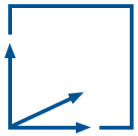
Module IN 2018

Introduction to Augmented Reality

Prof. Gudrun Klinker



Displays

SS 2018

Literature

- “Optical versus Video See-Through Head-Mounted Displays”, J.P Rolland and H. Fuchs, in Fundamentals of Wearable Computers and Augmented Reality (chap. 4), 2001, pp.113-156
- “A Head-Mounted Three Dimensional Display”, I. Sutherland, in Proceedings of the Fall Joint Computer Conference, pp. 354-356
- “Präsenz und Raumwahrnehmung in virtuellen Umgebungen”, Jan Hofmann, Doktorarbeit am Lehrstuhl für Ergonomie, Maschinenwesen, TU München, 2001.
- “Dynamic Virtual Convergence for Video See-through Head-mounted Displays: Maintaining Maximum Stereo Overlap throughout a Close-range Work Space”, A. State, J. Ackerman, G. Hirota, J. Lee and H. Fuchs, ISAR 2001, pp. 137-146. http://www.cs.unc.edu/~andrei/pubs
- “Perceptual Issues in Augmented Reality”, D. Drascic, P. Milgram, in SPIE Vol. 2653: Stereoscopic Displays and Virtual Reality Systems III, pp. 123-134, 1996. http://gypsy.rose.utoronto.ca/people/david_dir/SPIE96/SPIE96.full.html

Agenda

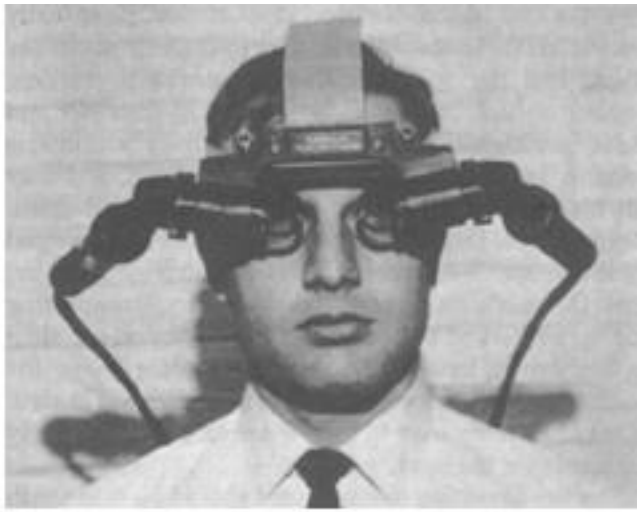
1. Head-Mounted Displays (HMDs)
2. Other Displays for AR

1. Head-Mounted Displays (HMDs)

- 1.1 Overview (History, Human Eye, Devices)
- 1.2 Technological Issues
- 1.3 Human Factors and Perceptual Issues
- 1.4 Extension: Dynamic Virtual Convergence

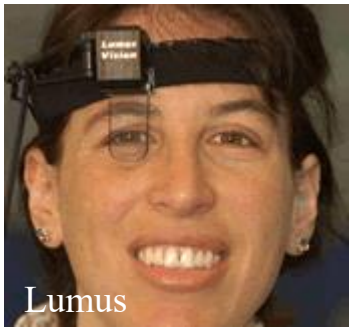
1.1 Overview (History, Human Eye, Devices)

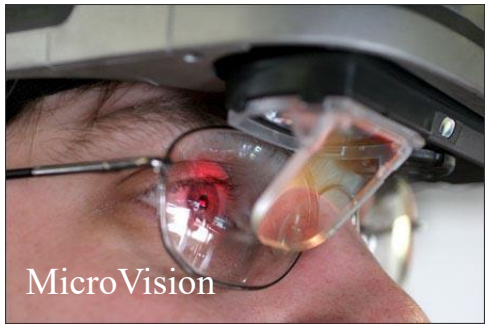
History: Ivan Sutherland 1968



1.1 Overview (History, Human Eye, Devices)

Examples of existing devices





1.1 Overview (History, Human Eye, Devices)

Examples of existing devices

1.1 Overview (History, Human Eye, Devices)

Examples of existing devices

AR-Rift

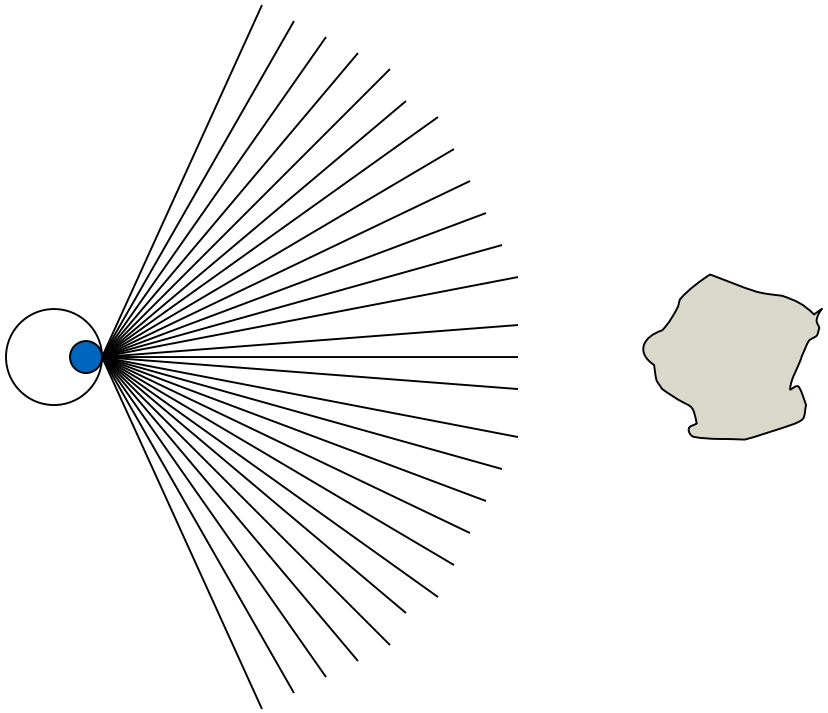
Google-Cardboard

HTC Vive

MS HoloLens

1.1 Overview (History, Human Eye, Devices)

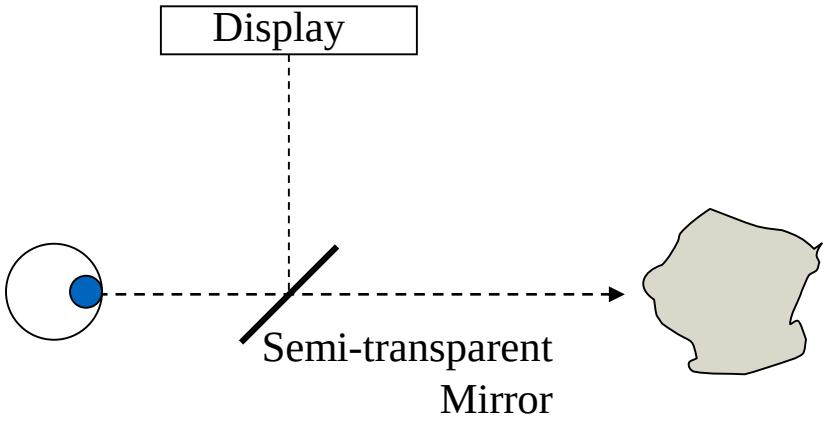
The human eye



- Speed: > 25 Hz (< 40 ms)
- Smooth rotation: 100 deg/s
  - Center of eye rotation ???
- Angular resolution: 1/60 deg
- Field of View: ~180 deg
- Depth of field:
  (pupil 2 - 4 mm diameter)
  - at 1 m: [0.94 m .. 1.04 m]
  - at 17 m: [11 m .. 33 m]
- Distance between eyes

