VRIJE UNIVERSITEIT BRUSSEL

Next Generation User Interfaces

Virtual and Augmented Reality

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Mixed Reality

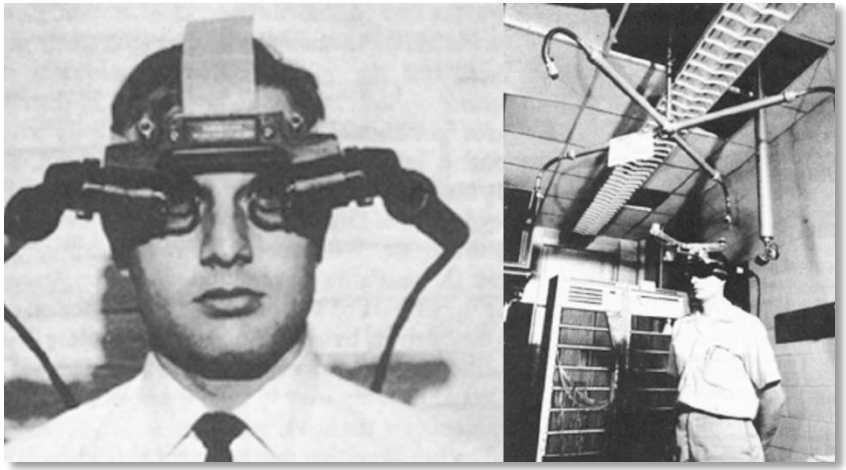
- *Reality–Virtuality continuum*
  - introduced by Paul Milgram and Fumio Kishino in 1994
- Merging of real and virtual environments
  - physical and digital objects co-exist and interact in real time
  - *mixed reality* is the spectrum between the real environment and the purely virtual environment
  - *augmented reality* as well as *augmented virtuality*

Virtual Reality

- Virtual Reality (VR) is an *artificial environment* which is experienced through *sensory stimuli* (e.g. sight or sound) provided by a computer and in which a *user's actions* partially determine what happens in the environment
- Main issues
  - create acceptable *substitutes for real world objects or environments*
  - *sense* the virtual environment
  - *navigate* through the virtual environment
  - *interact* with the virtual environment
- Opportunities
  - experience situations that would be too dangerous or expensive in the real world

The Sword of Damocles

- *First virtual reality (VR) system* and augmented reality (AR) head-mounted display (HMD)
  - developed by Ivan Sutherland and his student Bob Sproull in 1968
  - binocular display with simple stereoscopic view of wireframe rooms
  - heavy HMD attached to a mechanical arm suspended from the ceiling
    - head tracking to change the perspective shown by the software



Virtual Reality Applications

- Architecture
  - experience and navigate in virtual buildings
- Education
  - visualisation and interaction with complex data
- Medicine
  - training
  - virtual robotic surgery
- Engineering
- Military
- Entertainment

Virtual Reality Applications …

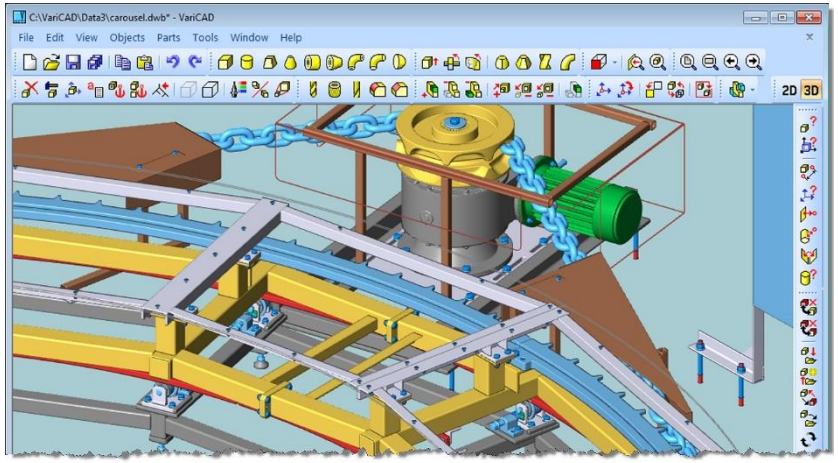
- Sport
- Simulations
- Modelling
- Information Systems
- Fashion
- Games
- …

