AR with head-mounted Displays

Vorlesung „Augmented Reality”

Prof. Dr. Andreas Butz

Head-mounted Displays (HMDs)

- Some history
- Optics of the human eye
- HMDs: Working Principles, Problems
  - Closed (video only)
  - Optical see-through
  - Video see-through
- Examples of commercially available HMDs
- Head-up displays
- Proposed solutions to existing problems
- Research prototypes

Geschichte:

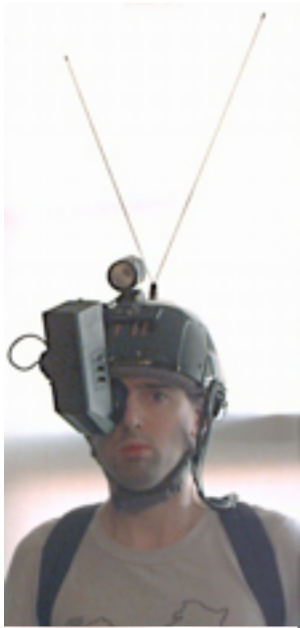
(Quelle: auszugsweise und überprüft aus Wikipedia)

- 1966: Ivan Sutherland und Raymond Goertz (Argonne National Laboratory) experimentierten an der Harvard University mit dem Prototyp der ersten HMDs sowie eines Datenhandschuhs.
- 1968: Ivan Sutherland baut das erste funktionsfähige HMD. Dieses HMD ist so schwer, dass es zusätzlich von der Raumdecke getragen werden musste.
- 1985: Vor allem militärische Entwicklungen, beispielsweise die des IHADSS (Integrated Helmet and Display Sight System) für den AH -64 Apache Helikopter. Dieses System war in den Helm des Piloten integriert. Es war unter anderem ausgestattet mit einer Projektionsfläche vor dem rechten Auge, einem Nachtsichtgerät und einem Kopf/Sicht-Richtungssystem für die Bewaffnung des Helikopters.
- 1991: Der VRD (Virtual Retinal Display) wurde in den Human Interface Technology Lab (HIT) entwickelt.

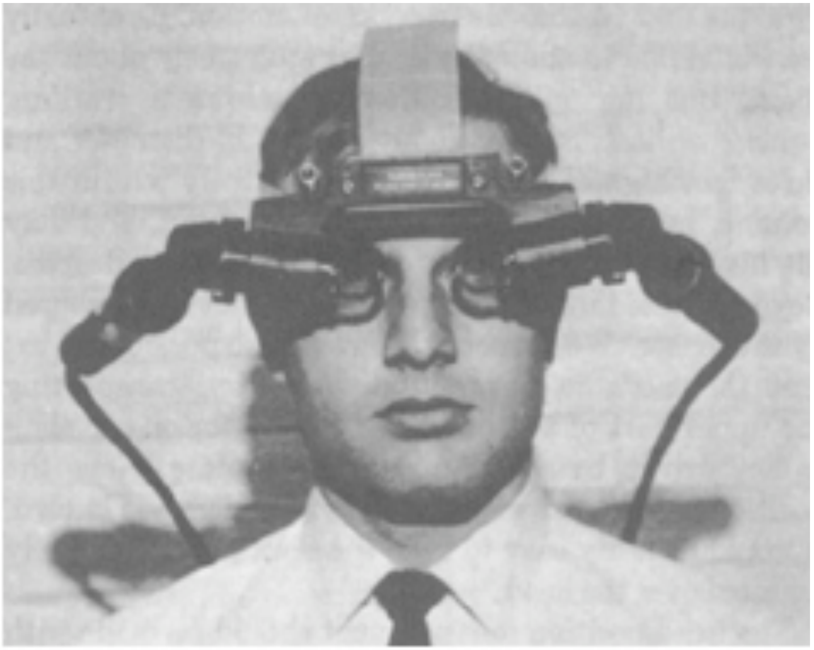
Geschichte:

(Quelle: auszugsweise und überprüft aus Wikipedia)

- 1994: Steve Mann, Professor am MIT, experimentiert seit den 80ern mit Wearable Computers. Mitte der 90er verbindet er seinen Wearable Computer mit einer Webcam. Per Funk stellte er die entstehenden Bilder ins Internet. Dies kommentierte er mit den Worten: "It's fun being a cyborg."
- 2000: Microvision entwickelt für die Airforce einen HDTV (1920:1080 pixel) HMD.
- 2006: eMagin stellt ein neues HMD vor. Mit dem Namen Eyebud 800 ist es für den direkten Anschluss an den Apple iPod gedacht.