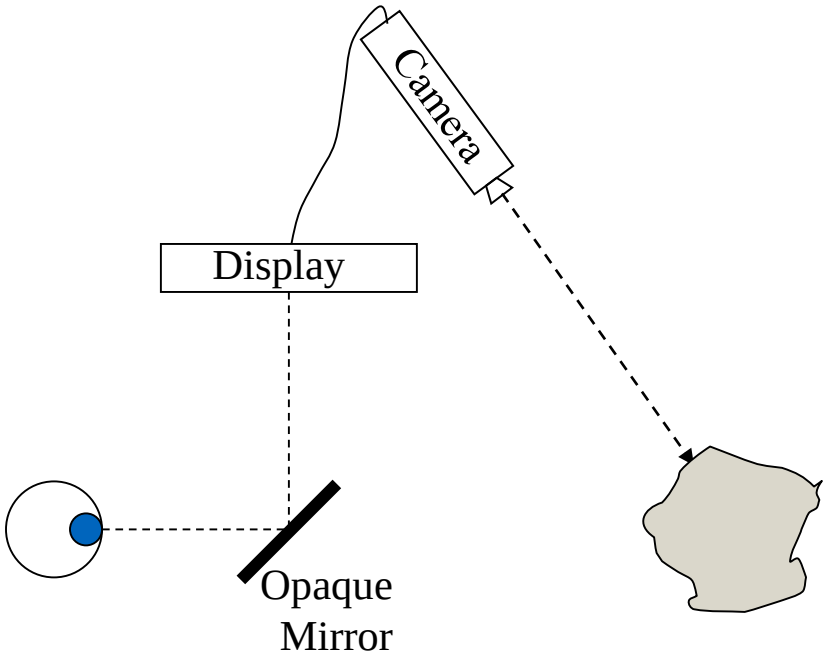
1.1 Overview (History, Human Eye, Devices)

Optical See-Through HMD



1.1 Overview (History, Human Eye, Devices)

Video See-Through HMD



1. Head-Mounted Displays (HMDs)

1.1 Overview (History, Human Eye, Devices)

→ 1.2 Technological Issues

1.3 Human Factors and Perceptual Issues

1.4 Extension: Dynamic Virtual Convergence

Overview

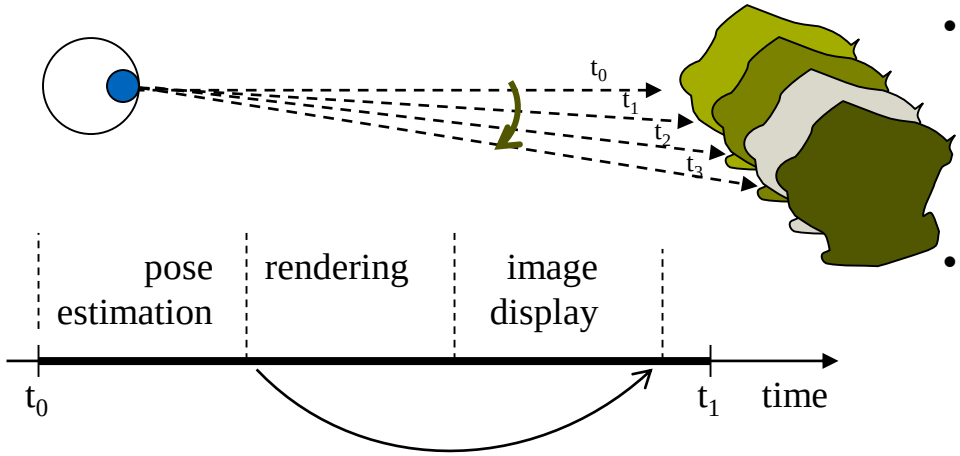
1.2 Technological Issues

- 1.2.1 System latency (lag)
- 1.2.2 Angular resolution
- 1.2.3 Field of view (FOV)
- 1.2.4 Resolution vs. FOV
- 1.2.5 Viewpoint matching
- 1.2.6 Engineering, cost factors

1.2.1 System Latency (Lag)

Requirements

- Speed: > 25 Hz (< 40 ms)
  → update rate
- Smooth rotation: 100 deg/s
  → lag



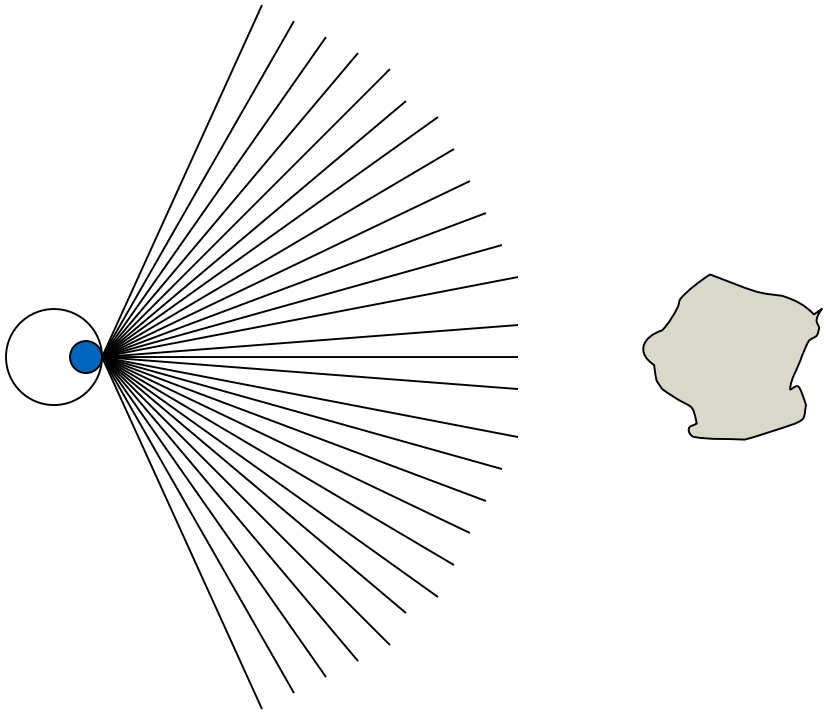
State of the Art

- Optical See-Through HMDs
  - "Swimming"
    - For moving objects:
      Augmentation lags behind
    - For moving HMD:
      Augmentation runs ahead
  - Predictive tracking
- Video See-Through HMDs
  - Delay displaying "real image" until "virtual image" is rendered
  - Sensory conflicts (hand-eye)
- Eye Tracking
  - Simplified rendering during fast eye motion

1.2.2 Angular Resolution

Requirements

- Angular resolution: 1/60 deg



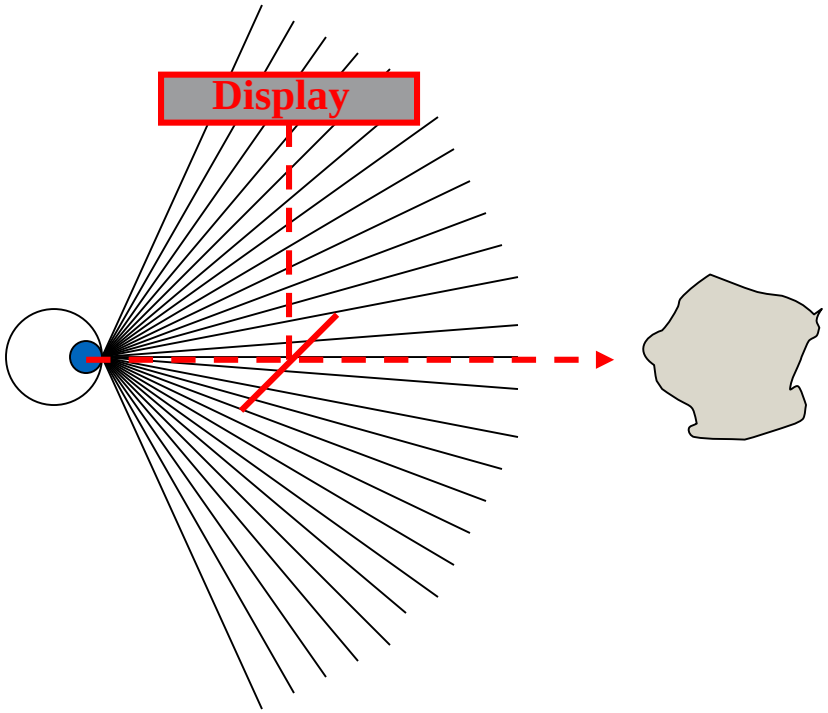
State of the Art

- Optical See-Through HMDs
  - –
  - –
  - –
- Video See-Through HMDs
  - –
  - –
  - –

