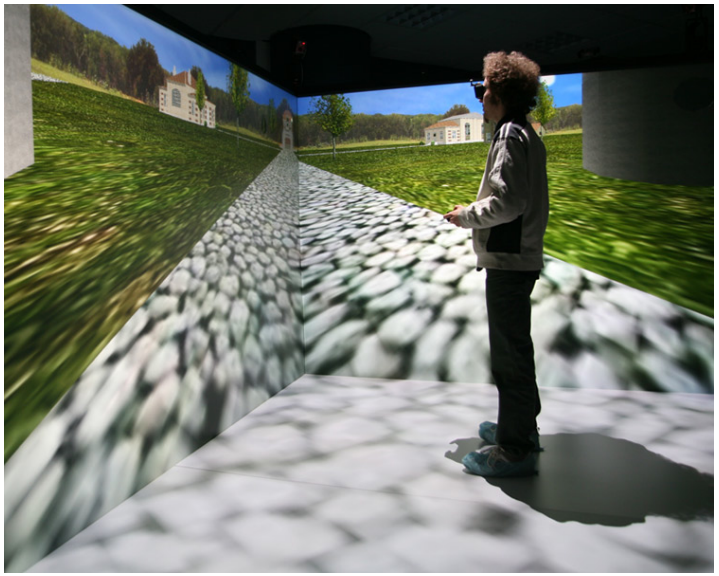
Augmented vs Virtual Reality

- What is the distinction?



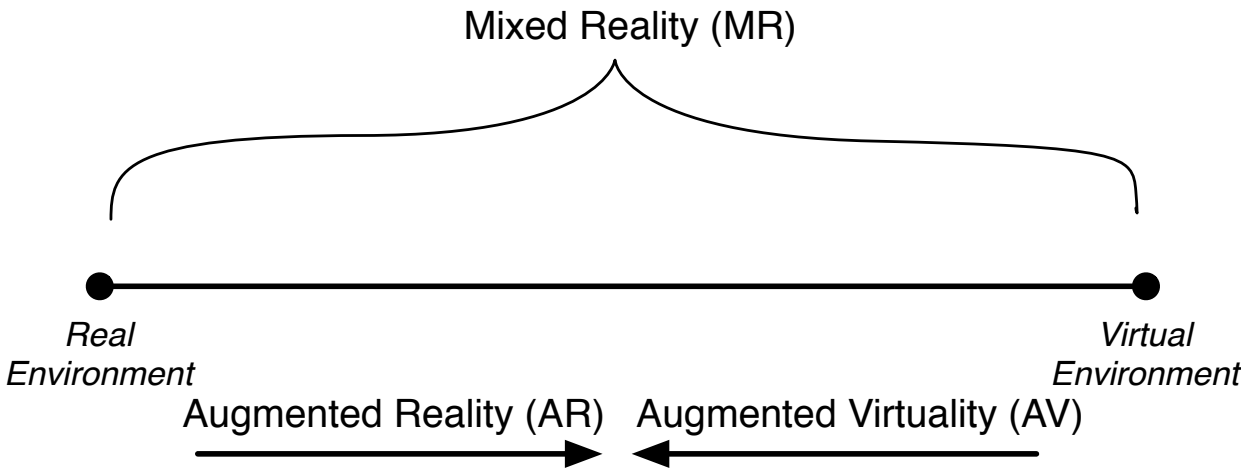
Augmented vs Virtual Reality (cont.)

- Augmented reality = augmenting the real world with digital information
- Virtual reality = allowing humans to explore virtual worlds



Augmented vs. Mixed vs. Virtual Reality

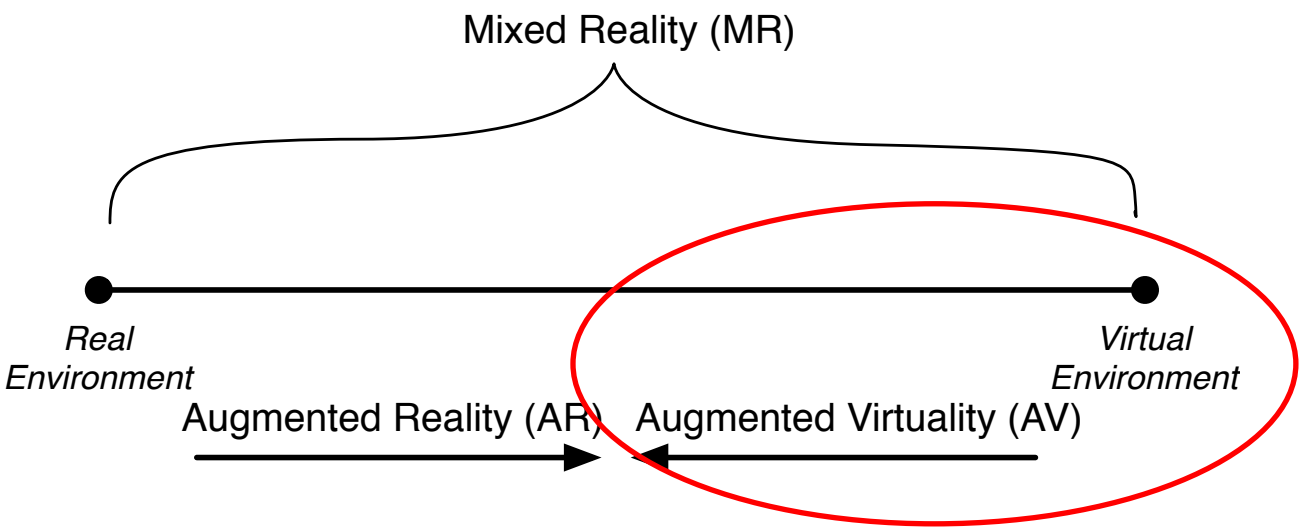
- The Reality-Virtuality Continuum
  - defined by P. Milgram and F. Kishino in 1994
- Two extremes: the real world, and the purely virtual world
- A full spectrum between these two extremes



Virtual Reality

- Augmented virtuality: augment the virtual reality with natural inputs (gesture, voice, tangibles, etc.)

- Virtual reality = allowing humans to explore virtual worlds
  - the human has to enter into /adapt to a virtual environment