Immersion

- Perceptual immersion (physical immersion or sensory immersion) is about the *perception of being physically present in a non-physical virtual environment* which is created by surrounding images, sound or other stimuli by the VR system
  - panoramic 3D vision
  - 3D surround sound
  - touch and force feedback
  - taste
  - smell
  - direct connection to the human nervous system

Non-Immersive Virtual Reality

- *Non-immersive virtual environments* show a real-time 3D environment on a desktop screen
  - typical applications: CAD, simulations, 3D computer games, …
  - also called *"desktop virtual reality"*



- Continuum from non-immersive to partially immersive and fully immersive systems

Virtual Reality Technologies

- Large screens
- Binocular Omni-Orientation Monitor (BOOM)
- Cave Automatic Virtual Environment (CAVE)
- Head-mounted Display (HMD)

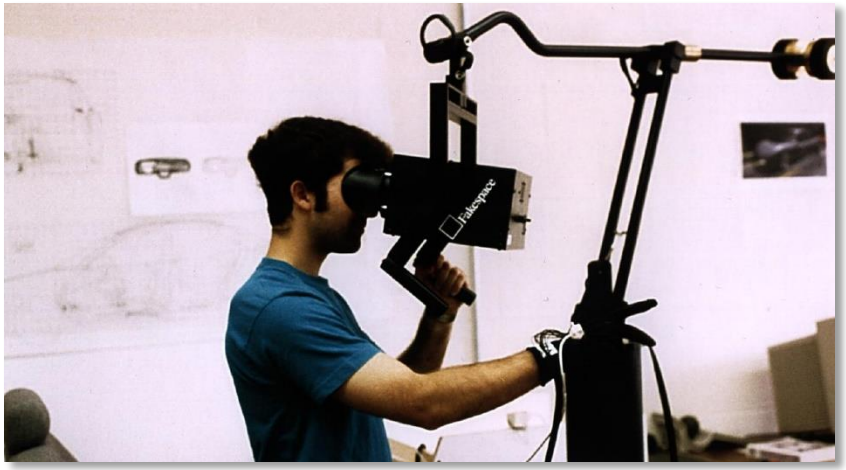
Large Screens

- Large (panoramic) screen displays
  - flat displays
  - cylindrical displays (up to 360°)
  - hemispherical or spherical displays

- Displays can be implemented with or without stereoscopy

BOOM

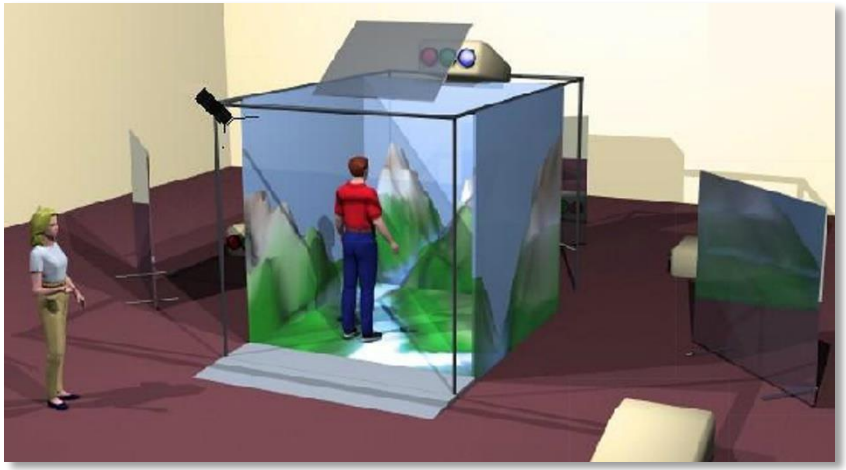
- Binocular Omni-Orientation Monitor
- Head-coupled stereo-scopic display device
- Screens are housed in a box that is attached to a multi-link arm
  - user looks into the box and can move the box to different positions
  - head tracking is realised via sensors in the joints of the arm holding the box