1.2.2 Angular Resolution

Requirements

- Angular resolution: 1/60 deg



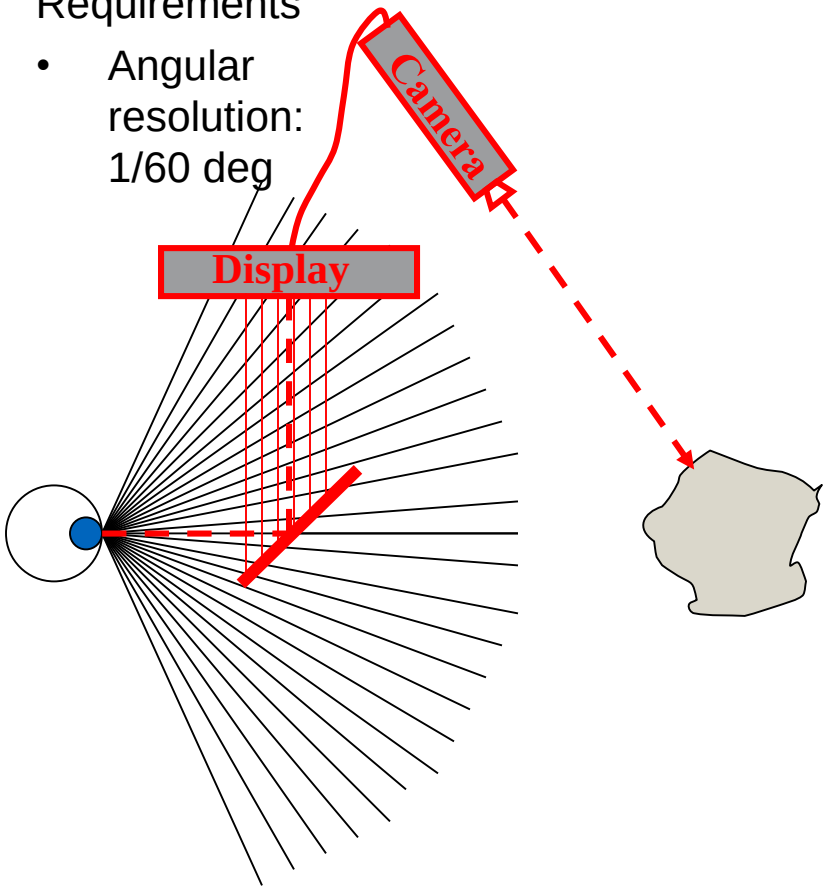
State of the Art

- Optical See-Through HMDs
  - High resolution (view of “reality”)
  - Negligible distortion
  - Dimmed view
- Video See-Through HMDs
  -
  -
  -

1.2.2 Angular Resolution

Requirements

- Angular resolution: 1/60 deg



State of the Art

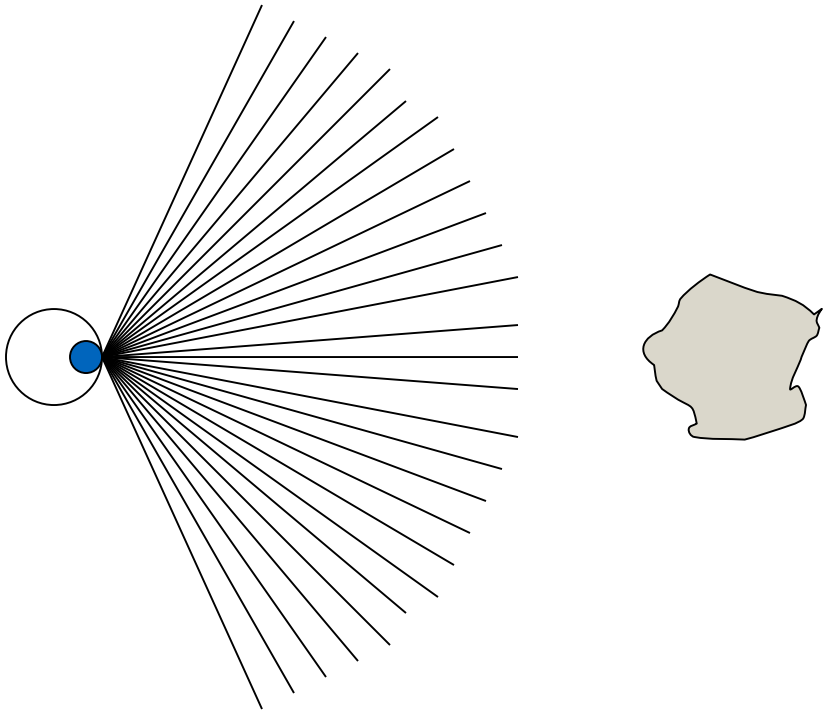
- Optical See-Through HMDs
  - High resolution (view of “reality”)
  - Negligible distortion
  - Dimmed view
- Video See-Through HMDs
  - 640 x 480 pixels
  - But, for 20 deg FOV:
    20*60 = 1200 pixels required
  - Distortion can be compensated

nVisor ST60 NVIS
- 1280x1024
- €11.400
- FoV 50 deg.
- 40% transp.
- 1300 g

1.2.3 Field of View (FOV)

Requirements

- Field of View: ~180 deg
- Large FOV → Fewer head movements
  → Greater situation awareness



State of the Art

- Optical See-Through HMDs
  - –
  - –
- Video See-Through HMDs
  - –
  - –

1.2.3 Field of View (FOV)

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→ Fewer head movements
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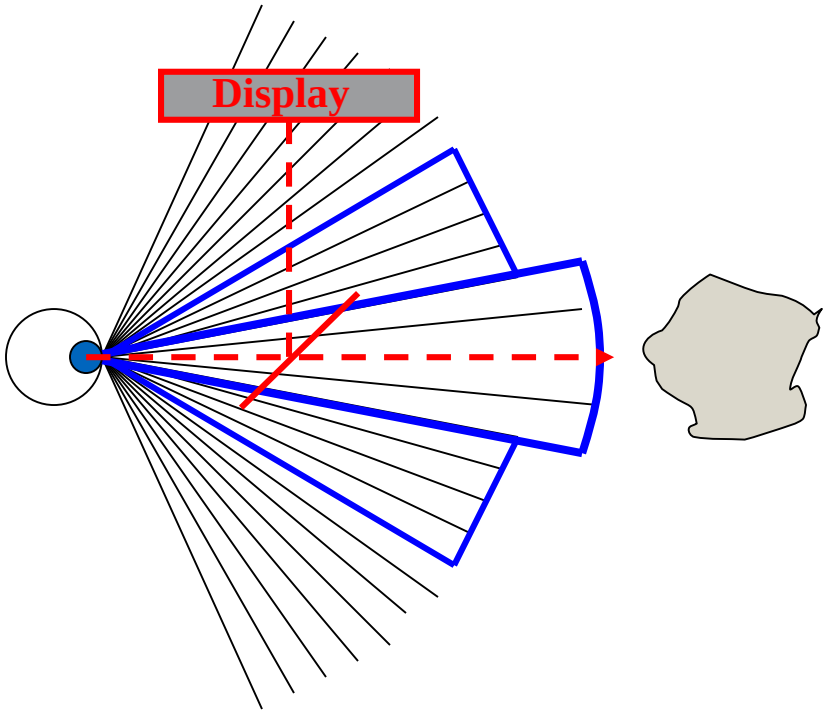