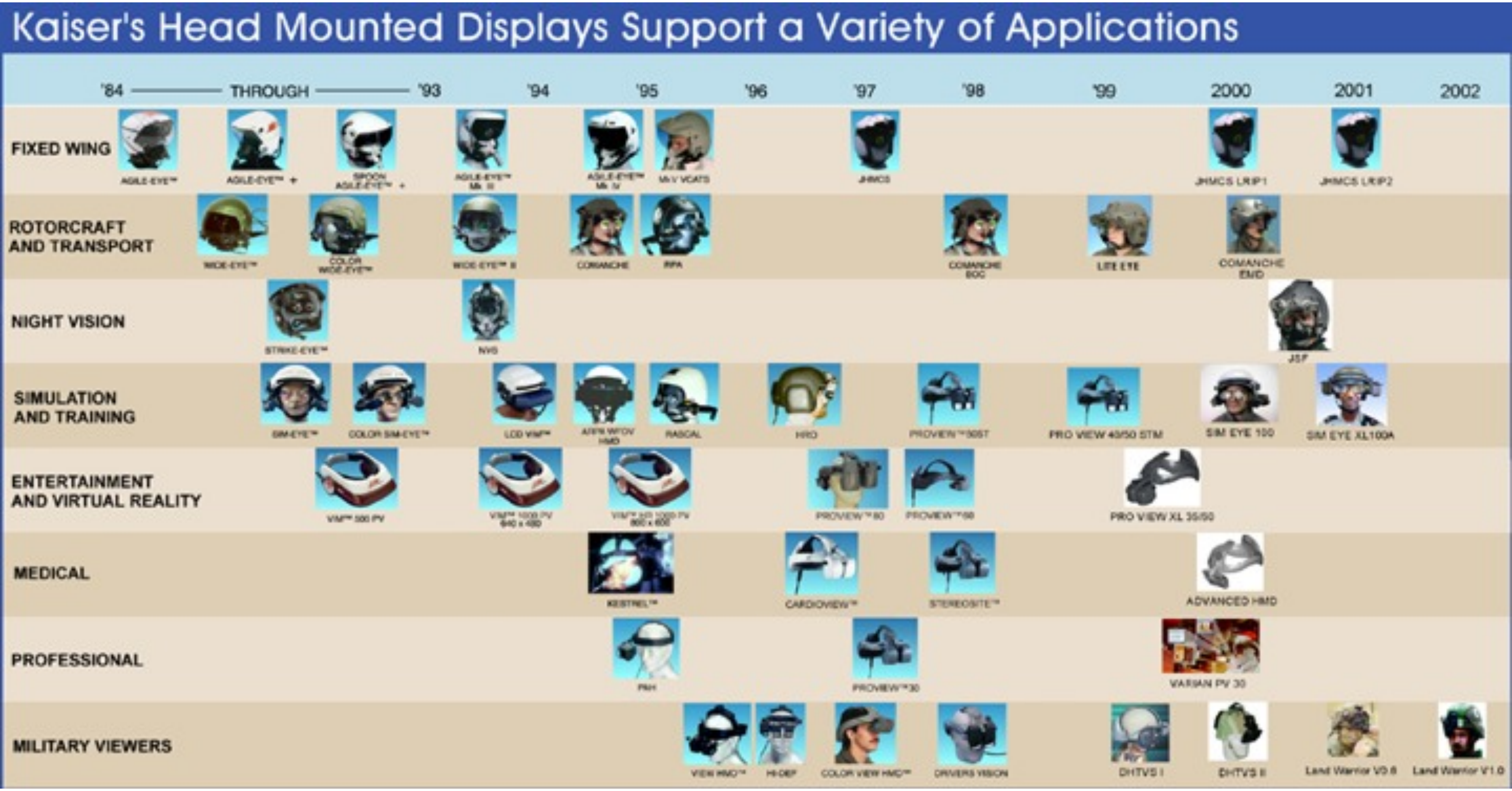
Ivan Sutherland‘s HMD



- Quelle: "A Head -Mounted Three-Dimensional Display," Sutherland, I.E. AFIPS Conference Proceedings, Vol. 33, Part I, 1968, pp. 757-764.

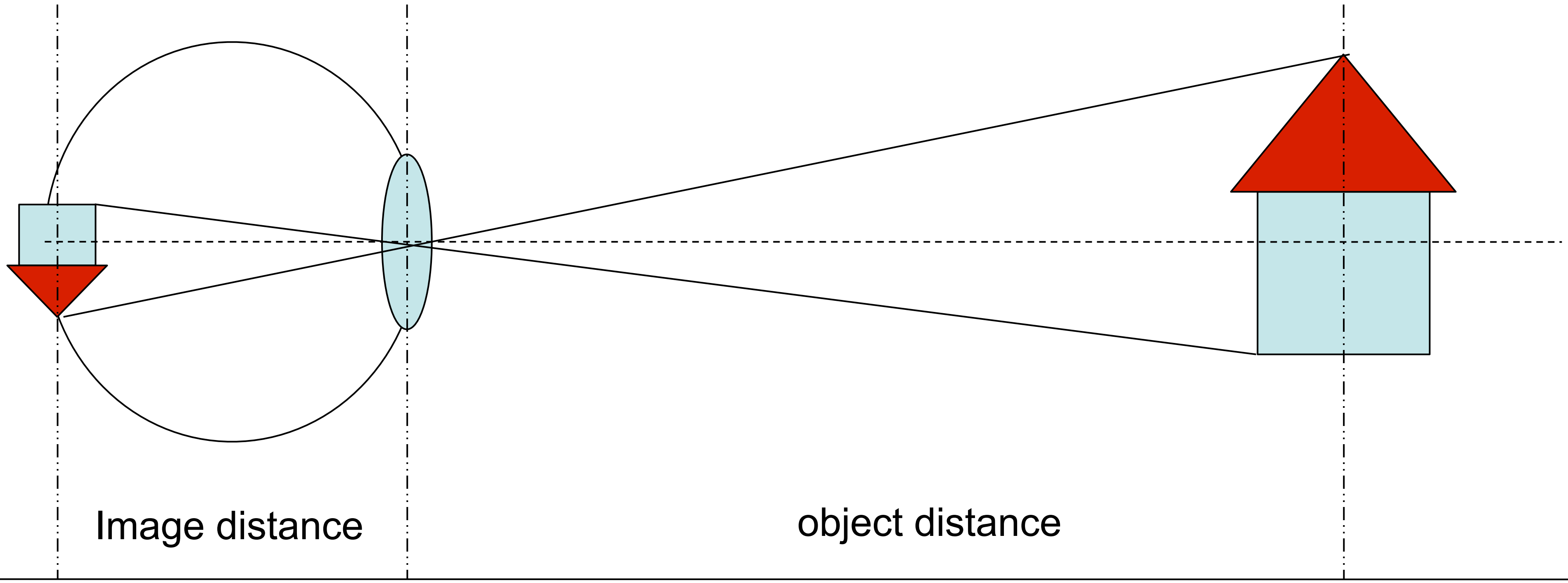
Example Product Timeline

(http://www.keo.com/ now offline)



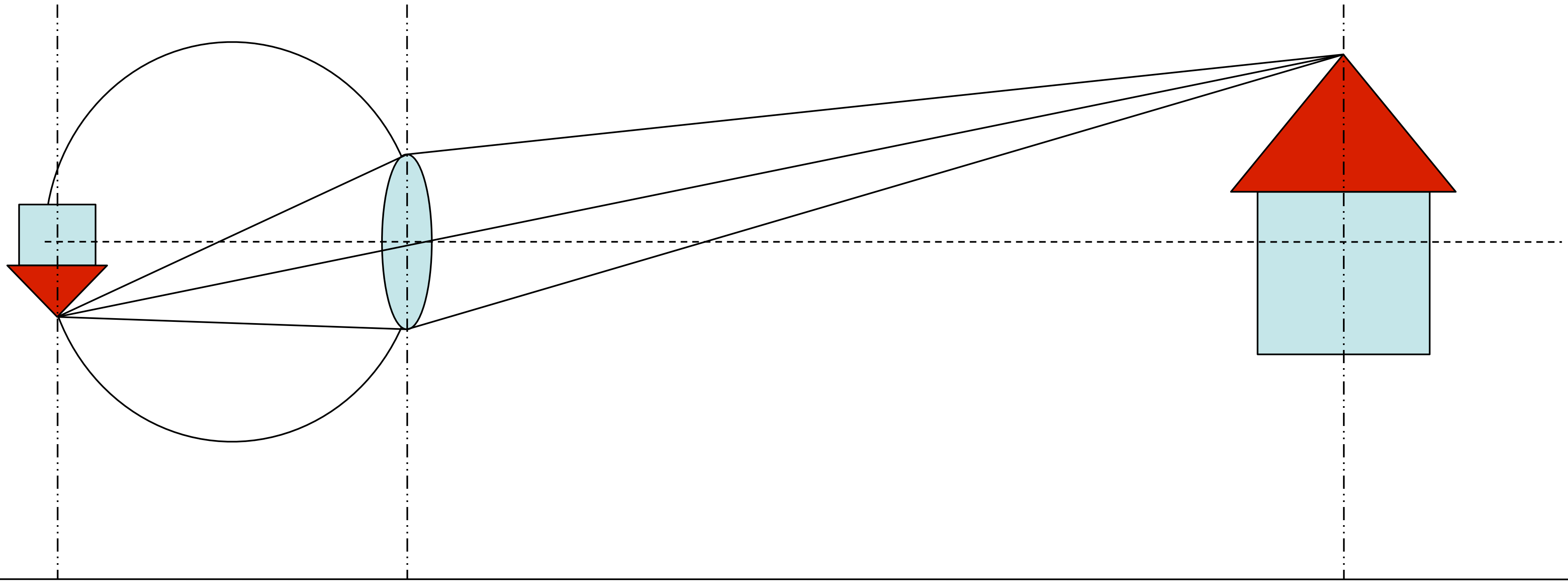
Optical system of the human eye (1)

- Simplified principle: the pinhole camera
- Only one light beam from each object point to the corresponding image point