[http://www.umich.edu/~vrl/intro/AndreOnBoom.jpg]

CAVE

- A *Cave Automatic Virtual Environment (CAVE)* provides the illusion of immersion by projecting stereo images on the walls and floor of a room-sized cube



- Users wear stereo glasses
- Head tracking system continuously adjusts the stereo projection to the current position of the leading viewer
  - *only one view* for multiple users

Head-mounted Display (HMD)

- A *head-mounted display* is a lightweight virtual reality device that the user wears to have video information directly displayed in front of their eyes

Oculus Rift virtual reality headset

  - one or two small displays (LCD, OLED) embedded in the helmet, glasses or visor
  - lenses are used to give the perception that the images are coming from farther away
    - moves the virtual image to a distance that allows the eye to focus comfortably

Navigation and Interaction

- Virtual reality is about creating *computer-generated scenes* in which a user can *navigate and interact*
- *Navigation* is the ability to move around and explore the features of the virtual environment (3D scene)
  - walk within a virtual building
- *Interaction* involves the selection and moving of objects in a scene
  - open a virtual door
  - move an atom
  - …

VR Navigation Techniques

- *Grabbing in the air*
  - user grabs points in the virtual world and drags and rotates them at will
- *Lean-based velocity*
  - lean forwards or backwards to move in the virtual world
- *Path drawing*
  - specify a path to be followed
- *Walking in place*
  - might be supported via a treadmill

Virtuix Omni

VR Interaction Techniques

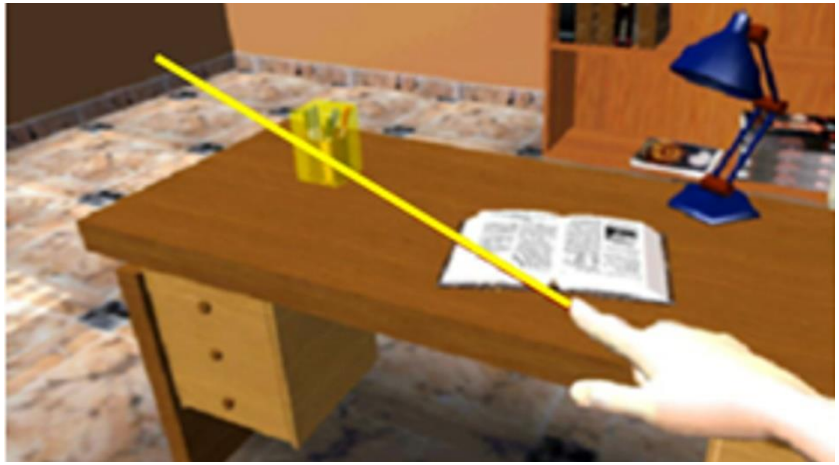
- Two types of interaction techniques
  - *non-immersive interaction*
    - e.g. via mouse or joystick
  - *immersive interaction*
    - e.g. using wearable device or capturing of limb positions

Power Glove for Nintendo, Mattel, 1989

- Gesture recognition
  - datagloves
  - optical, vision-based gesture recognition

VR Interaction Techniques …

- Interaction with the virtual world through
  - *virtual hand*
    - map the position of a user's hand to the virtual reality environment
  - *ray casting*
    - virtual light ray is leaving a user's hand and selects the first object that it hits
  - *image plane*
    - an object is selected with a pointing gesture and manipulated via the other hand



Ray casting

Augmented Reality

Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space […]

Ronald T. Azuma, *A Survey of Augmented Reality*, Teleoperators and Virtual Environments, 6(4), 1997