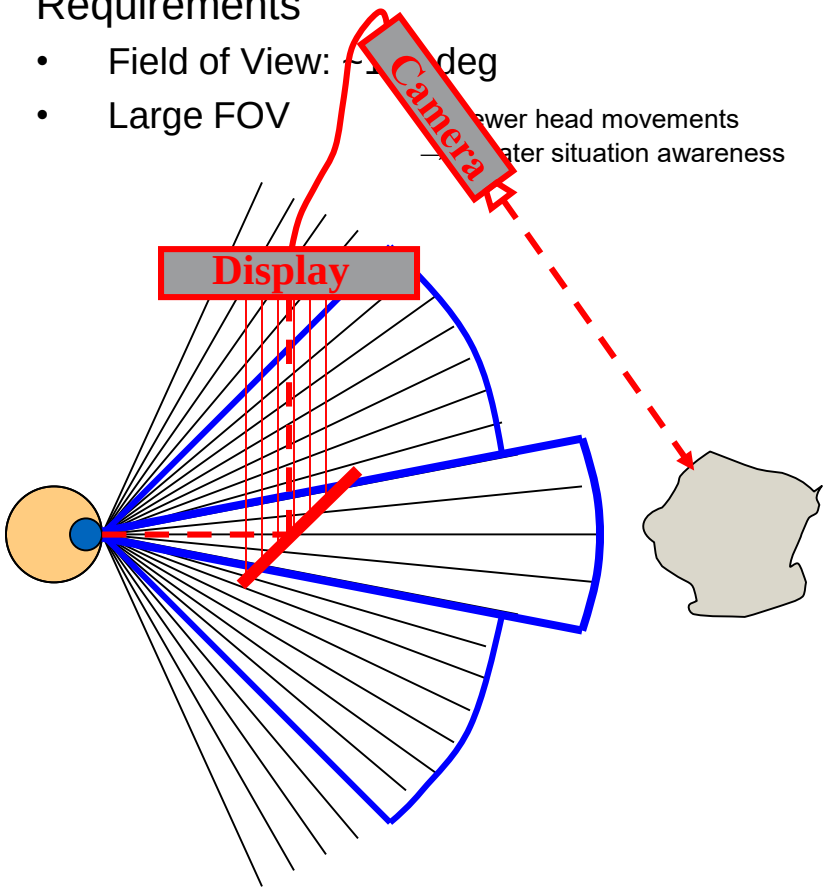
State of the Art

- Optical See-Through HMDs
  - Overlay FOV: 20 - 60 deg (max.: 82.5 deg “massive tech.”)
  - Peripheral FOV
- Video See-Through HMDs
  -
  -

1.2.3 Field of View (FOV)

Requirements

- Field of View: ~1[illegible] deg
- Large FOV



ewer head movements
ater situation awareness

State of the Art

- Optical See-Through HMDs
  - Overlay FOV: 20 - 60 deg (max.: 82.5 deg “massive tech.”)
  - Peripheral FOV
- Video See-Through HMDs
  - Overlay FOV: 20-90 deg (but generally small)

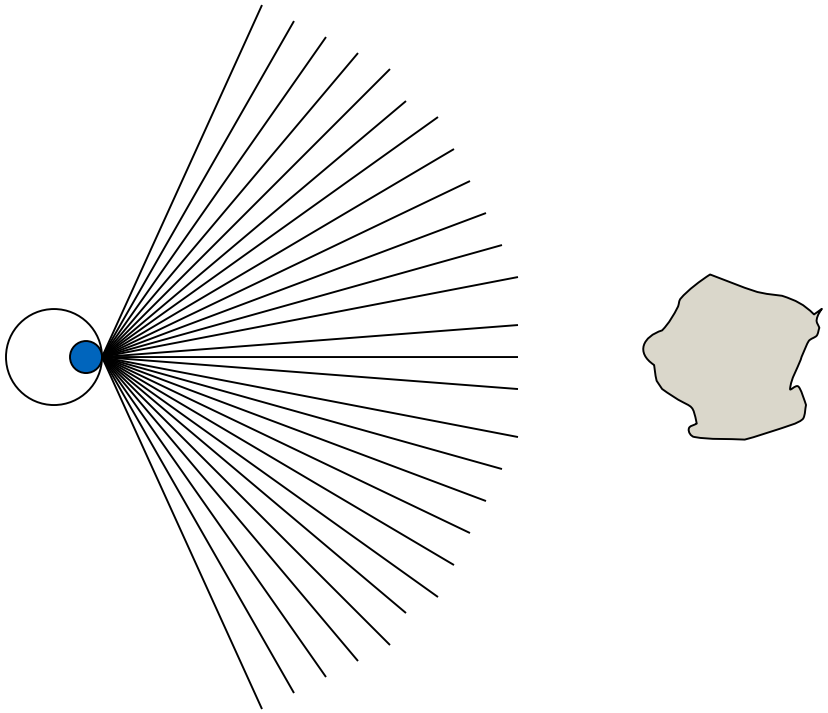
Oculus Rift
- 640x800
- €230
- FoV 90 deg.
- 0% transp.
- 379 g

  - Peripheral FOV:
    - often excluded
    - otherwise: seamless transition?

1.2.4 Resolution vs. FOV

Requirements

- Angular resolution: 1/60 deg
- FOV: ~180 deg



State of the Art

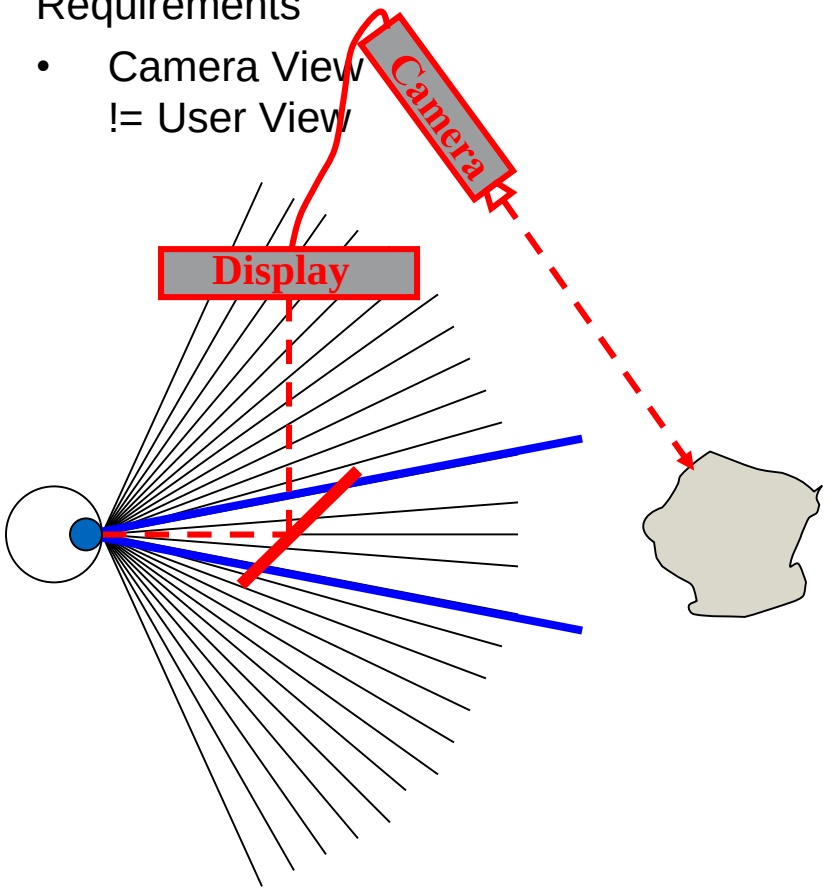
- High-res trend: more resolution for smaller FOV
- Tiling: high res + large FOV (series of mini displays)
- High-res insets at center