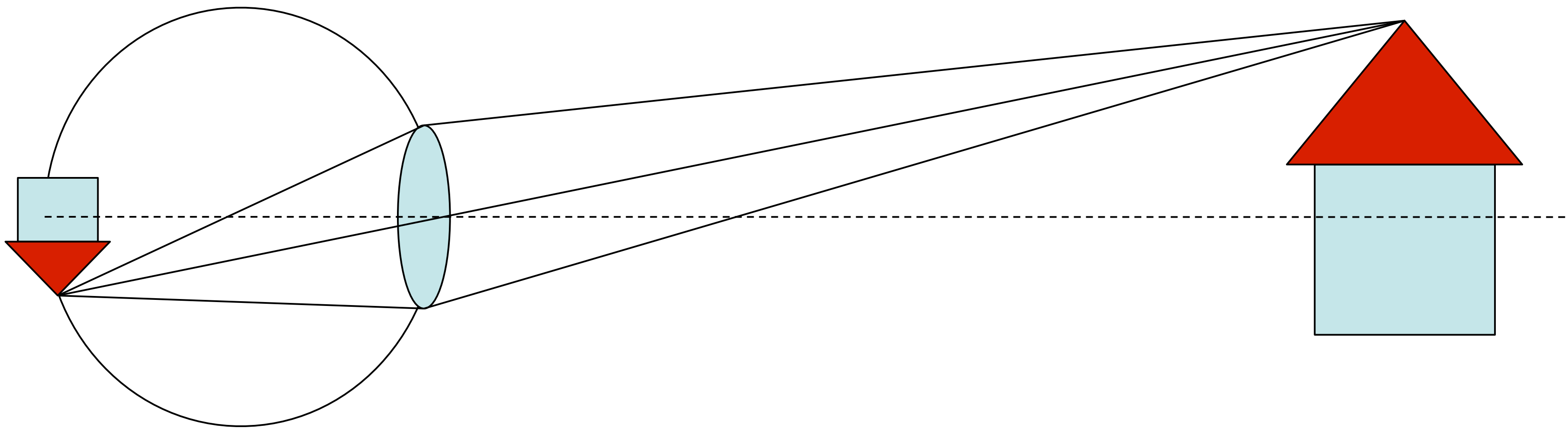


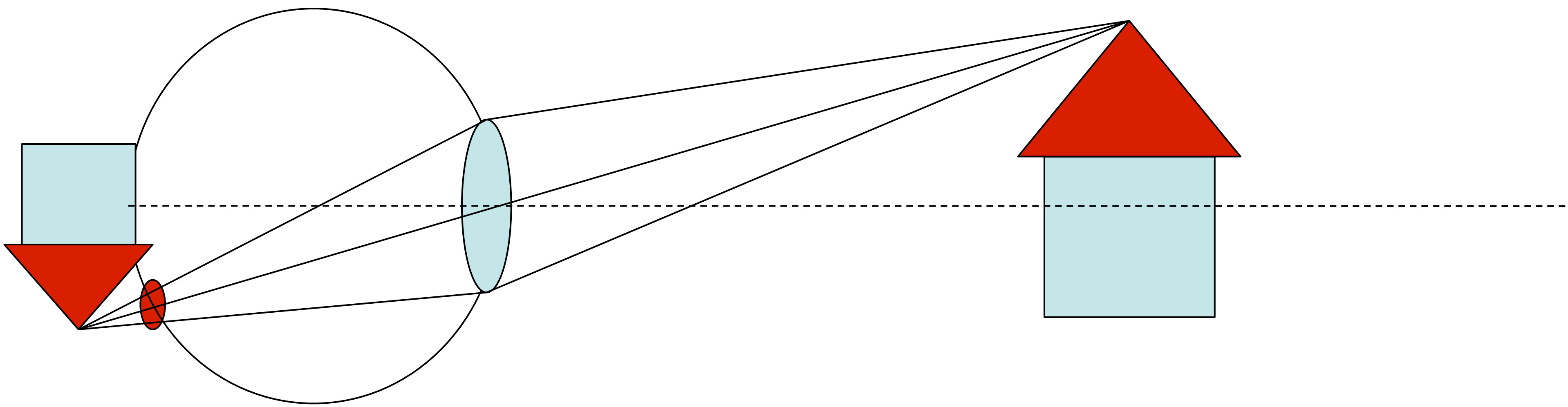
Optical system of the human eye (2)

- Reality: a lens which has to be focused
  - all light rays from one object point have to meet in the same image point!

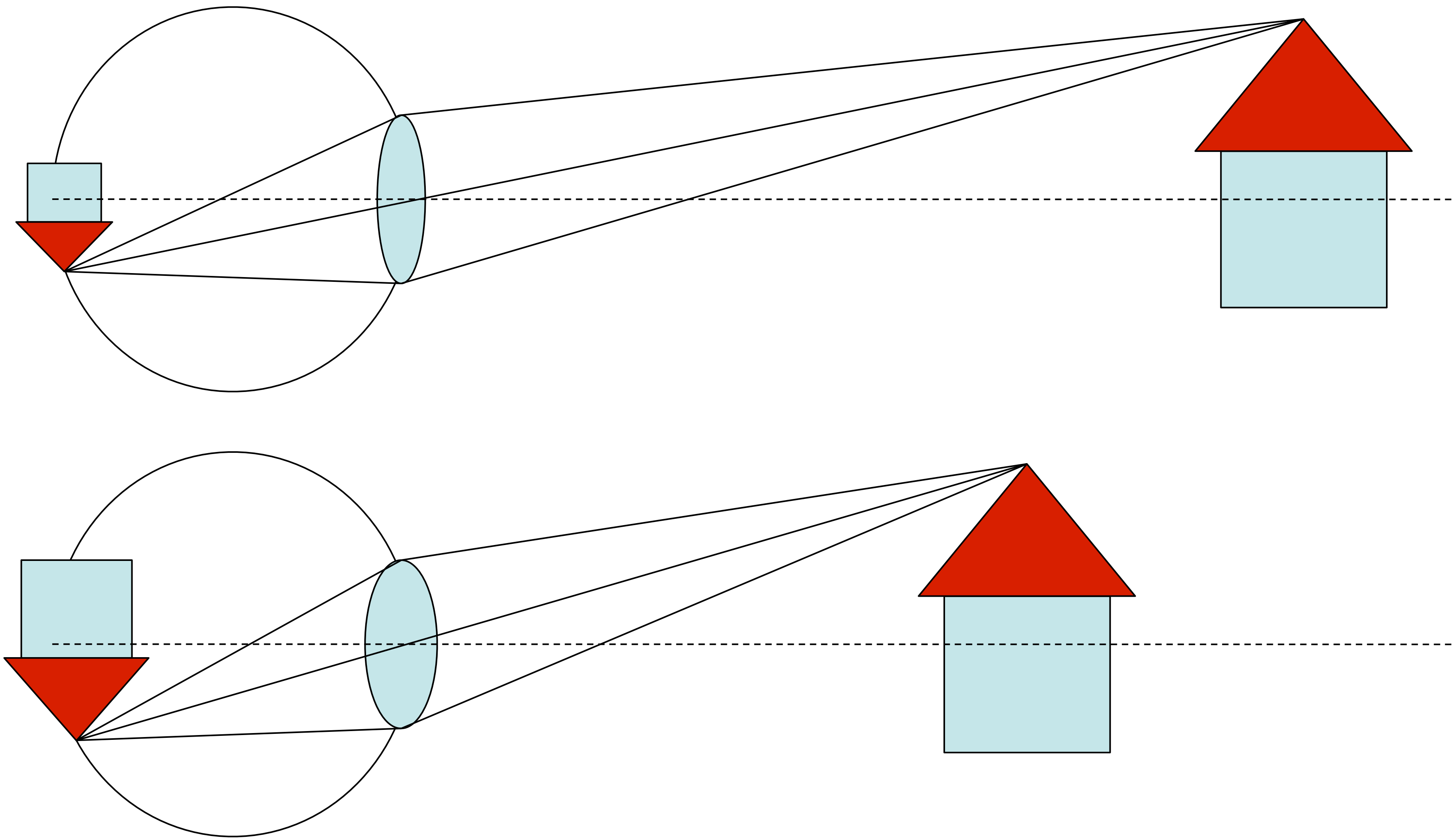


Objects out of focus (depth of field)