Augmented Reality Applications

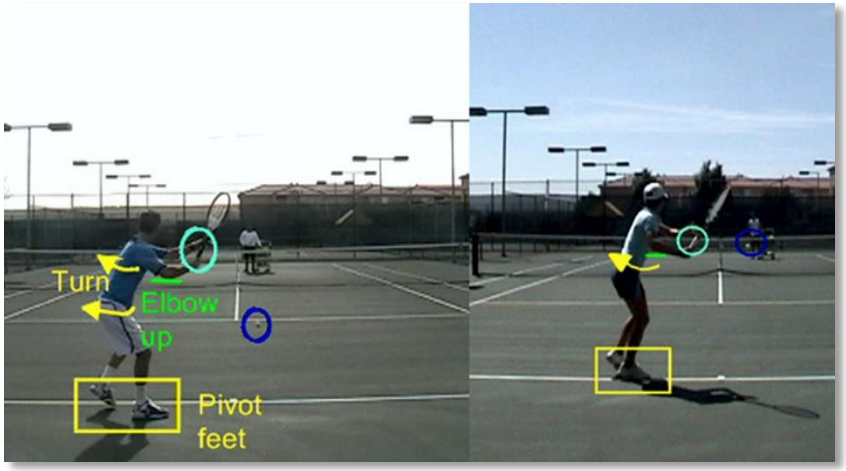
- Maintenance
- Architecture
- Education
- Medicine
- Entertainment
- Navigation
- Gaming
- Advertising
- …

Augmented Reality Techniques

- Video compositing
- Head-up displays
- Direct projection
- Magic lens metaphor
- Magic mirror metaphor
- Magic eyeglass metaphor

Video Compositing

- Virtual information is overlaid in a video stream of a real scene
  - can happen in real time or in post processing



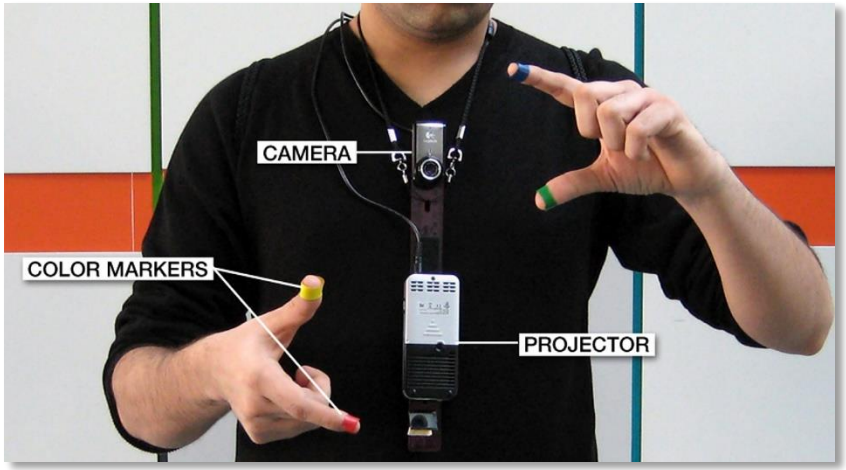
Video: Augmented Life Music Performance

Head-up Displays (HUDs)

- Head-up displays are used in civil and military aircrafts as well as in some cars
- The overlaid information is generally not directly connected to the objects seen through the window
  - *weak blend* between virtuality and reality

SixthSense (Direct Projection)

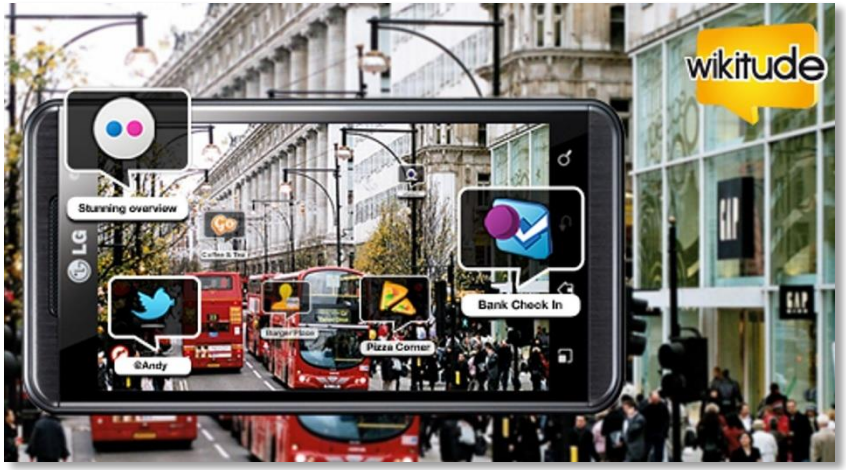
- Wearable augmented reality interface
  - small camera and projector
  - developed at MIT Media Lab
    - Pranav Mistry and Pattie Maes
- Visionary wearable augmented reality system
  - what happened to the SixthSense?