- Head-Mounted Projective Displays: Beamer on your head

1.2.5 Viewpoint Matching

Requirements

- Camera View != User View



State of the Art

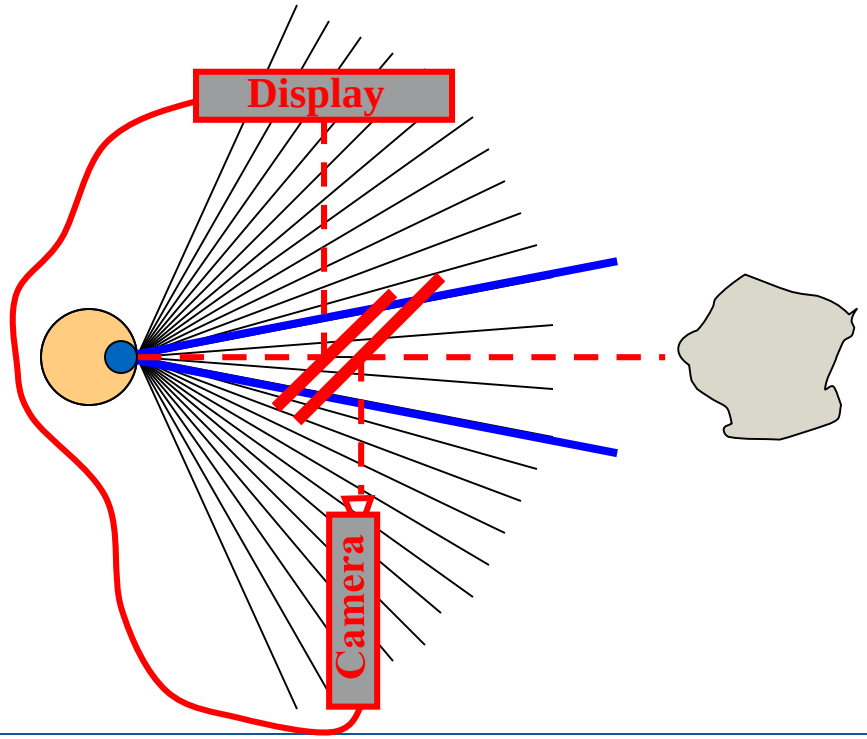
Video See-Through HMDs

- Camera viewpoint must be matched with human eye
- Spatial shift between video image and real scene

1.2.5 Viewpoint Matching

Requirements

- Camera View = User View



State of the Art

Video See-Through HMDs

- Camera viewpoint must be matched with human eye
- Spatial shift between video image and real scene

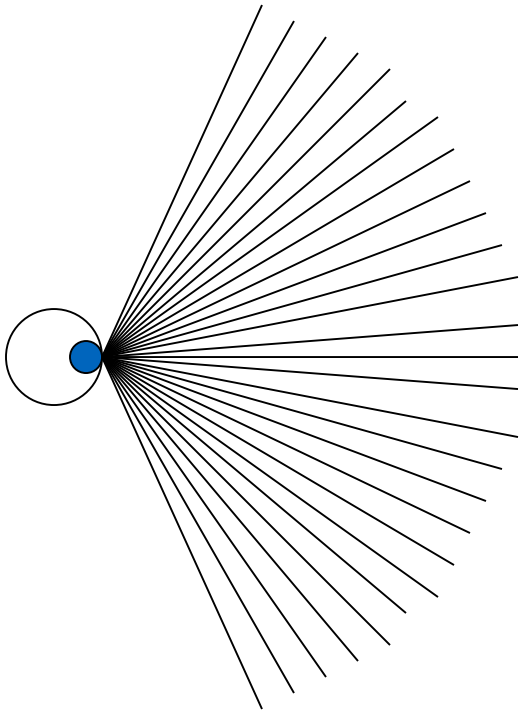
ARvision 3D HMD TRIVISIO
- 752x480
- €6.000
- FoV 34 deg.
- 0% transp.
- 290g

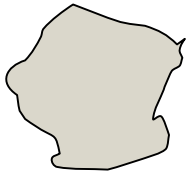
Canon

1.2.6 Engineering, Cost Factors

Requirements

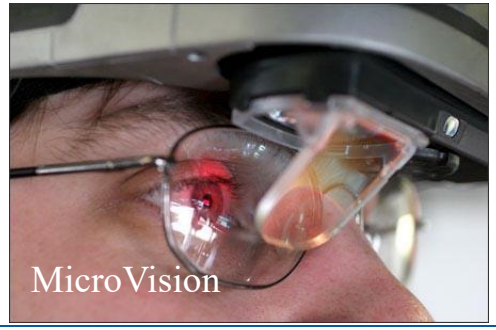
- Lightweight HMD (similar to a pair of eyeglasses)





State of the Art

- Low resolution
- Limited FOV (<20 deg): use mirrors to fold optical path
- Inter-Pupilar Distance (IPD): cameras function of eye distance and eye movement
- Ergonomic design
- Weight



1. Head-Mounted Displays (HMDs)

1.1 Overview (History, Human Eye, Devices)

1.2 Technological Issues

→ 1.3 Human Factors and Perceptual Issues

1.4 Extension: Dynamic Virtual Convergence

1.3 Human Factors and Perceptual Issues

- 1.3.1 User acceptance and safety
- 1.3.2 Depth perception
- 1.3.3 Adaptation
- 1.3.4 Peripheral FOV
- 1.3.5 Depth of field

1.3.1 User Acceptance and Safety

- Will anyone actually wear an HMD for extended periods?

Problems

- Video See-Through HMDs
  - Resistance in the work place
  - Lack of trust in safety-critical situations
  - Failure mode: No reality!
  - May be ok, if large peripheral FOV exists
  - Poor image quality
- Optical See-Through HMDs
  - Failure mode: Reality still there; but no augmentations

1.3 Human Factors and Perceptual Issues

1.3.1 User acceptance and safety

→ 1.3.2 Depth perception

1.3.3 Adaptation

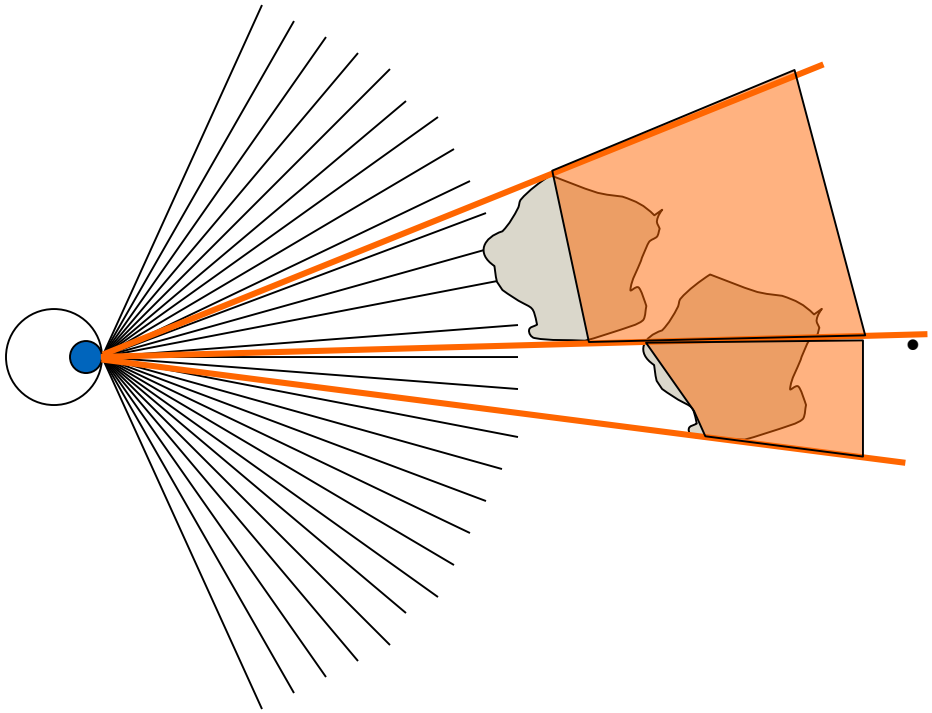
1.3.4 Peripheral FOV

1.3.5 Depth of field

1.3.2 Depth Perception

Occlusion

- Very strong monocular cue



Description

- Prerequisite: dynamic reality model
- Optical See-Through HMDs
  - Occluded virtual objects: ok
  - Occluded real objects: cannot be completely erased; use beam splitters and change contrast between virtual and real images; controlled illumination
- Video See-Through HMDs
  - Occluded real objects: pixel wise overwrite or blend

1.3.2 Depth Perception

Accommodation

- Strong monocular cue

Description

- The lens of an eye contracts or extends in order to see the object as sharply as possible