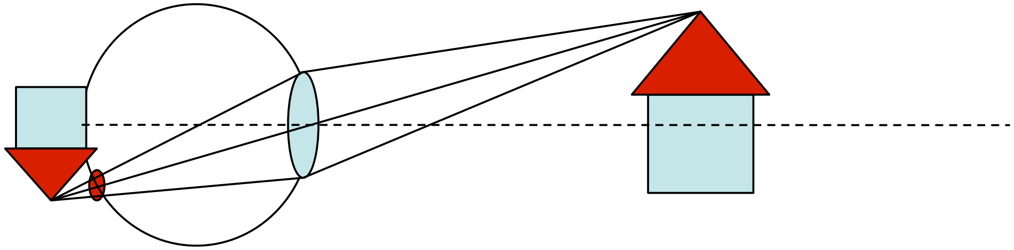


Focusing the eye by adjusting the lens



Resulting properties of the human eye

- Focal length of the lens can be adjusted to
  - Objects at infinite distance
  - Objects at ~20cm from the eye
  - Everything between these distances
  - Only one distance (range) at a time
- Eye needs time to adjust between objects at different distances
  - constant refocussing is exhausting
  - constant focus distance also exhausting



Spatial vision: Depth Cues

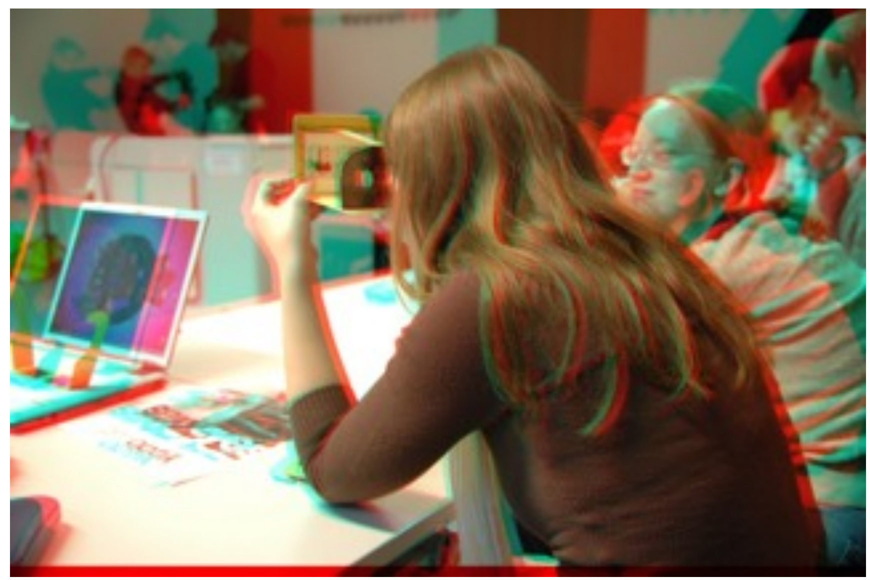
- Several different types of cues used by human visual system
  - Static monocular cues
  - Stereopsis
  - Motion parallax
  - Oculomotor cues
    - Accommodation-convergence mismatch

Static Monocular Cues

- Occlusion
- Relative Size
- Relative Height
- Linear Perspective
- Aerial Perspective
- Texture Gradient
- Shading

Stereopsis

- Static, binocular cue
- Each eye gets a slightly different image
  - Monocular cues from each image
- Only effective within a few feet of viewer
  - Useless if only distant objects



Motion Parallax

- Dynamic, monocular cue
- Near objects move faster than far objects
  - used in very simple 2D arcade games

- Generally more important than stereo!
- → head tracking is very important!

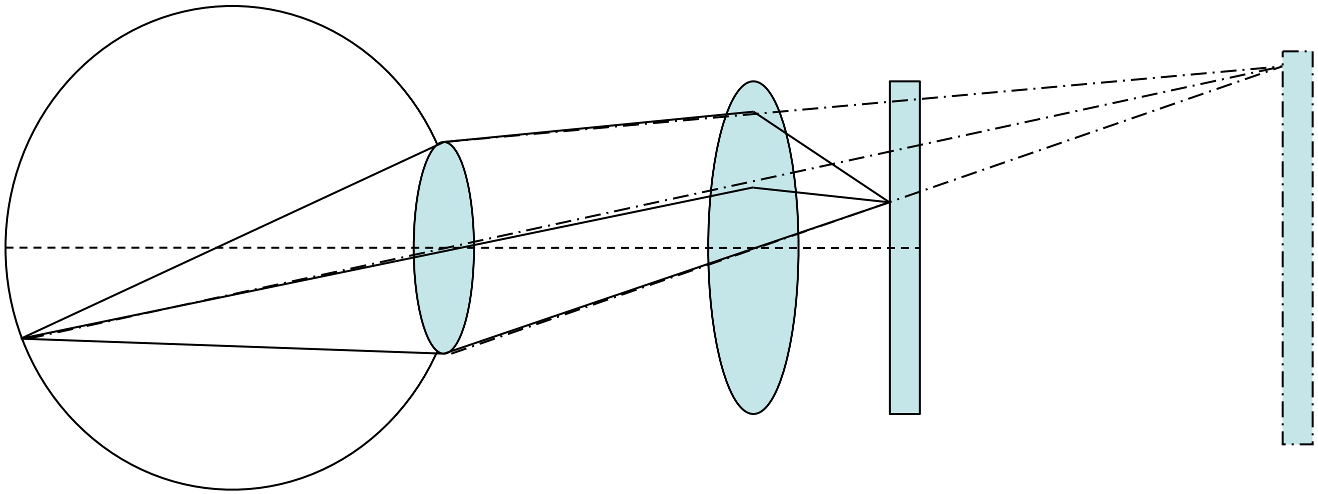
Oculomotor Cues

- Based on information from eye muscles
- Accommodation: lens shape
- Convergence: gaze direction