Video: SixthSense

Wikitude World Browser (Magic Lens)

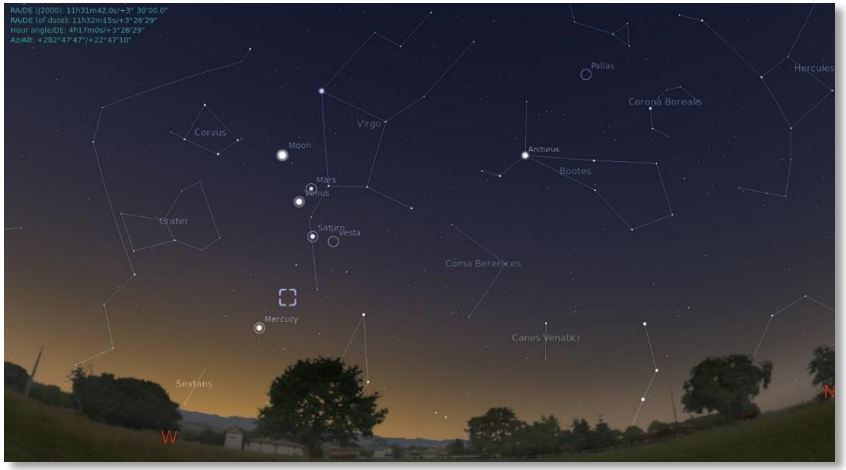
- The *WIKITUDE World browser* presents information about nearby physical landmarks as well as content added by other users



- Real-time augmentation of mobile phone camera view
  - *location-based augmented reality* based on GPS, compass and accelerometer
- *WIKITUDE.me* authoring tool to add points of interest
- *WIKITUDE API* for augmented reality applications

Google Sky Map

- Mobile phone application that can be used as a magic lens to get information about stars in the sky
- Real-time augmentation of the sky based on the mobile phone's position (e.g. via GPS) and orientation



ARToolKit

- Tracking library to overlay virtual imagery
- Calculates real-time camera position and orientation relative to square physical markers

- Fast enough for real-time AR applications
- Free and open source
  - https://artoolkit.org
- Multiple spinoffs
  - ARTag, MRToolkit, osgART, ARToolKitPlus

Video: IKEA Augmented Reality

Magic Mirror Metaphor

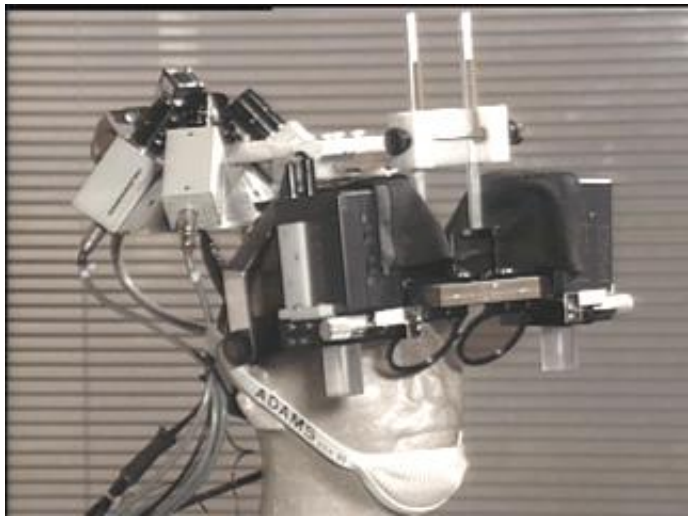
- Technically the concept of a magic mirror is very similar to the magic lens, except for the orientation of the camera
- Typically used to overlay information on the user
  - e.g. in fashion