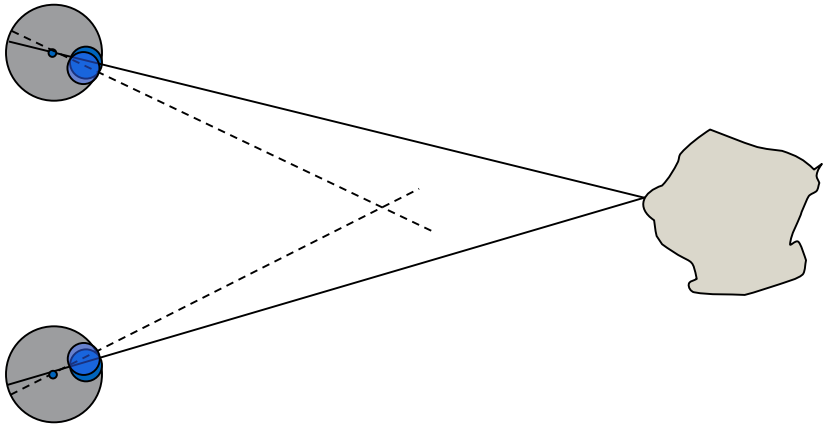
1.3.2 Depth Perception

Convergence

- Strong binocular cue

Description

- Both eyes turn inward (converge) or outward (diverge) s.t. the viewed objects are projected to the central area of the retina (fusional vergence)



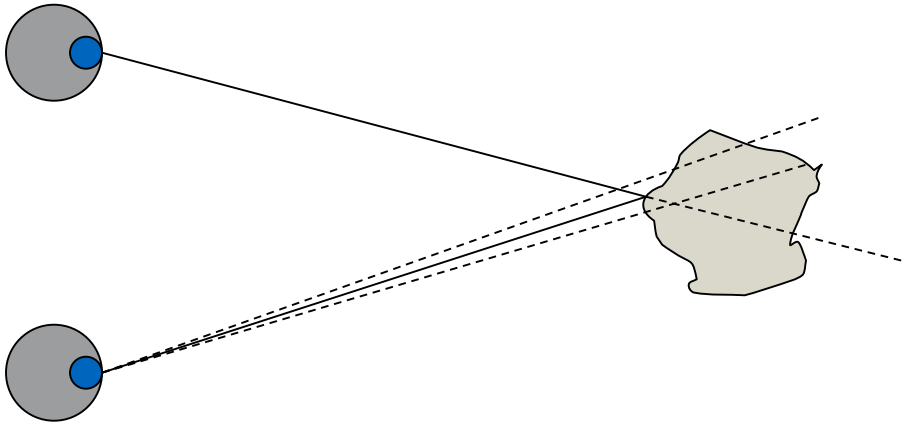
1.3.2 Depth Perception

Stereo Disparity

- Where are the user's eyes?

Problems

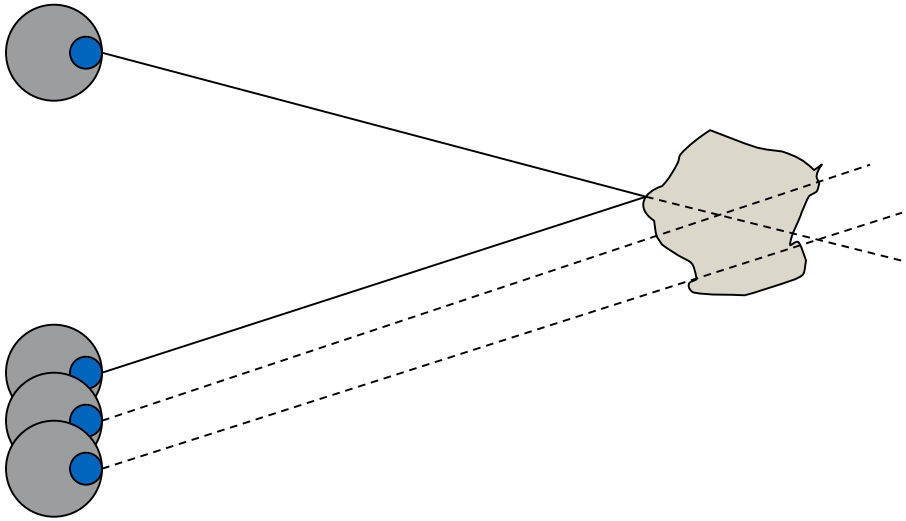
- Inaccurate display calibration
- Wrong FOV estimation for HMD



1.3.2 Depth Perception

Stereo Disparity

- Where are the user's eyes?



Problems

- Inter-pupilar distance
- Wrong eyepoint location
  - Eyepoint: nodal point, pupil entrance or center of rotation (optical see-through)?
  - Aligned image acquisition for two eyes (video see-through)

1.3 Human Factors and Perceptual Issues

1.3.1 User acceptance and safety

1.3.2 Depth perception

1.3.3 Adaptation

1.3.4 Peripheral FOV

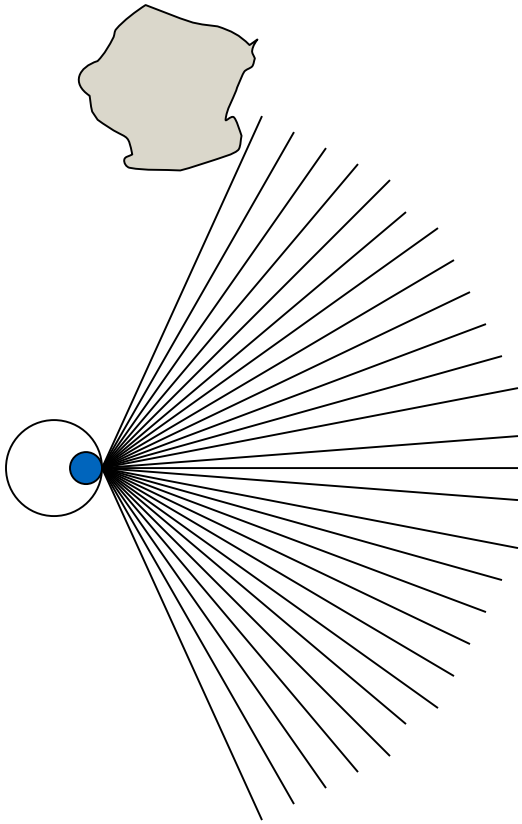
1.3.5 Depth of field

1.3.3 Adaption

Description

- Adaptation to visual displacement (Video See-Through)
  - Increasing performance over time
  - Negative aftereffects
- Adaptation to conflicting cues („mixed signals“)
- Implications of aftereffects
  - Recovery period after HMD use
  - Duration?
  - Gradual or dual adaptation?

1.3.4 Peripheral FOV



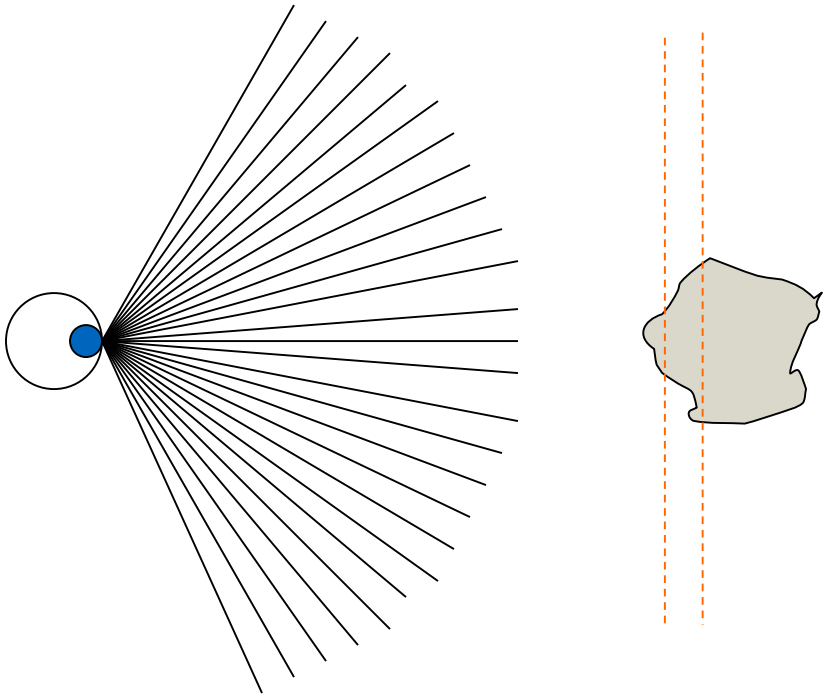
State of the Art

- Optical See-Through HMDs
  - Intuitive
- Video See-Through HMDs
  - User can see around the video area
  - Questions regarding the different presentation style in overlay (video) and peripheral (optical) area:
    - Different accommodation efforts for user!
    - Conflicting cues?
    - Discomfort?