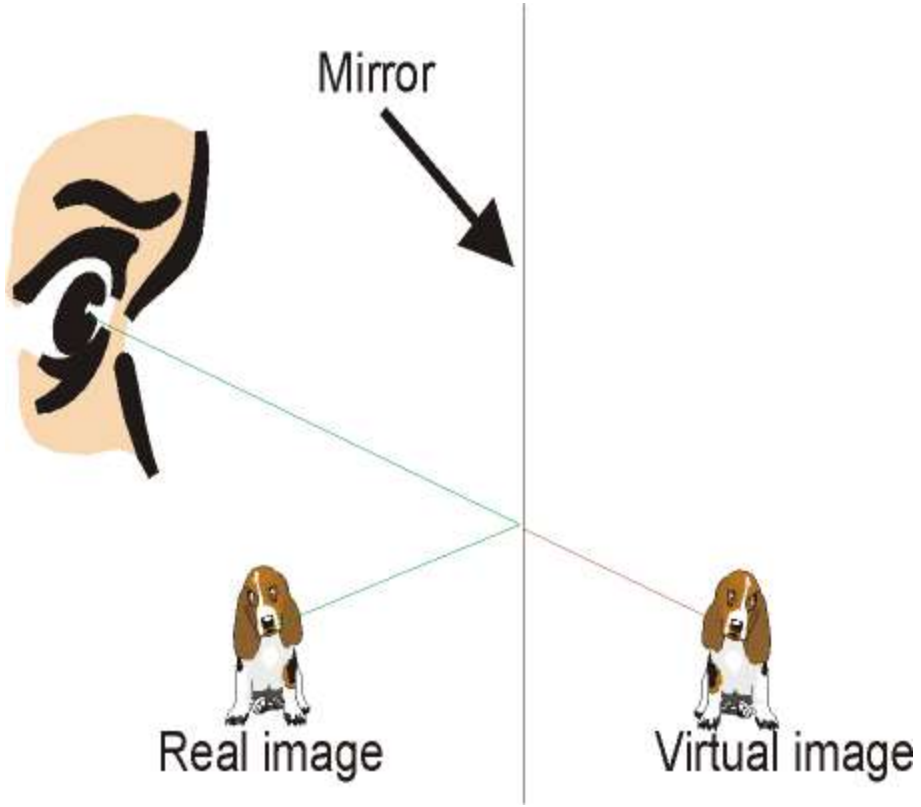


Definition of Virtual Reality

- *Virtual reality (VR) is an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which the user's actions partially determine what happens in the environment*
- In other words:
  - create acceptable substitutes for real objects or environments
  - sense the virtual environments
  - navigate through the environments
  - interact with them

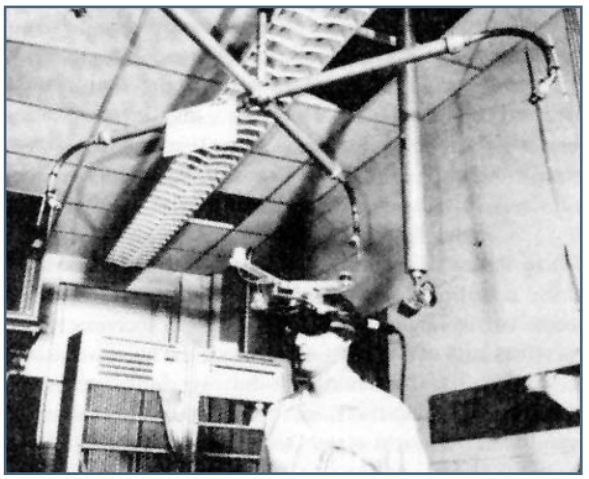
Origin

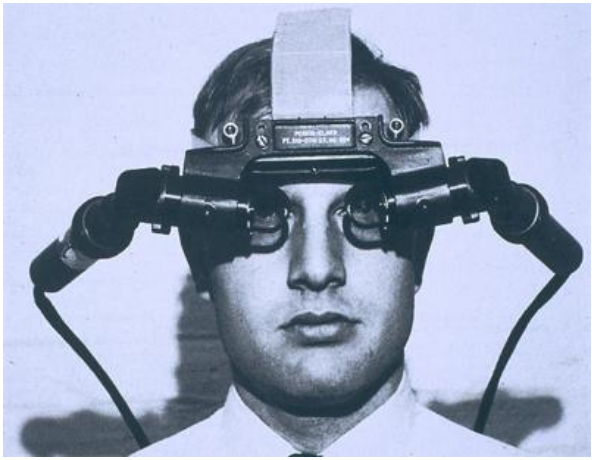
- A simple mirror produces virtual images (of real ones).

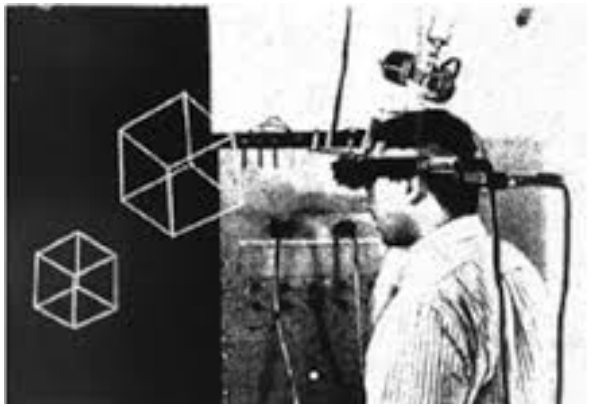


First Virtual System

- Created by Ivan Sutherland in 1968
- Head-mounted display (HMD)
- Stereoscopic wire-frame graphics
- Main goal: immersion
- *The Sword of Damocles* based on his paper *"The Ultimate Display"* (1965)
  - ➢ considered as the first Head Mounted Display (HMD), with appropriate head tracking and wireframe graphics.





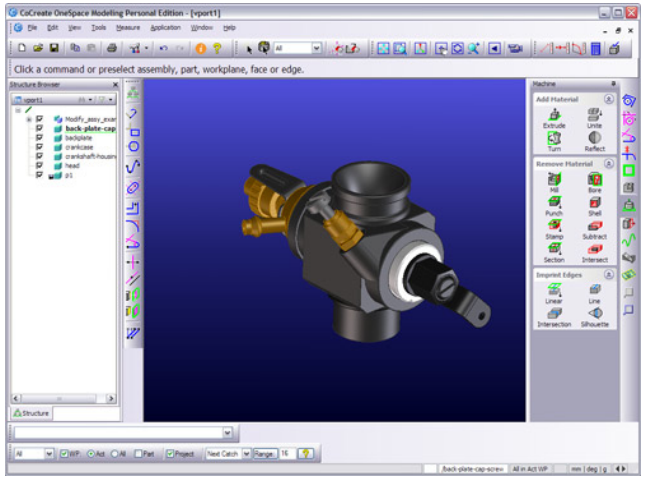


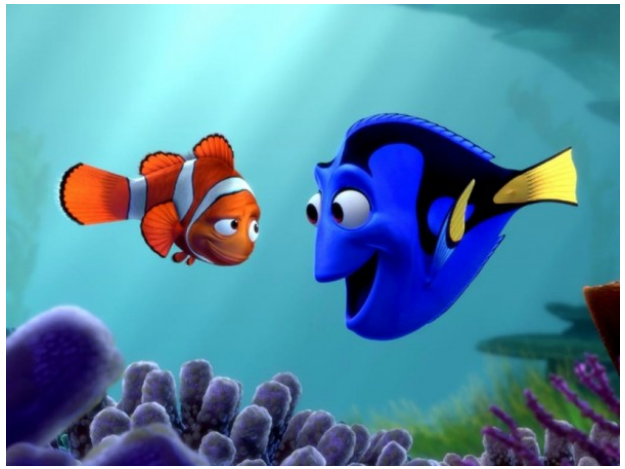
Virtual Reality: Immersion -> Presence

- Perceptual immersion (or sensory/physical immersion) is when human senses are under control of the virtual environment system which generates inputs to user's sensory system
  - 3D vision
  - 3D sound
  - environmental conditions (temperature, wind, ...)
  - taste/smell
  - touch/force feedback
  - motion/acceleration /vibration
  - direct connection to human nervous system
- Psychological immersion (or mental immersion) occurs when users feel involved, absorbed, engaged, etc.
  - increases sensation of **presence** within the virtual world

Immersive vs. Non-Immersive VR

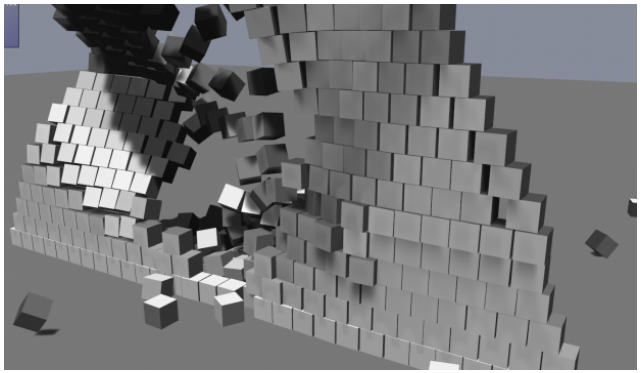
- A wider definition of virtual reality includes non immersive virtual environments
- Linked to any system displaying a real-time 3D environment
  - also called “Desktop Virtual Reality”
  - typical applications: CAD, 3D computer games, simulations
- A continuum: non-immersive – partially immersive – fully immersive