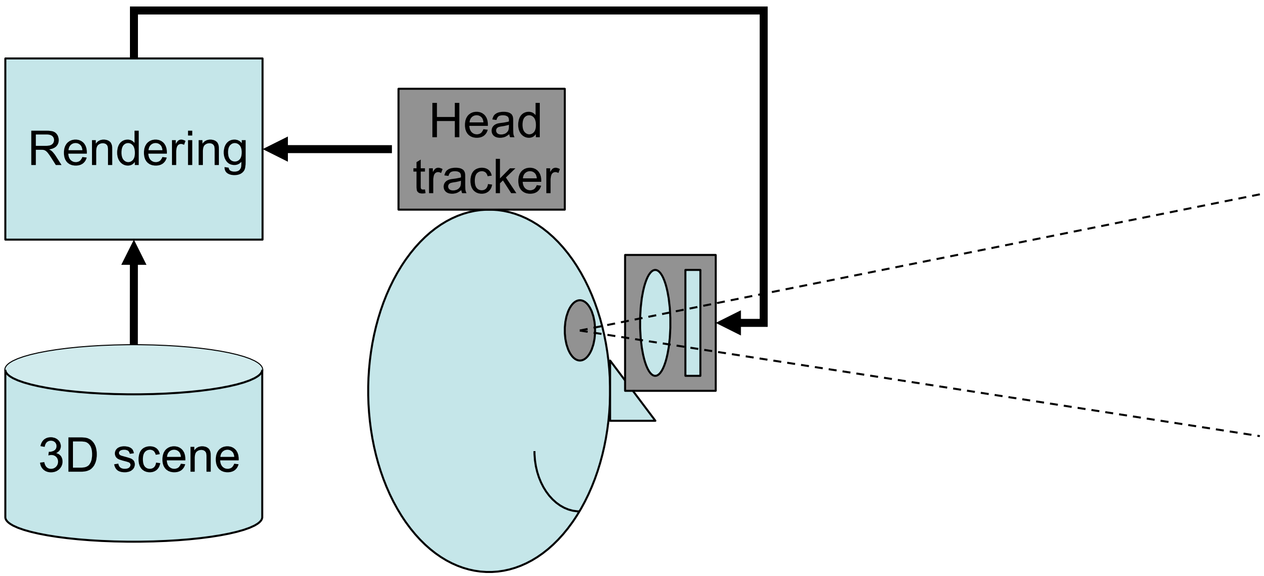
- HMDs confuse the brain with oculomotor cues
  - *Accommodation focuses eye at one distance*
  - *Convergence says objects are at different distance*

Principle: closed (video only) HMD

- Monitor is mounted very close to the eye
- Additional lens makes it appear distant
- ➔ all images appear at the same distance
  - Usually at infinity or slightly less



Creating VR with a HMD



Challenges with HMDs in VR

- Lag and jitter between head motion and motion of the 3D scene
  – Due to tracking → predictive tracking
  – Due to rendering → nowadays mostly irrelevant
- Leads to different motion cues from
  – Eye (delayed) and
  – Vestibular system (not delayed)
- Result: cyber sickness

nVision Industries

„The Datavisor 80 contains wide field of view optics modules integrated with high-resolution CRTs. Designed to be worn for extended periods of time, the Datavisor 80 is built with optical, mechanical, and electrical components distributed around the unit for better balance and ergonomics.“ ;-)

- Datavisor HiRes:
  - Field of view: 72 deg
  - Resolution: 1280x1024

SEOS HMD 120/40

- Resolution:
  1280 x 1024
- Field of View:
  80° x 67° per eye
- Overlap: 50%
  (resulting in 120x67 deg FoV with a 40x67 deg stereo overlap)
- Weight: 1 Kg

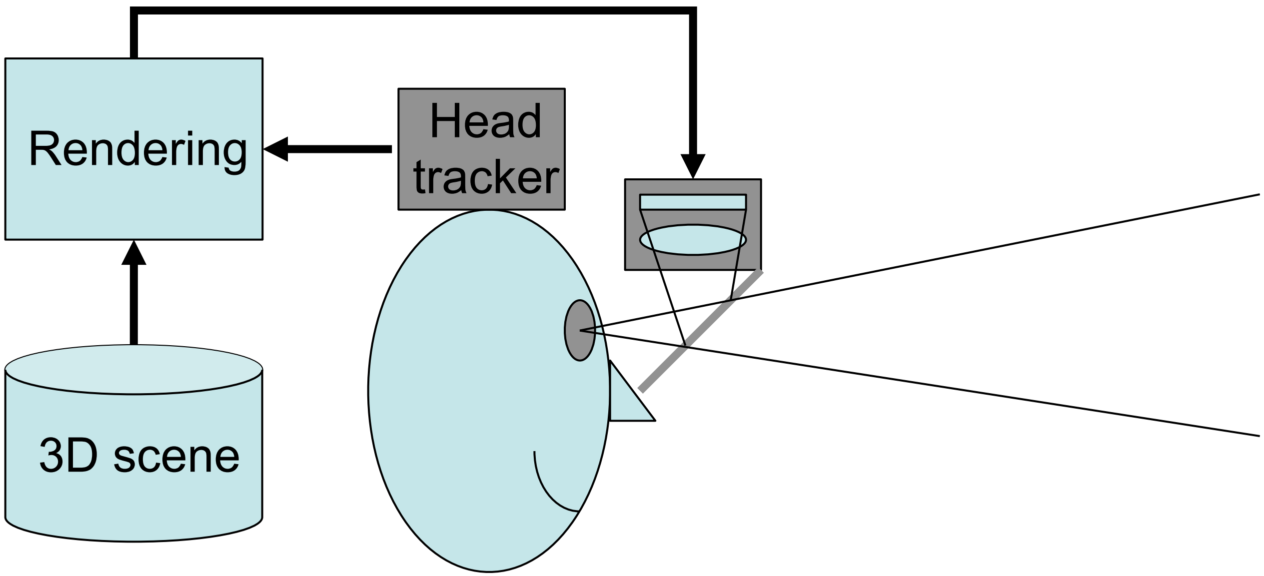
Icuiti ™ *M920*


CompactFlash Type
II Interface, no external
batteries required
Lightweight Video
Eyewear (3.5 0z)
Compatible
with most
Windows Mobile
Pocket PC's
High Res LCD display,
4x the resolution of
a PDA

Kaiser Electro Optics *ProView SO35 Monocular*

- Field of View: 32°x24°
- Resolution: 800x600
- Mounting: Clip on to helmet (Display module); Clip on to belt (Display Controller)
- Temp.: Operating: -32° to +55°C; Storage: -32°C to +71°C
- Humidity: Six 48-hour cycles, 20°C to 55°C, 95% RH
- Salt Fog: Four 24-hour cycles
- Vibration: Random vibration, 6 axis, 5 Hz to 2500Hz, up to 40 gs
- Immersion: Immersion in 1 meter of water for 2 hours
- $10,500

Creating AR with optical see-through HMDs



Advantages of optical see-through HMDs

- Preserve the richness of the world
  - Very high resolution of physical image
  - No lag between motion and phys. image
  - Physical objects can be focused at their correct distance

Challenges with optical see-through HMDs

- Lag and jitter between the physical and the virtual image
- Misalignment of physical and virtual image (registration)
- HMD can only add light to physical image
  – Looks like ghost images
  – Always in front of physical objects
- High dynamic range of the phys. image
  – Use in bright sunlight almost impossible
- Virtual objects always focused at same distance
  – Permanent adaptation back and forth

Construction: Boeing, 1994

- Assembly of wire harness for airplanes
- Assembled on a large board
- Traditionally tedious task
- Equip board with markers
- Show in HMD where to mount next wire

i-O Display Systems

- Resolution: 110,000 pixels per LCD Panel = 230 x 173 lines of resolution
- Full color
- Stereo sound
- Field of view: 30 deg

- Price: 300$

Sony Glasstron

- Initially built for watching DVDs
- Video resolution
- No longer manufactured
- Amount of see-through can be regulated

SAAB *AddVisor™ 150*

- Field of view: 46 deg
- Eye overlap: 100% or 50%
- Resolution: 1280x1024
- Full color