1.3.5 Depth of Field

Pupil 2-4 mm diameter

- At 1 m: [0.94 m .. 1.04 m]
- At 17 m: [11 m .. 33 m]



State of the Art

- The larger the depth of field, the smaller the need for accommodation
- Accommodation plays an important role at close working distance
- Video See-Through HMDs
  - Cameras must have depth of field according to current working distance (autofocus?)
- Optical See-Through HMDs
  - User's pupil enlarged due to reduced light --> smaller depth of field
  - Problem: real/virtual objects at different depths

1. Head-Mounted Displays (HMDs)

1.1 Overview (History, Human Eye, Devices)

1.2 Technological Issues

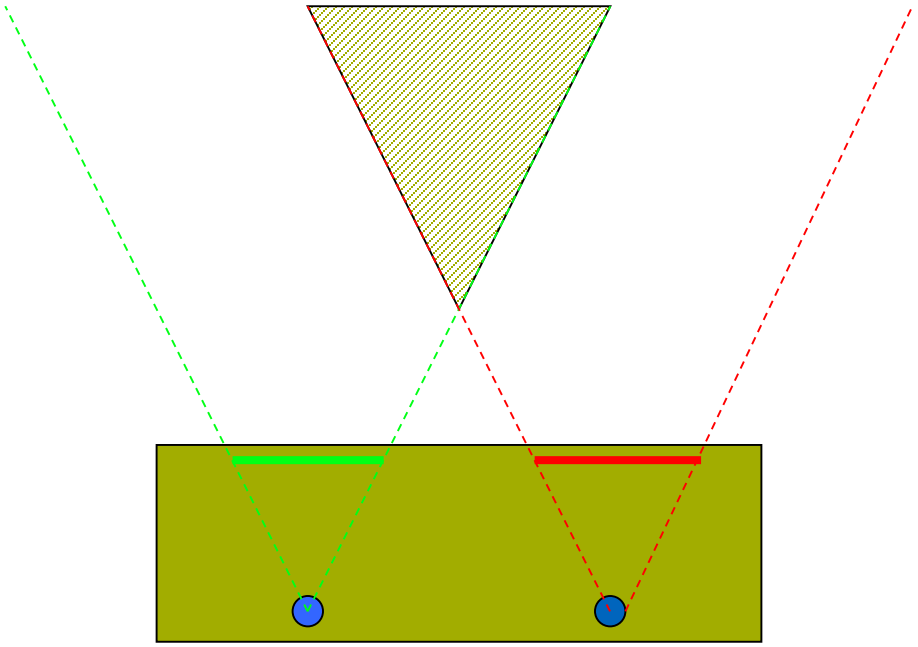
1.3 Human Factors and Perceptual Issues

→ 1.4 Extension: Dynamic Virtual Convergence

1.4 Extension: Dynamic Virtual Convergence

The problem:

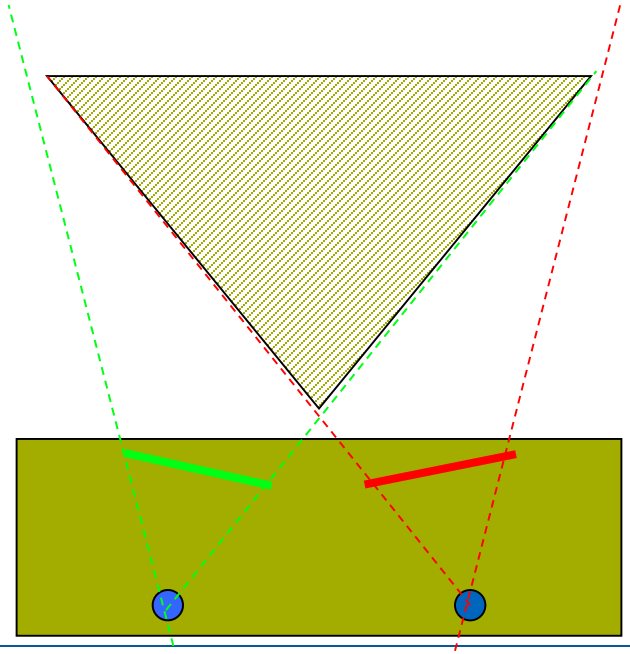
- Limited overlapping viewing range in stereo HMDs



1.4 Extension: Dynamic Virtual Convergence

Hardware-based solution:

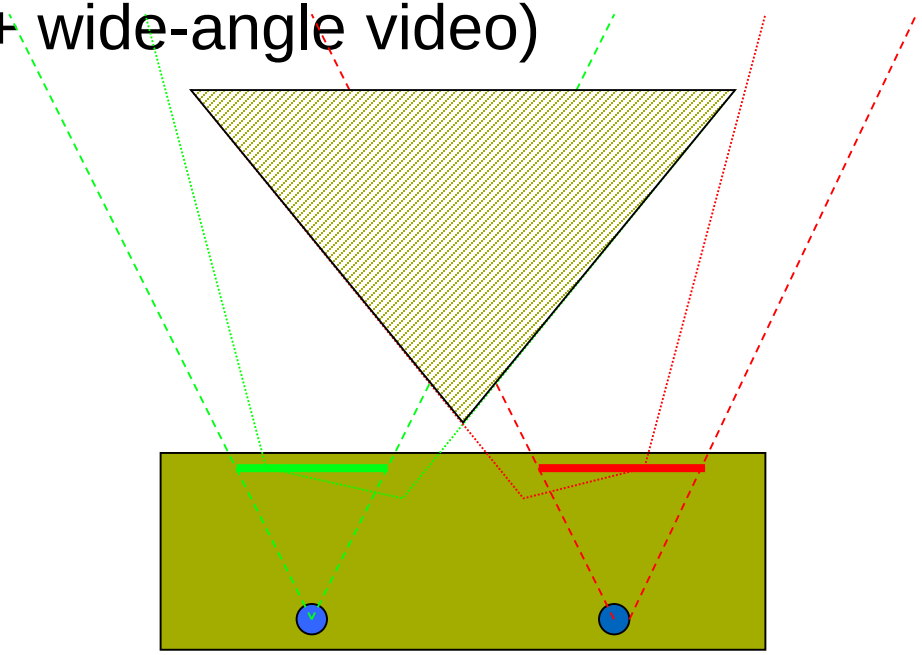
- Physically rotate the displays inwards
  - Ok for close viewing ranges
  - Moving parts



1.4 Extension: Dynamic Virtual Convergence

Software-based approximation (video see-through)

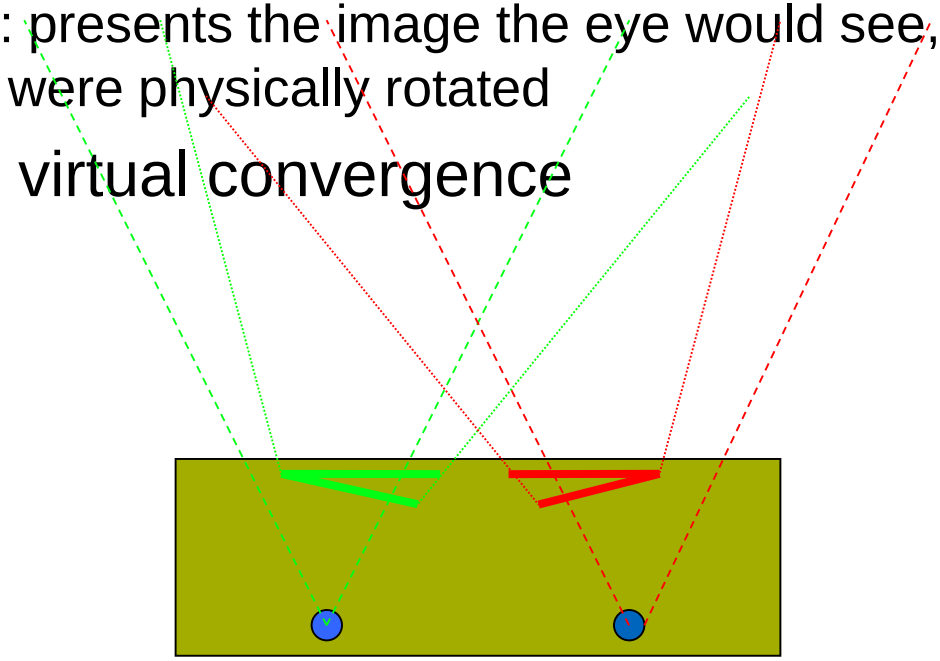
- Fixed optical arrangement (parallel viewing axes)
- Synthetically „bend“ viewing rays (graphics + wide-angle video)