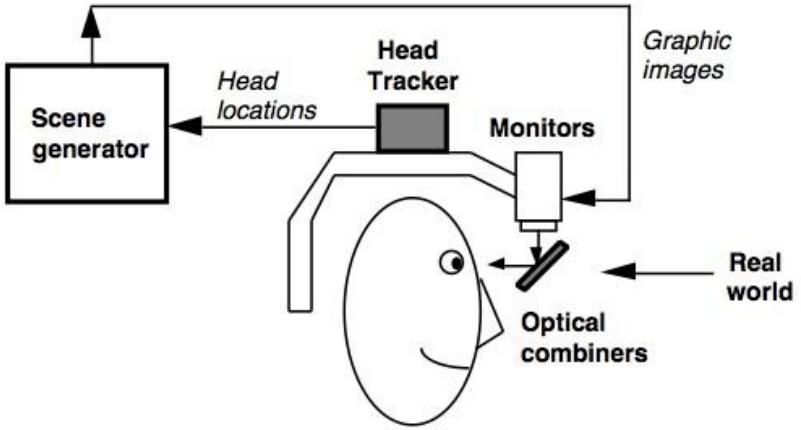
Magic Eyeglass Techniques

- *See-through* head mounted displays
- 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

Optical See-through HMDs

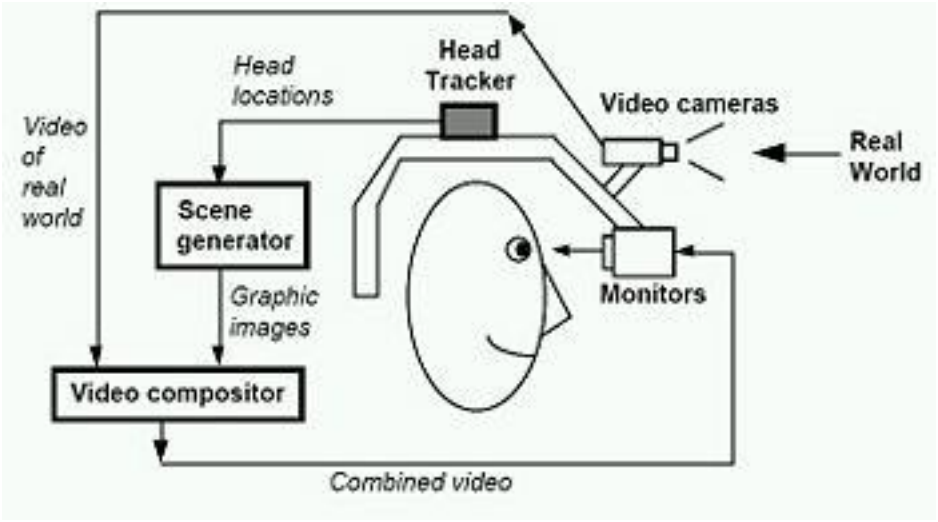
- With optical see-through HMDs, the virtual images are produced on semi-transparent surfaces (LCD panels) or reflected on semi-transparent mirrors
  - example: Microsoft HoloLens