Creating Virtual Environment

- **VR** relies on 3D computer graphics
- Computer graphics is a wide subject:
  - **modeling** (building the virtual environment : list of polygons, light, …)
  - **rendering** (image creation, perspective view, coloring, shading, …)
  - lighting and shading
  - ray-tracing and radiosity
  - physical simulation
    - ✓ gravity
    - ✓ inertia
    - ✓ deformation
    - ✓ friction
    - ✓ viscosity



VR Applications: Architecture

VR Applications: Safety Training

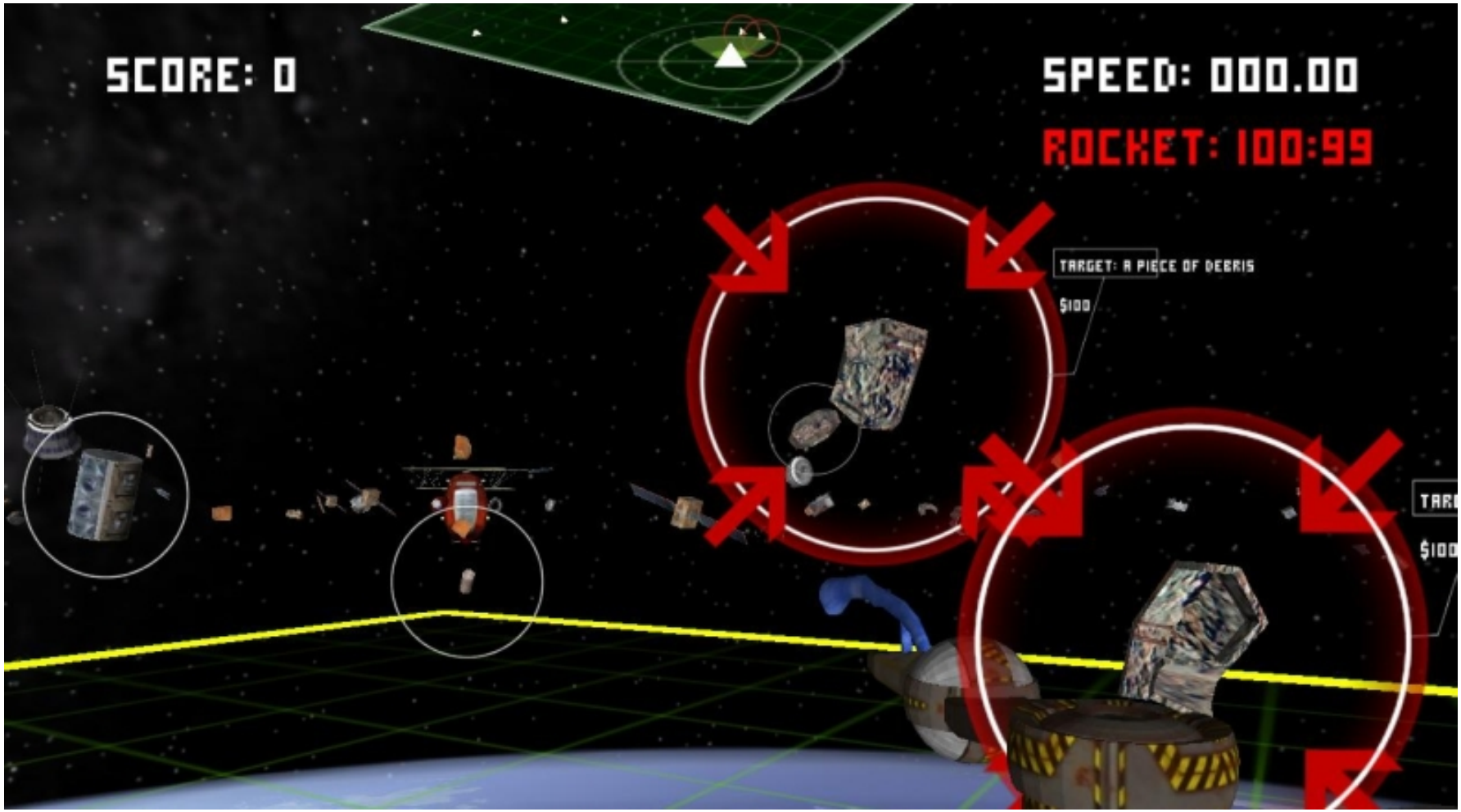
Industrial Design

- Hardware optimized ray-tracing can produce an outstanding **photo-realistic rendering**.

VR Applications: Military Training

VR Applications: Medical

VR Applications: Entertainment

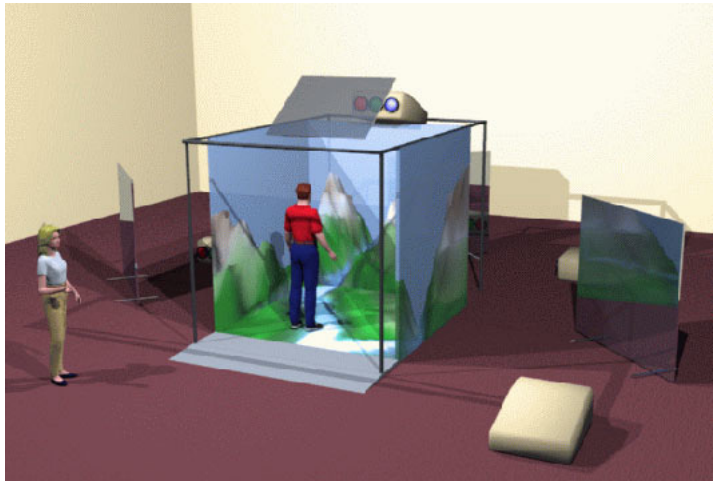


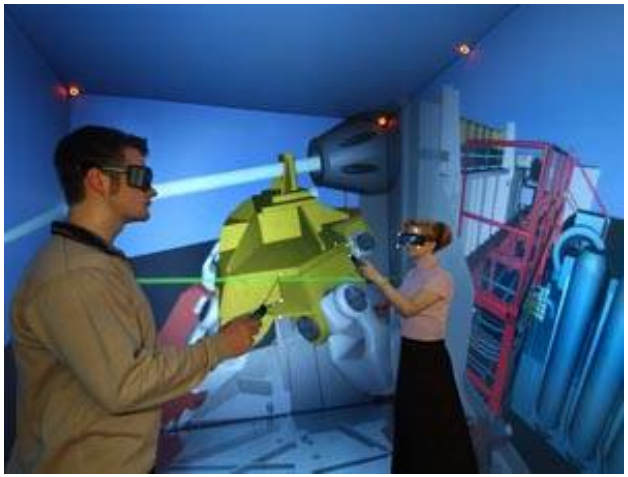
Technologies: Flat Screens

- Large screen (panoramic) displays
  - either flat
  - or cylindrical 180° <-> 360°
  - … or hemispherical or spherical
  - with or without stereoscopy
- Virtual tables
  - flat area + Video projector (beamer)
  - with or without stereoscopy