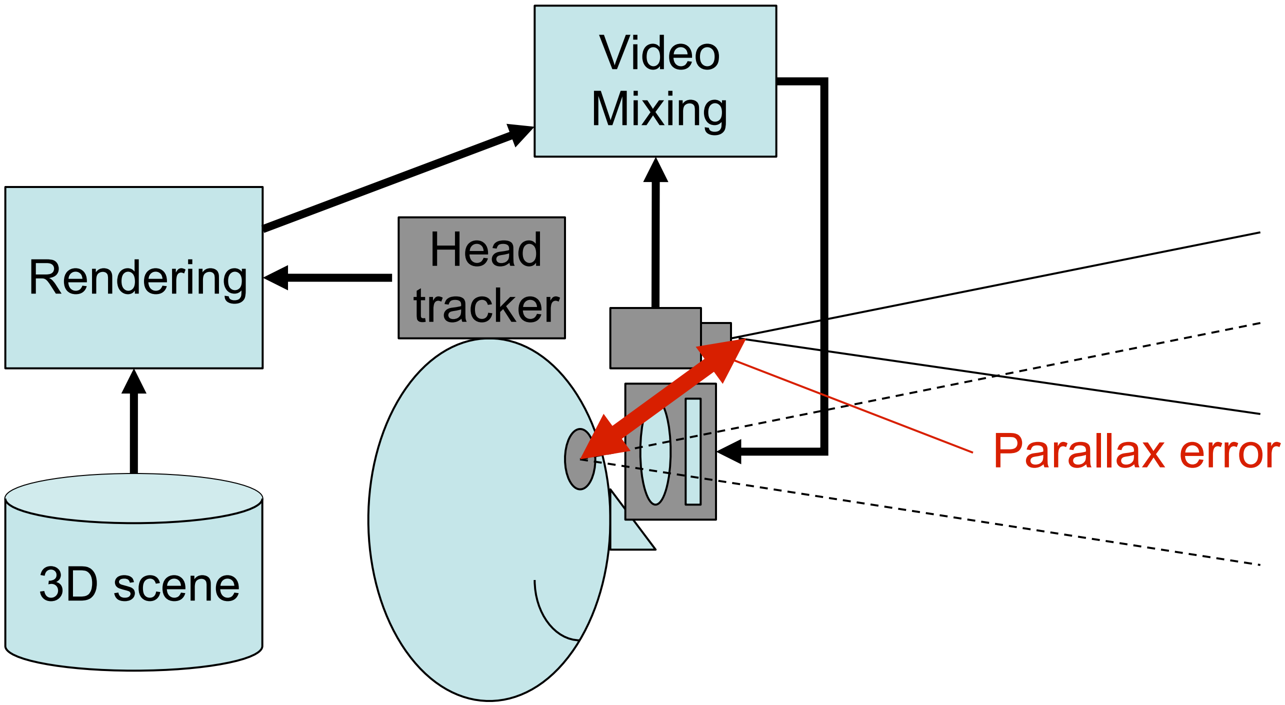
nVision Industries

- Datavisor SeeThrough:
  - Field of view: 72 deg
  - Resolution: 1280x1024

KEO Sim Eye XL100A

- Resolution 1024x768
- Contrast: > 20:1
- Field of View: 50° x 100° with 30° Overlap
- Transmission: See through > 20%
- Collimation: Greater than 30ft. but less than infinity
- Weight: almost 3Kg
- Price: $87,500

Creating AR with video see-through HMDs



Advantages of video-based see-through

- Lag between physical and virtual image can be compensated
- Camera can be used for tracking as well
  - Physical image = raw tracking data
  - Perfect registration possible
- Video mixer can add or subtract light
  - Virtual objects can be drawn in black
  - Physical objects can be substituted
  - Virtual objects can be behind physical objects
- Just one image with a given focus distance

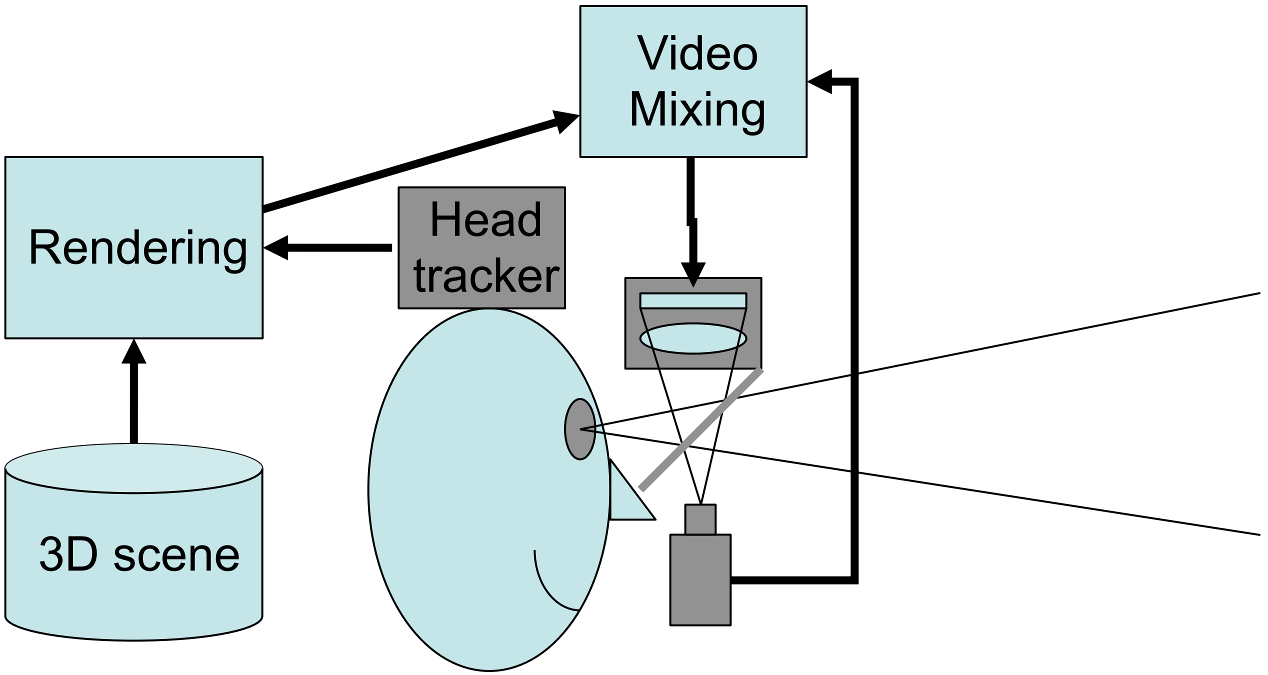
Challenges of video-based see-through

- Lag between physical and virtual image can be compensated
  - …by delaying the physical image
  - Leads back to the cyber sickness problem
- Parallax error can not be corrected electronically
  - Wrong stereo cues when used for stereo
- Richness of the world is lost
  - Video image just 0.5 megapixels
  - Resolution of human vision is much higher (>10x)