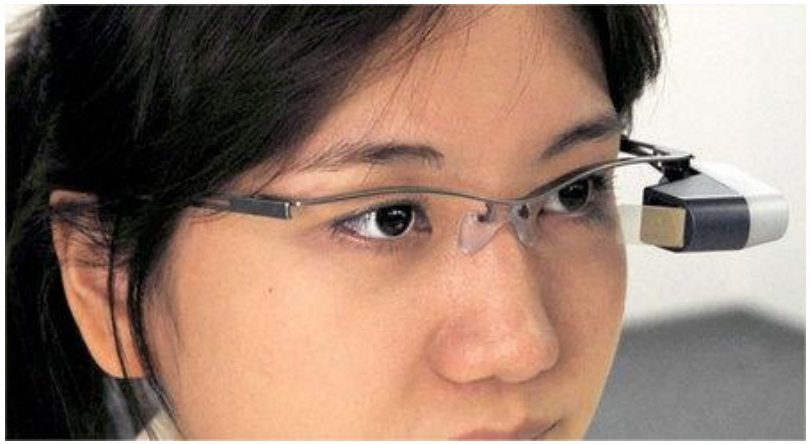
Video See-through HMDs

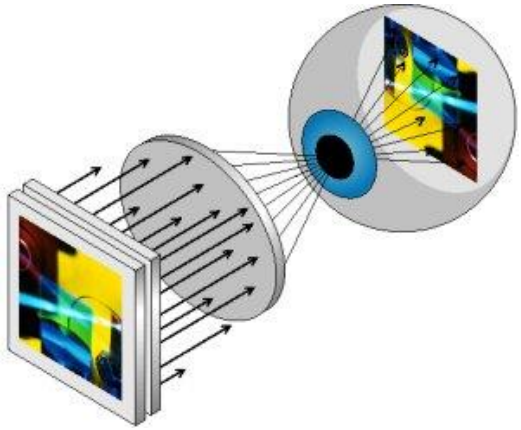
- With video see-through HMDs, real video images are captured by one or two video cameras installed in the unit and overlaid with computer graphics (virtual) images



Virtual Retinal Displays (VRD)

- *Virtual retinal display (VRD)* or *retinal scan display (RSD)*
- Projects three modulated light beams directly onto the retina of the eye producing a rasterised image
- Illusion of seeing the source image like a conventional display floating in space in front of the eye
  - example: Google Glass





Google Glass

- Android-based headset
  - Bluetooth connection to mobile phone
  - display with "picture in picture" experience
  - camera and microphone
  - voice and touch-based interaction

- What about using voice navigation in public space?
  - do people for example use Siri in public space?
- What about *privacy* and *safety*?
  - recording pictures and movies or recognising people's faces
- What about the *social acceptance* of Google Glass?

Video: Looking Through Google Glass

Microsoft HoloLens

- Lenses to combine superimposed images
  - optical waveguides
- Integrated processor
  - all the processing happens on the HoloLens
- Depth camera and other sensors to "understand" the environment

- Developer version available in Europe from November 2016 on
  - SDK and simulator already available