Technologies: CAVE

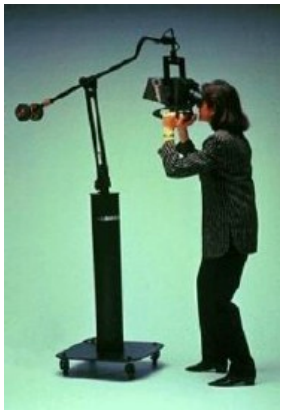
- A CAVE (Cave Automation Virtual Environment) provides the illusion of immersion by projecting stereo images on the walls and floor of a room-sized cube (generally 3-5m.)
- Users wear stereo glasses
- A head tracking system continuously adjust the stereo projection to the current position of the leading viewer

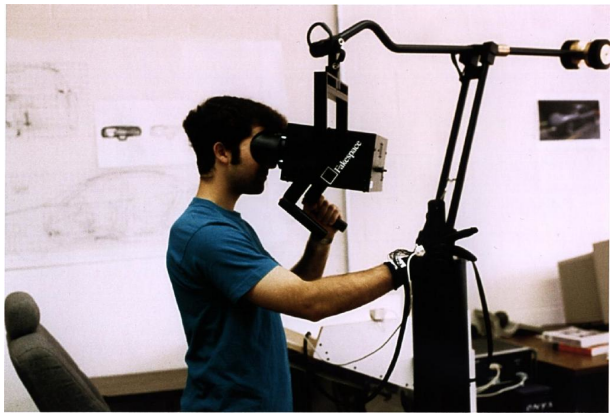




Technologies: BOOM

- "Binocular Omni-Orientation Monitor"
- Head-coupled stereoscopic display device
- Screens and optical system are housed in a box that is attached to a multi-link arm
- The user looks into the box through two holes, sees the virtual world, and can guide the box to any position
- Head tracking is accomplished via sensors in the links of the arm that holds the box





Technologies: Head-Mounted Displays

- A Head-Mounted Display (HMD) is a lightweight virtual reality device that the user wears on the head to have video information directly displayed in front of the eyes
- One or two small displays (LCD, OLED...) are embedded in a helmet, glasses or visor
- Lenses are used to give the perception that the images are coming from a greater distance

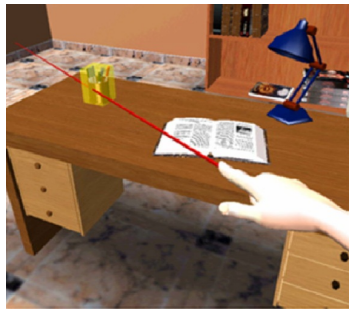
Occulus Rift

http://www.oculusvr.com/

VR Navigation and Interaction

- Communicate to the system how to navigate in 3D and to interact with objects placed at different depths
- 6 degrees of freedom problem!
  - position in 3D + orientation in 3D
- Navigation: Move around and explore the VR
  - e.g. walk in a virtual building, turn a molecule
  - movement tracking system (optical, ultra-sonic, …)
  - eye gaze, head direction, walking peripherals, joystick (non-imm.)
- Interaction: ability to move objects in a scene
  - for example: open a virtual door, move an atom, etc.
  - 3D-Joysticks, 3D- or 6D-Mouse
  - data-gloves (problem of grabbing)
    - ✓ Virtual hand, Ray-casting
  - other sensors (breathing, heart-pulse, …)



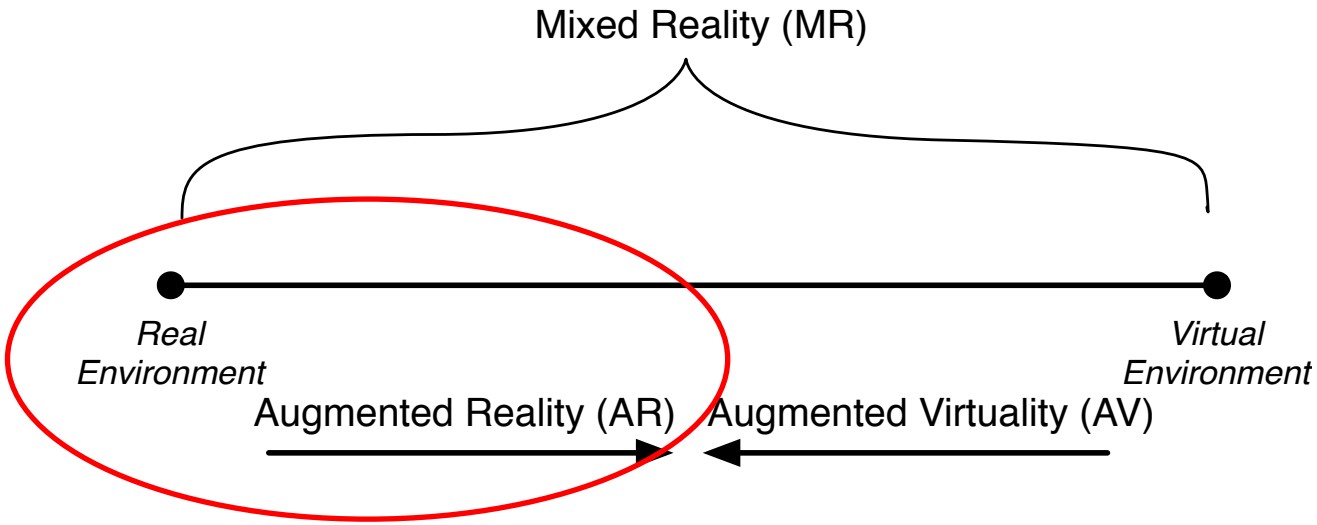
Modelling ML and Rendering engines

- OpenGL (Open Graphics Library) cross-language API for rendering 2D and 3D vector graphics
  - developed by SGI from 1991
  - designed to be implemented mostly or entirely in hardware
- VRML *Virtual Reality Modeling Language* is a (human-readable) scene description language
  - originally developed by *Silicon Graphics* (SGI) to provide a higher layer of programming for OpenGL and to allow web-based VR
- X3D (eXtensible 3D Graphics) is the successor to VRML and is an open ISO standard for real-time 3D computer graphics
  - incorporated in the MPEG-4 multimedia standard
  - integration in html5 (similarly as SVG)
- OGRE (Object-Oriented Graphics Rendering Engine) is a real-time 3D rendering engine.
  - most popular open-source graphics rendering engine (sourceForge)

BREAK

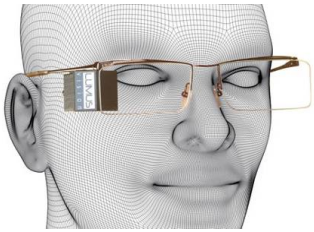
Augmented Reality

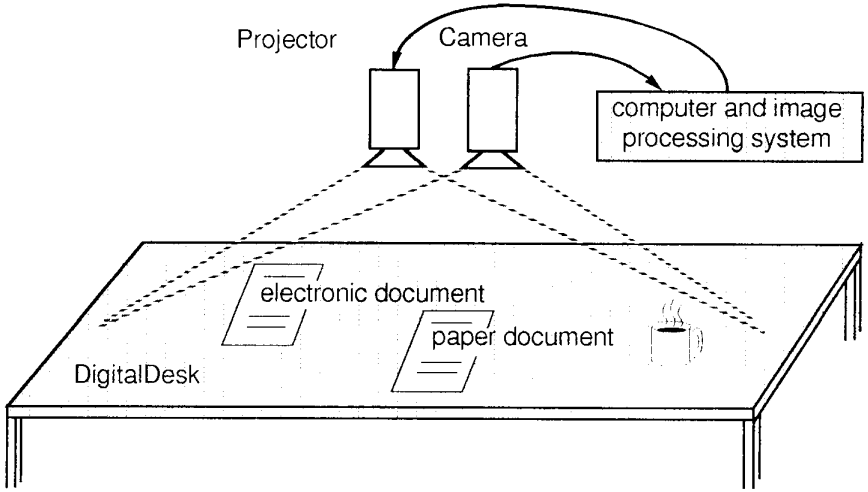
- The real world is augmented with virtual world objects
  - augmented reality is overlaying the real world with layers of additional – mostly visual – information
  - virtual images (computer generated) are overlaid upon a normal view of the real world



An Initial Scenario

- **Added value** for the observer by overlaying virtual information onto the real world.