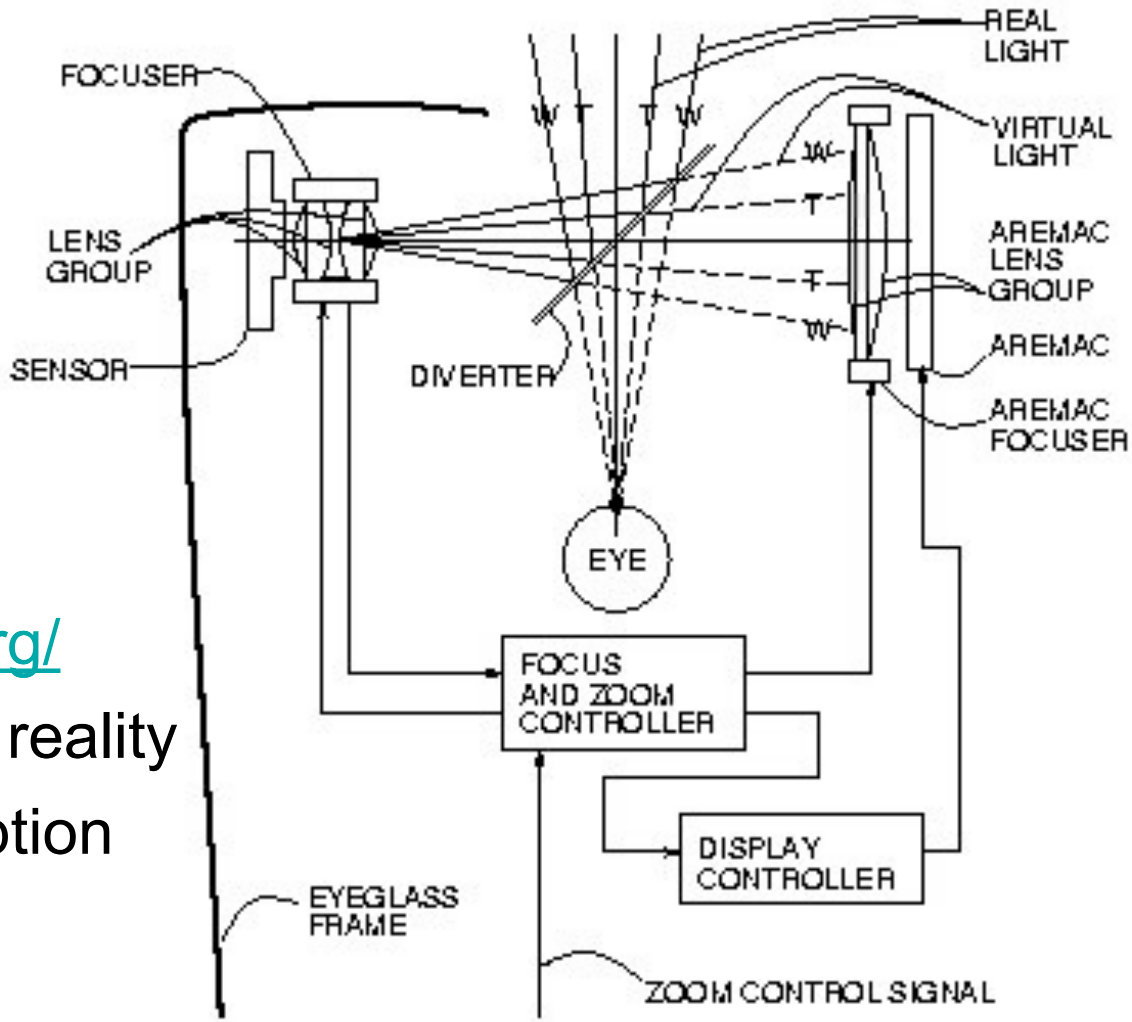
Video see-through examples

- Here: just 1 camera between the eyes
  - No stereo
  - Minimized parallax error

Video see-through HMD without parallax error (e.g., eyetap device)

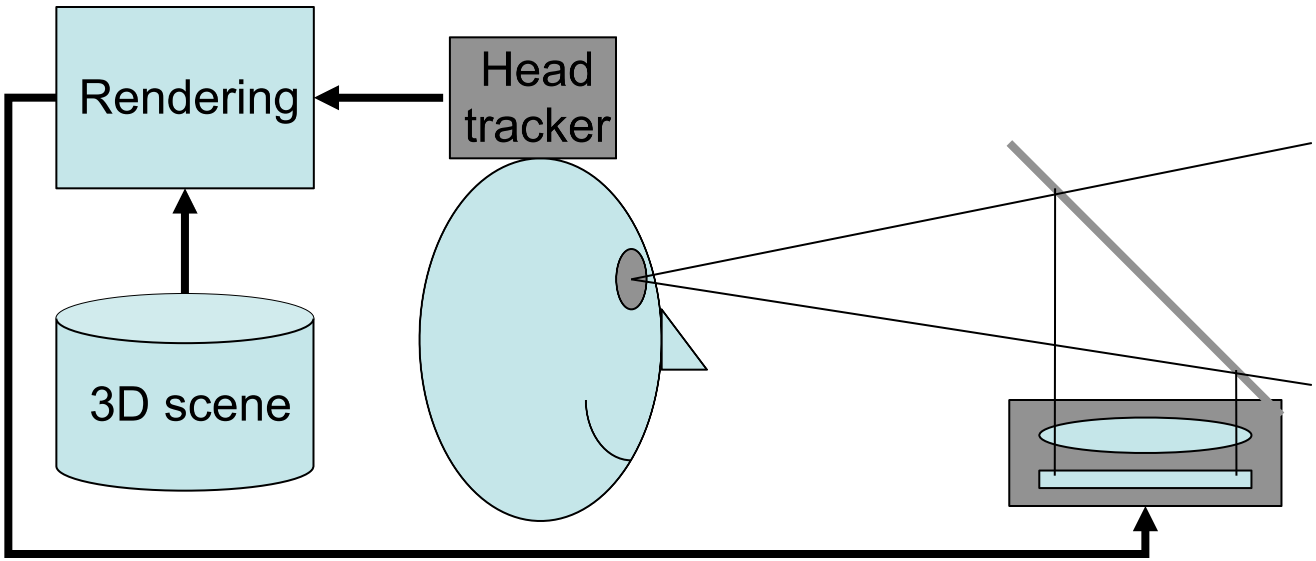


Eyetap Technology



- http://www.eyetap.org/
- Computer mediated reality
- modify visual perception
  - Augment
  - Diminish
  - Alter

Creating AR with Head-up Displays (HUDs)



Head-Up Display with 3D registration

- Currently mostly military use
- Fixed Display
- Very exact head or eye tracking needed
  - Easy for jet pilots
- High brightness and dynamics needed