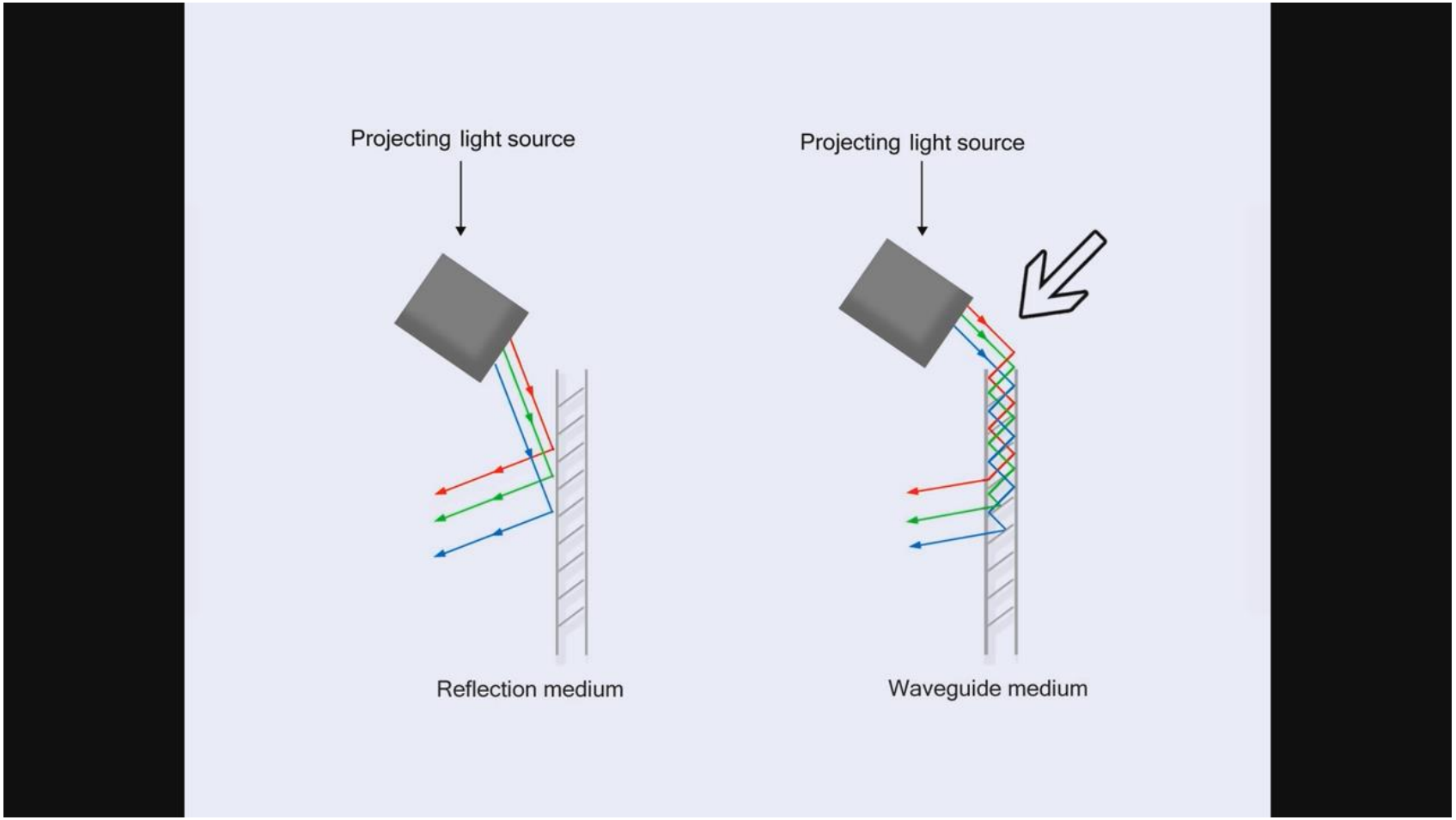
Video: Microsoft HoloLens

Magic Leap

- Promising but secretive startup company
- Photonic Lightfield Display Chip
  - *control* the *flow of photons* instead of the flow of electrons
  - physically embedded structures
- Might be based on some display technology from Zebra Imaging
  - use light to edge highly sophisticated photonic structures into a display medium
- Optical waveguides
  - image injected into the medium rather than just reflected on the surface
- …

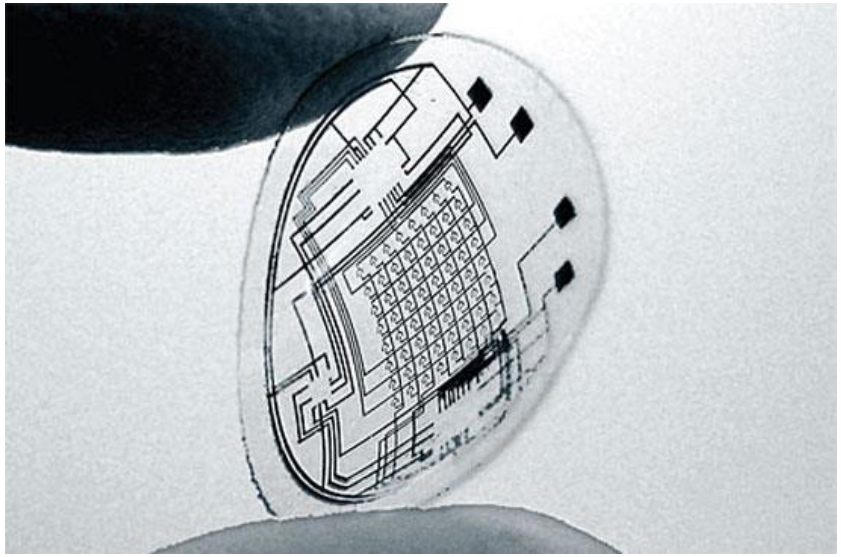
Video: Magic Leap Teaser

Video: Magic Leap Concepts Explored



The Future of Augmented Reality?

- New forms of less distracting augmentations
  - e.g. augmented contact lenses
- Improvements in tracking technologies
  - e.g. see Microsoft HoloLens
- What about the social acceptance?



B.A. Parviz, University of Washington

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