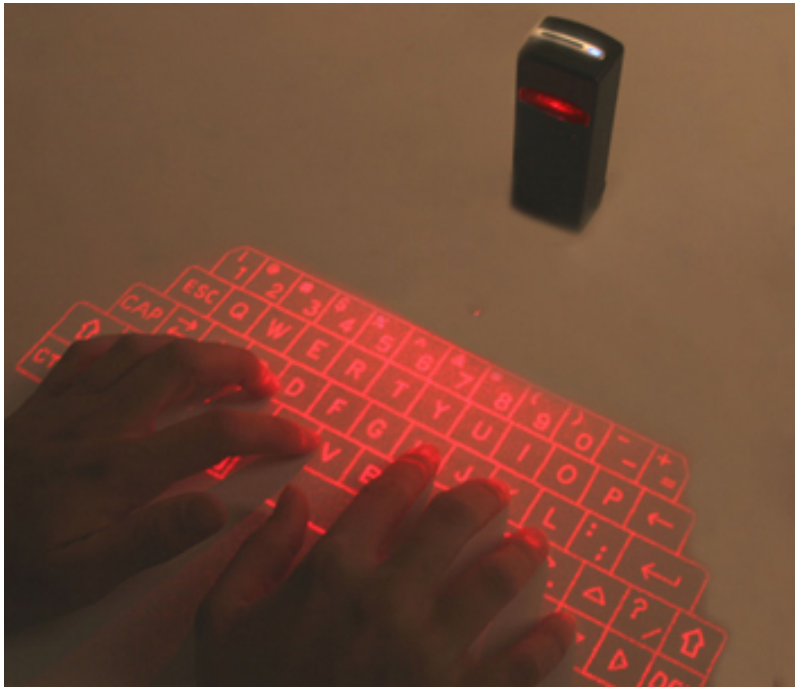




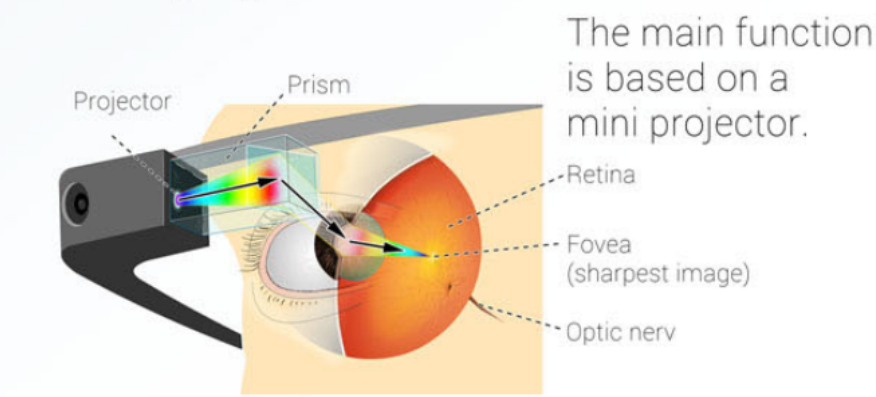
⇨ **Augmented Reality**

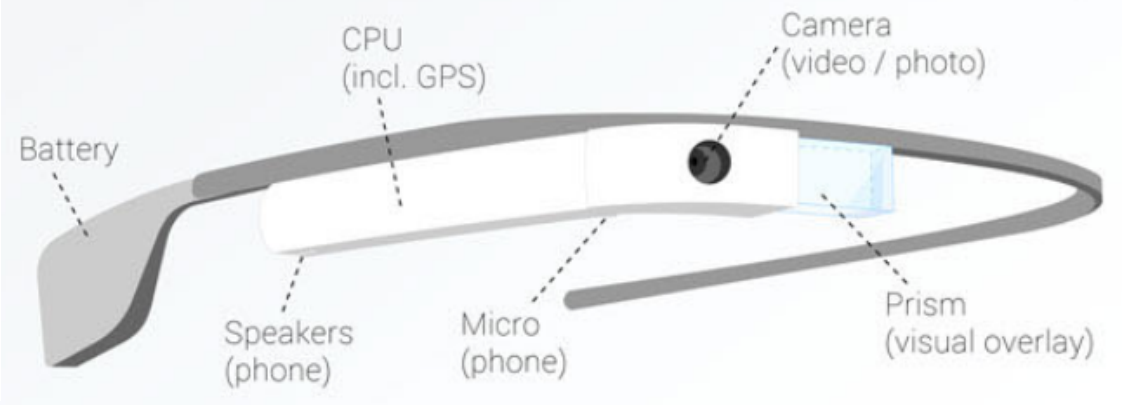
Example: Augmented Reality Kitchen

Example: Virtual Keyboard



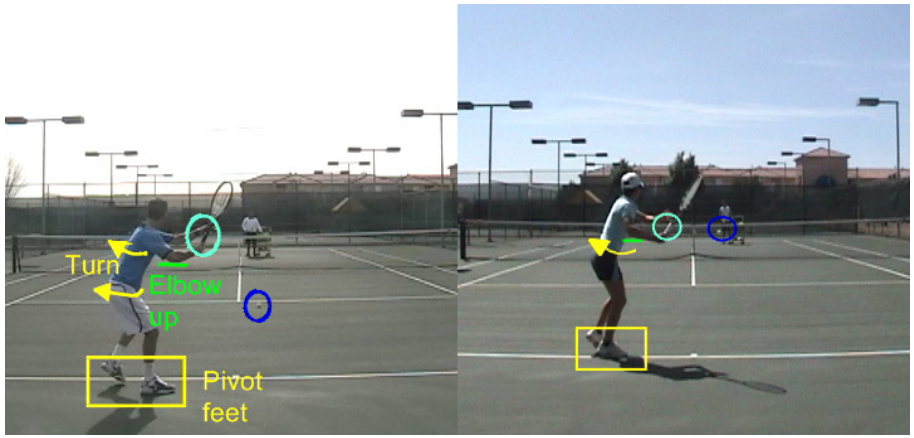
Examples:
Google Glass or Microsoft Hololense

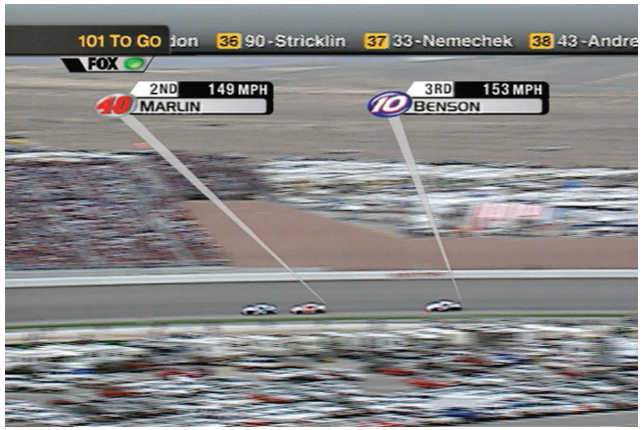




Techniques: Video Compositing

- Virtual information overlaid in a video stream of a real scene
  - either in real time, or in post-processing