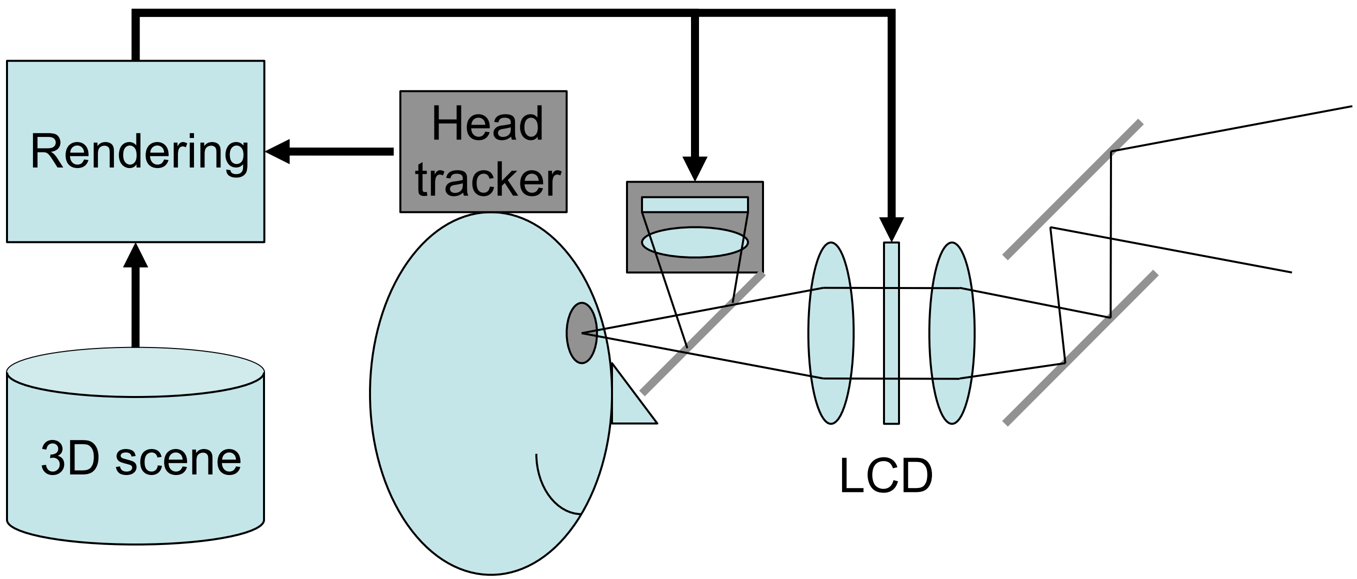
HUD without 3D registration

- Optional Equipment in premium cars (image source: www.bmw.ch)
- easy: no tracking needed! -> not AR!

HUD app for iPhone

- can be bought from app store
- put iPhone under wind shield
- uses GPS and accell sensors to sense car motion
- can display speed, heading, ...

Optical see-through with occlusion
[Kiyokawa et al., ISAR 2000]



Optical see-through

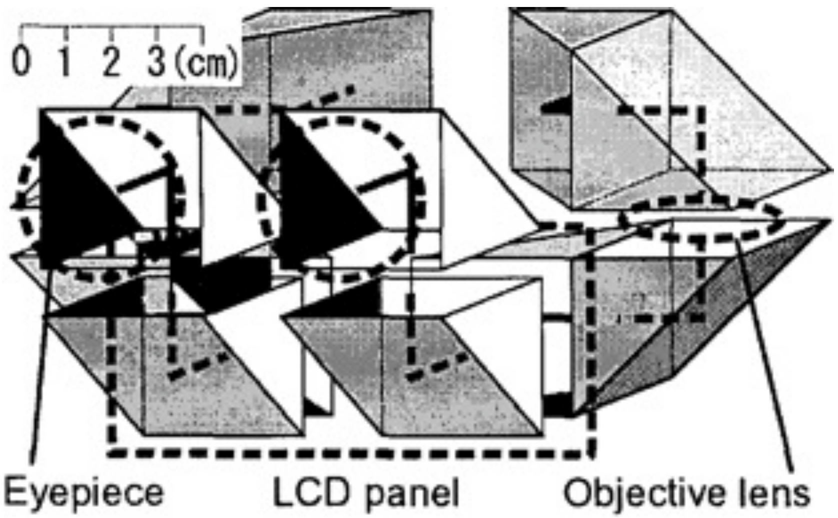


Figure 18. A compact optics design of the display.

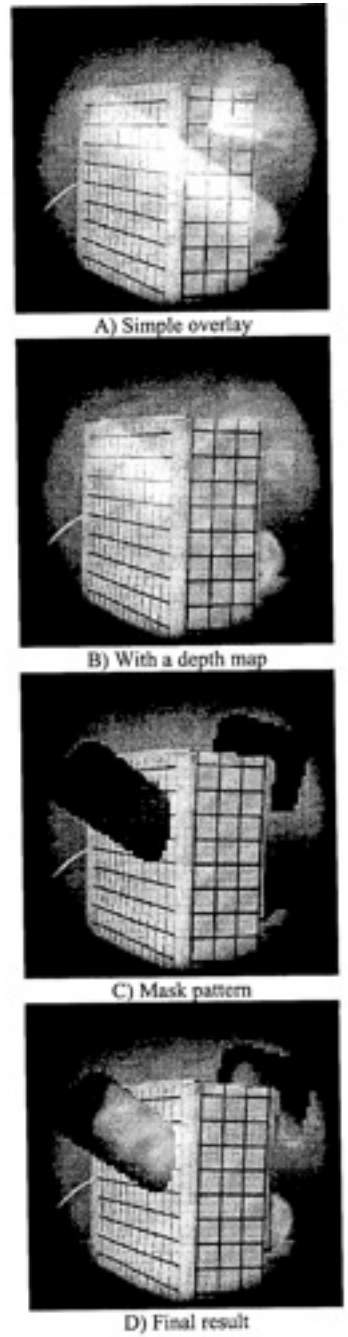


Figure 16. Four patterns of overlaid images seen through the first prototype display.

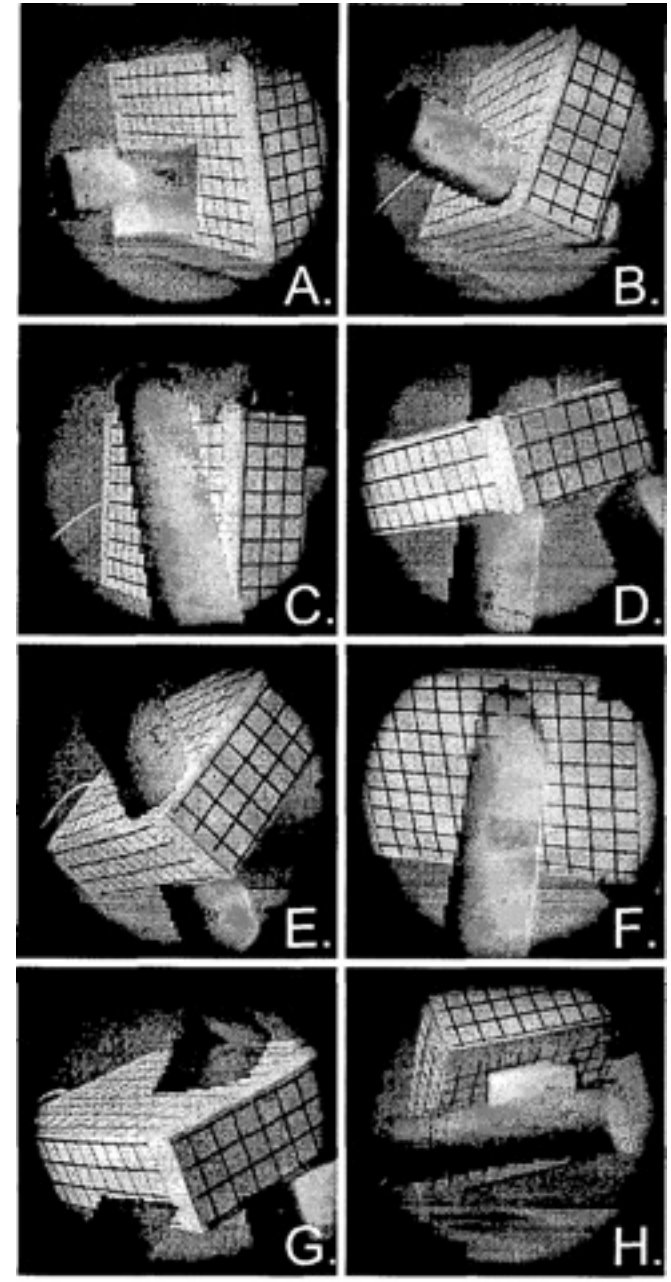


Figure 17. Real-time image overlay.

Optical see-through with occlusion
[Kiyokawa et al., ISMAR 2003]