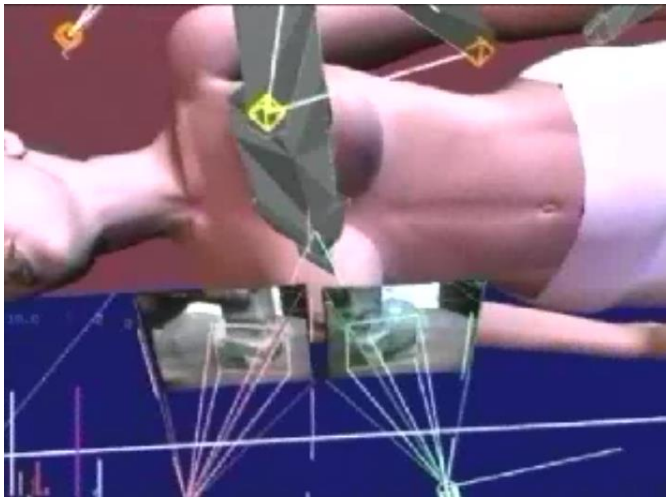
1.4 Extension: Dynamic Virtual Convergence

Issues

- Sheared vs. rotated frustums
  - Shearing: coplanar image planes for both eyes
  - Rotation: presents the image the eye would see, if the real displays were physically rotated
- Automatic virtual convergence



1.4 Extension: Dynamic Virtual Convergence



1.4 Extension: Dynamic Virtual Convergence

Conflicts between

- Accommodation (A): lens contraction for optimal focus (2m)
- Disparity (D): stereo viewing
- Vergence (V): turning eyes inward for max. resolution

Virtual convergence setting	Available close-range stereo overlap	Where are depth cues Accommodation (A), Disparity (D), and Vergence (V)?		Conflicts between depth cues
		Close-range	Wide-range (2m .. ∞)	
OFF	Partial	D, V	A	A-D, A-V
ON	Full	D	A,V	A-D, D-V

Agenda

1. Head-Mounted Displays (HMDs)
2. Other Displays for AR

2. Other Displays for AR

Limitations of current HMDs

- Resolution
- Field of View
- Contrast
- Weight
- Cables

- Issues
  - User safety
  - User comfort
  - Shared views for collaborative discussions

2. Other Displays for AR

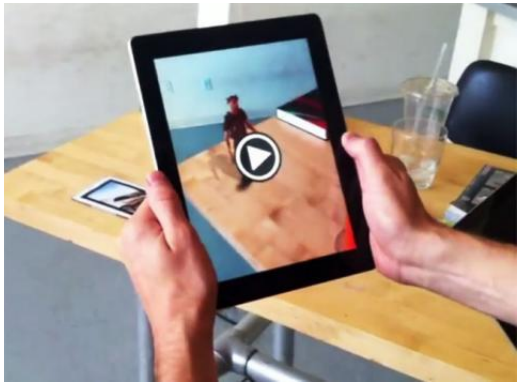
Augmented Reality: Yes, but where?

- In front of a user's eyes: "Classical AR"
  - HMDs

2. Other Displays for AR

Augmented Reality: Yes, but where?

- In front of a user's eyes: "Classical AR"
  - HMDs
- On a portable display: "Window into the world"
  - Palmtops, cellular phones, tablet PCs
  - Intelligent instruments



2. Other Displays for AR

Augmented Reality: Yes, but where?

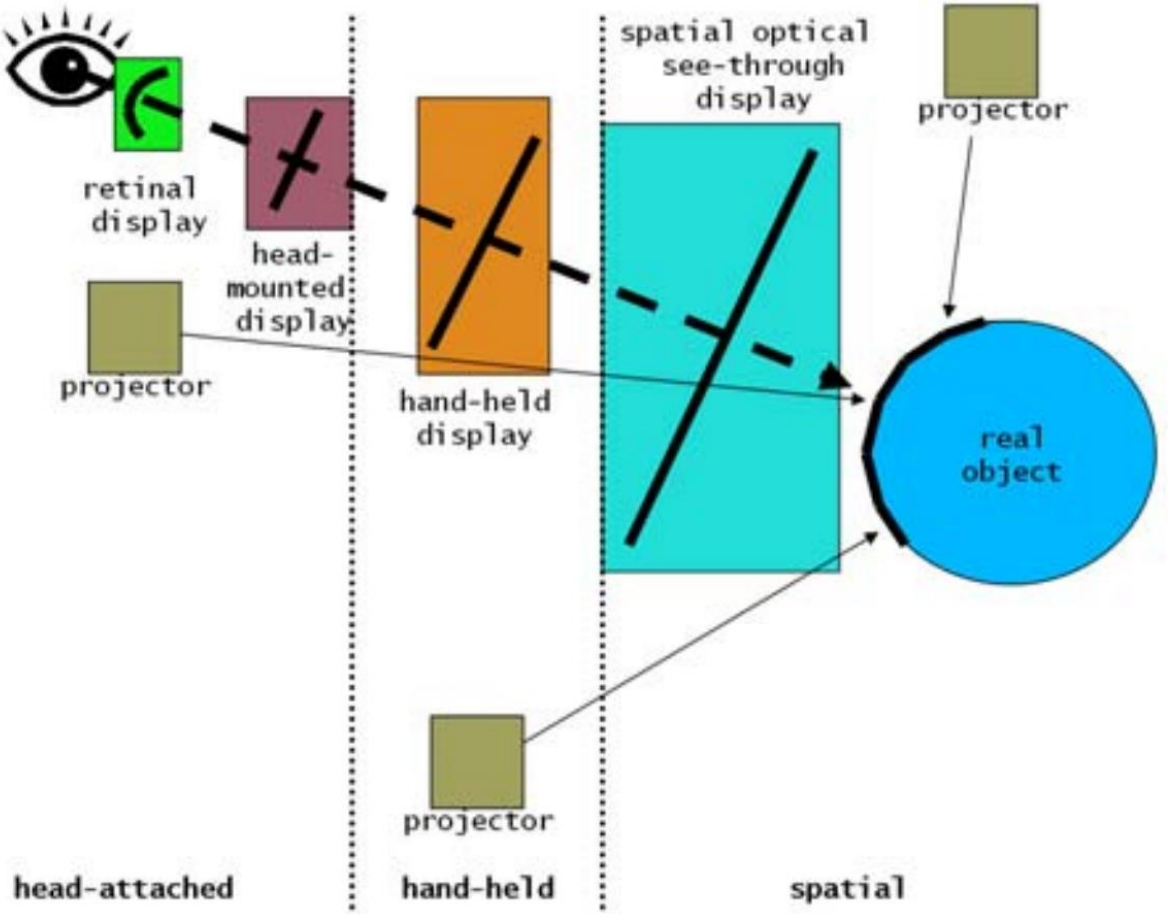
- In front of a user's eyes: "Classical AR"
  - HMDs
- On a portable display: "Window into the world"
  - Palmtops, cellular phones, tablet PCs
  - Intelligent instruments
- On stationary monitors: "Intelligent environments"
  - See-through displays integrated into a work area
  - Wall-mounted displays

2. Other Displays for AR

Augmented Reality: Yes, but where?

- In front of a user's eyes: "Classical AR"
  - HMDs
- On a portable display: "Window into the world"
  - Palmtops, cellular phones, tablet PCs
  - Intelligent instruments
- On stationary monitors: "Intelligent environments"
  - See-through displays integrated into a work area
  - Wall-mounted displays
- On real objects:
  "Virtual showcase"
  - Projectors

Image-generation for augmented reality displays



Thank you!