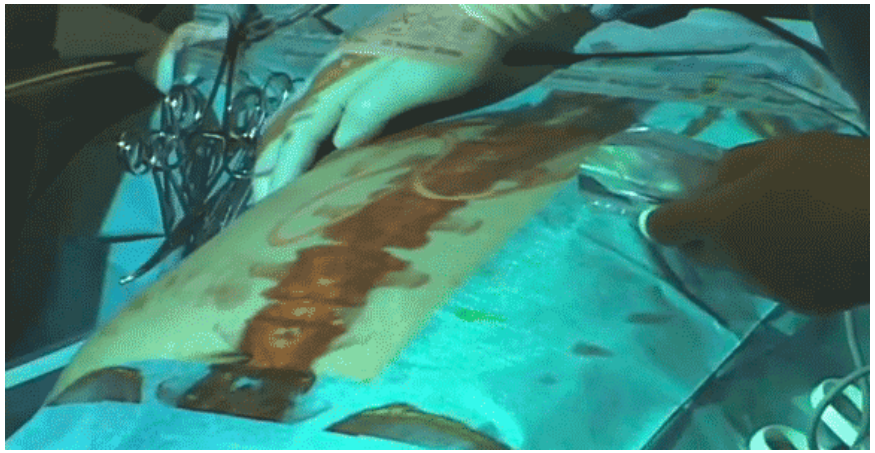


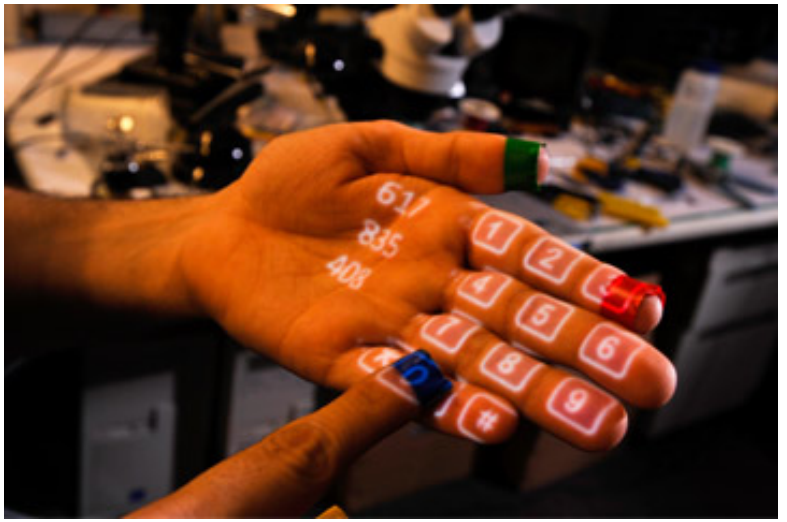
Techniques: Head-Up Displays (HUDs)

- Found in civil and military aircrafts, also in some cars
- However, overlaid information is in general not directly connected to the real objects seen through them
  - ➢ weak case of augmented reality

Techniques: Direct Projection

- A beamer is used to project information directly on top of objects
  - the beamer can either be at a fixed place (example: a surgery room) or portable (ex. Sixth Sense project)





Techniques: “Magic Lens” Metaphor

- Virtual information overlaid on top of a video recorded in real time
- User looks “through the lens” of, for example, the screen of a phone
- Scene + orientation recognition through computer vision

Techniques: “Magic Mirror” Metaphor

- Technically very similar to the “magic lens”, except for the orientation of the camera
- Typically used to overlay information on the user

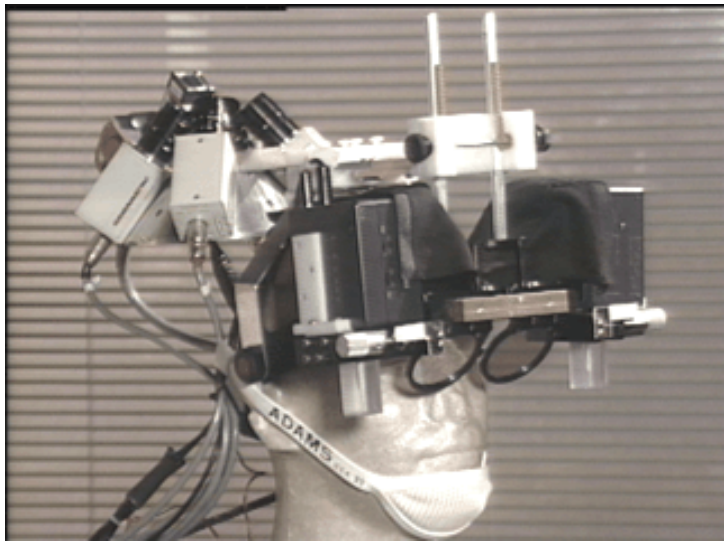
Techniques: “Magic Eyeglasses”

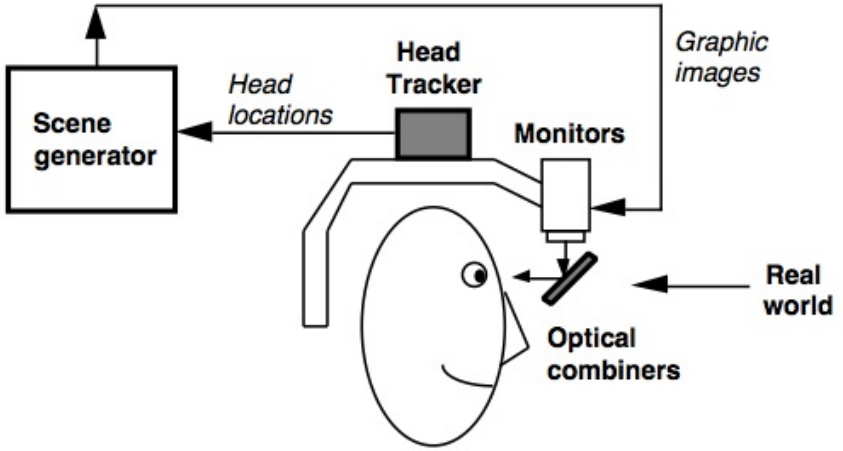
- See-through Head Mounted Displays (HMDs)
- Virtual images mixed with a real view of the world
- Three kinds of see-through HMDs:
  - optical see-through HMDs
  - video see-through HMDs
  - Virtual Retinal Displays

Broll et al., *ARTHUR: A Collaborative Augmented Environment for Architectural Design and Urban Planning*. JVRB - Journal of Virtual Reality and Broadcasting, 1(2004), no. 1.

Optical See-Through HMDs

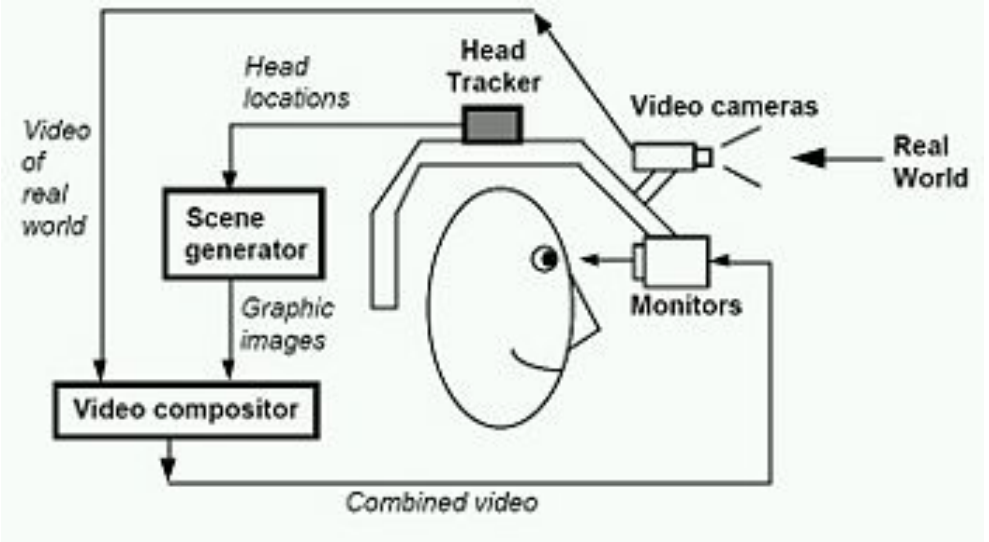
- On an optical see-through HMD, the virtual images are produced on semi-transparent surfaces (LCD panels) or reflected on semi-transparent mirrors





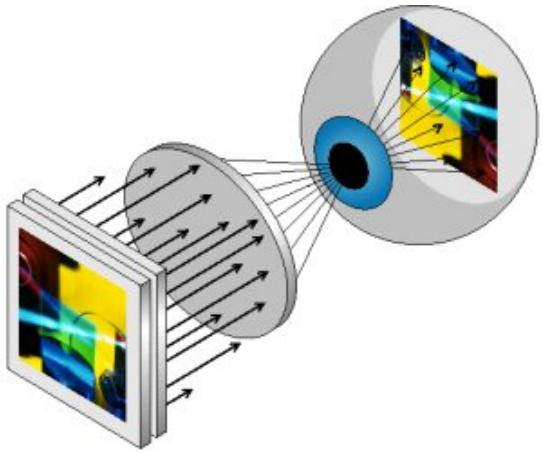
Video See-Through HMDs

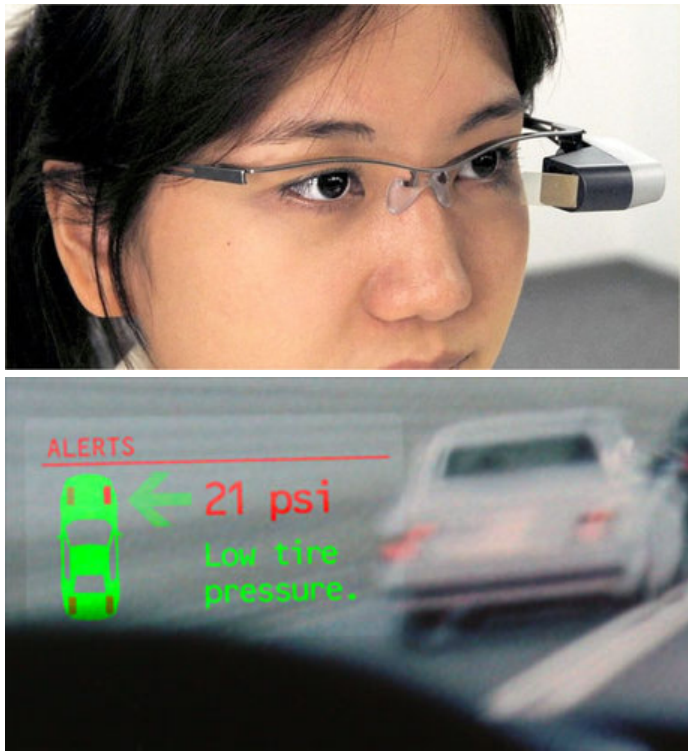
- On video see-through HMDs, real video images are captured by one or two video cameras installed in the unit and overlaid with computer graphic (virtual) images



Virtual Retinal Displays

- Virtual Retinal Display or Retinal Scan Display
- Projects three modulated beams of light directly onto the retina of the eye producing a rasterized image
- Illusion of seeing the source image like a conventional display floating in space in front of it
- Example: Google Glass

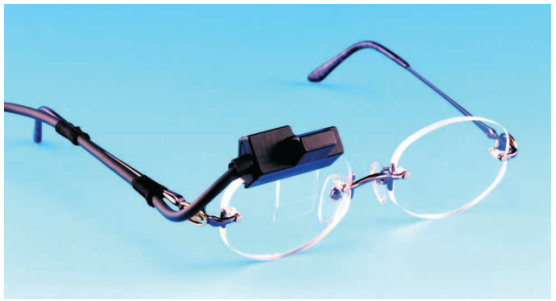
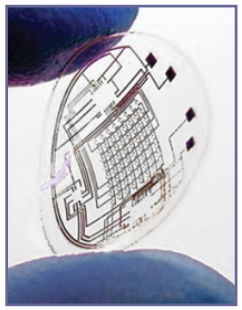
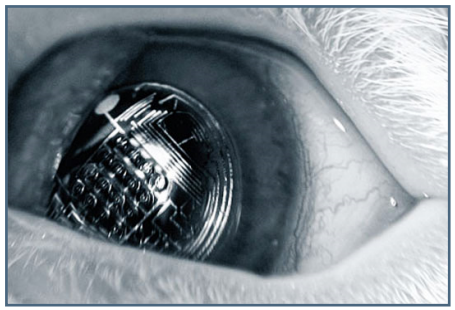




Head-Mounted Display (HMD)

- There are different degrees of immersion, obstruction, weight, comfort, and… elegance !
- Augmented Contact Lenses - the future ?
  - semi-transparent LEDs onto a thin lens
  - solar powered



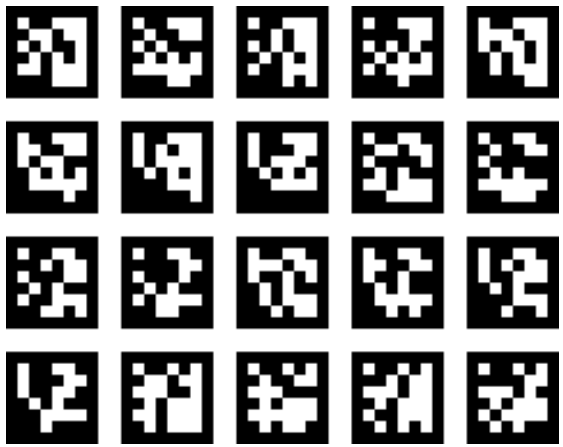
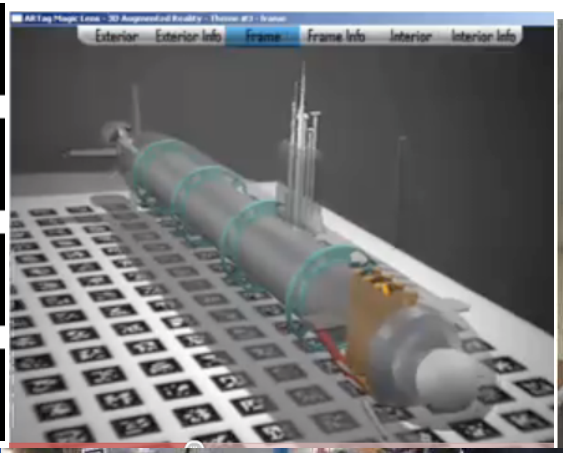
Virtual Elements Registration

- A stronger sense of connection can be obtained using semi-transparent goggles or video head-mounted displays
- User can move around in the real world and see real objects overlaid with computer images
- It requires an accurate and rapid **tracking system** to ensure that the two scenes are accurately aligned (*registration*)

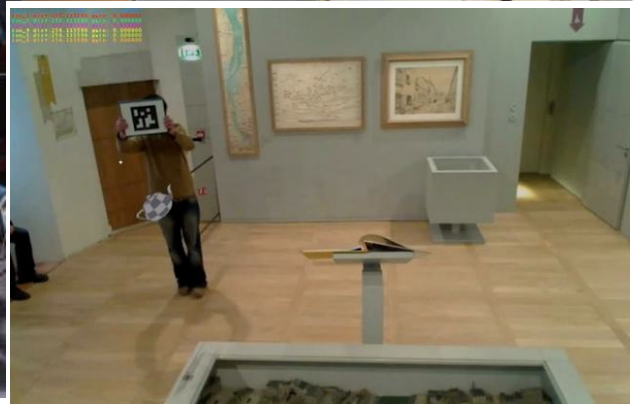
Of course, it is also possible to show information unrelated to the real world, for example the users could read their e-mails whilst walking around.

Tracking with markers

- Open source tracking library: overlay virtual imagery on real world
  - uses square physical markers
  - fast enough for real-time AR applications
- Multiple lib: ARToolKit, ARTag, MRToolkit, osgART, ARToolKitPlus





Video Markerless Tracking

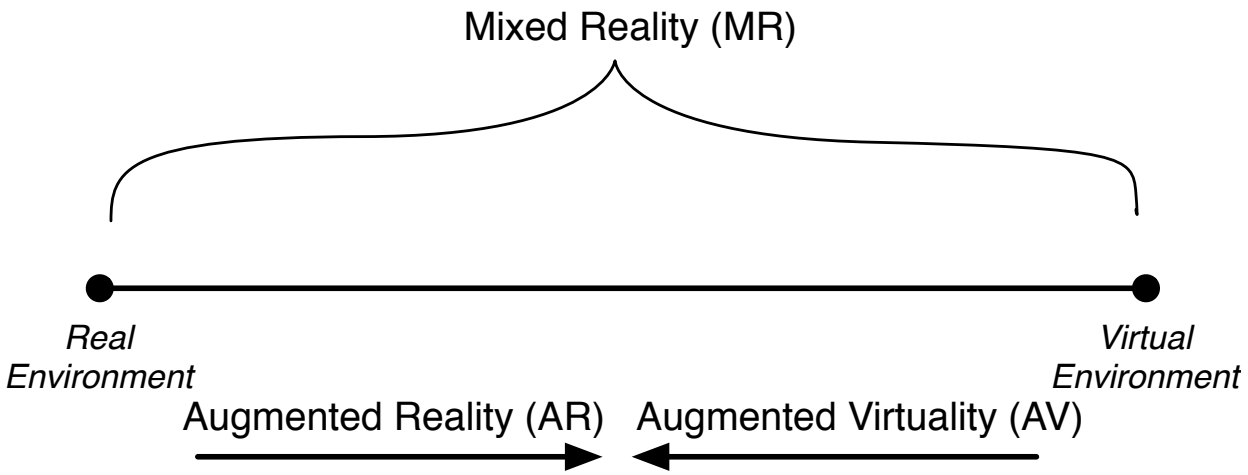
- Visual Tracking based on known elements in the real world
  - quite easy on plane objects (pictures, books/CD/DVD-cover, etc.)
  - more difficult on deformable surfaces
  - Aamost impossible on uniform, textureless objects

Tracking Systems

- The tracking system must deliver six-dimensional information about the position and orientation of the user's head/hand/body
- The most common technologies used are :
  - mechanical (e.g. BOOM)
  - electromagnetic transmitter/receiver
  - ultrasonic transmitter/receiver
  - inertial sensors (gyroscope, accelerometer, ev. magnetometer)
  - laser or infrared transmitter/receiver
  - optical (video-based) system
    - ✓ multiple cameras that look at the user from various angles (user equipped with markers : small balls fixed to critical joints)
    - ✓ single camera on the user and known markers (beacons, landmarks) placed in the environment
    - ✓ markerless (using texture information)
  - Bluetooth, WIFI, GPS, RFID…

Back to the Reality-Virtuality Continuum

- Along the continuum from reality to virtuality, three dimensions can be observed:
  - Extent of presence metaphor (~ Immersion)
    - ✓ From simple monitors, large Screen, CAVE, to HMDs
  - Extent of world knowledge
    - ✓ From unmodelled to fully modelled world
  - Reproduction fidelity
    - ✓ From wireframe, video, stereo video, 3D animation to stereo 3D



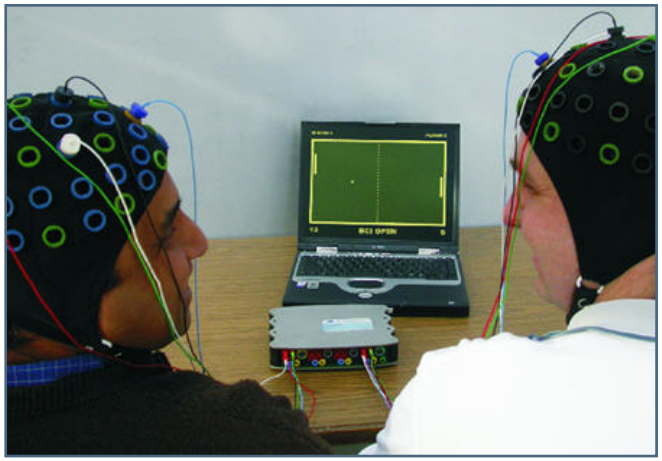
Future of Augmented Reality: Issues

(From Steven Feiner)

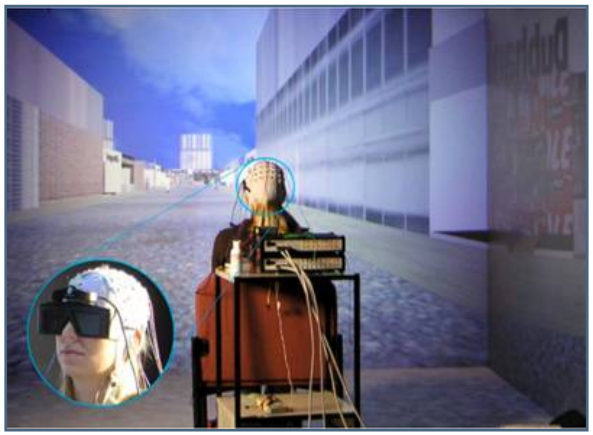
- Inaccurate tracking: GPS does not work in buildings, precision can vary greatly, problems with compass
  - Possible solution: Sensor fusion (inertial, video, GPS, RFID…)
- Real-time integration of real and virtual elements
- Handheld lifestyle, comfort (Google Glass-like eyewear?)
- Battery, processing capabilities
- Interaction (portable keyboard, voice, tapping…)

Far Future

- Virtual reality promises to extend the realm of possible brain-computer interface (BCI) systems.
- Examples :
  - Control of locomotion in a virtual reality environment



Emotive Systems



What You Should Be Able to Answer

- Explain the differences between virtual reality, augmented reality, augmented virtuality and mixed reality
- Give a definition of virtual reality
- Describe what immersion is, and how to get it
- Describe technologies for virtual reality
- Describe interaction techniques for virtual reality
- Describe techniques for augmented reality
- Explain the problem of tracking, and ways to solve it
- Describe the reality-virtuality continuum taxonomy

Do we want this?

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