Whitepaper

Head Mounted Displays & Data Glasses
Applications and Systems

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Content

- **System classes**
  Head Mounted Display (HMD) – Video glasses – Data glasses

- **Simulator disease / Cyber Sickness**

- **Application fields HMDs:**
  interior inspections, training, virtual hedging engineering / ergonomics

- **Application fields data glasses:**
  process support, teleservice, consistency checks, collaboration

- **Directions of development:**
  technical specifications, (eye) tracking, retinal displays, light field technology, imaging depth sensors

- **Application preconditions information & integration (human, IT, processes)**

- **Final remark**
Head Mounted Displays (HMDs) – Overview

- 1961: first HMD on market
- 1965: 3D-tracked HMD by Ivan Sutherland
- Since the 1970s a significant number of HMDs is applied in the military sector (training, additional display)

<table>
<thead>
<tr>
<th>Time frame</th>
<th>Program</th>
<th>Country</th>
<th>Platform</th>
<th>Developer</th>
<th>Program status</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1970s</td>
<td>Dash1</td>
<td>Israel</td>
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<td>Elbit Systems</td>
<td>Fielded</td>
<td>Mark 1 through 5 (VCATS)</td>
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<td>Development</td>
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</table>

Table: Important HMD-projects since the 1970s

[Quelle: Li, Hua et. al.: Review and analysis of avionic helmet-mounted displays. In: Op-tical Engineering 52(11), 110901, Novembre 2013]
Classification HMD – Video glasses – Data glasses

<table>
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<tr>
<th>Head Mounted Display</th>
<th>Video glasses</th>
<th>Data glasses</th>
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<tr>
<td>Characteristics</td>
<td>User integration in a interactive environment</td>
<td>Portable screen</td>
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<tr>
<td>Objective, operational purpose</td>
<td>Virtual Reality, optional Augmented Reality (AR) via Video-See-Through</td>
<td>Film/ image display</td>
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<td>Isolation</td>
<td>User isolation of the real environment</td>
<td>User isolation of the real environment</td>
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<td>Field of view</td>
<td>Large field of view, thus moving eye</td>
<td>Small field of view, thus generally dormant eye</td>
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<td>Tracking</td>
<td>Very fast and exact head tracking necessary</td>
<td>Not necessary</td>
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<td>Typical representatives</td>
<td>Oculus Rift</td>
<td>Carl Zeiss Cinemizer</td>
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</table>
Advantages of HMDs in comparison to projections

Systemic benefits of HMDs

- Compactness: enclosing VR system in the smallest physical space
- Price: inexpensive compared to multi-channel projections
- Isolation and immersion: User focuses completely on content and task, fades out reality
- Sense of direction always has to be served (due to simulator sickness)
- No accommodation conflict: In the haptic interaction in front of a projection screen, the user can either focus only on the projection or only on his hands. HMDs do not have this problem.
Disadvantages of HMDs in comparison to projections

Systemic disadvantages

- **Isolation:**
  - Lack of awareness of the environment leads to uncertainty
  - Lack of self-perception is confusing
- **Isolation:**
  Cooperative working is only possible to a limited extent
- **Acceptance:**
  Rejection of HMDs as a technical gimmick

*Image: Fh-IAO*
Disadvantages of HMDs in comparison to projections

Product inherent disadvantages

- Inadequate ergonomics:
  weight, weight distribution, cumbersome to put on, fit, fixation, hygiene
- Lack of appropriate input systems:
  no mouse or keyboard
- Moderate resolution: only upper price segment > 1280 x 1024
- Acceptance: impairment of hairstyle, cosmetics through fixation
- Fixed image distance
- Probability of cyber sickness / simulator sickness is high because of the isolating system
Cyber Sickness

Some people experience nausea or headaches in immersive environments: Why?

- Reason 1: Oculomotor depth criteria contradict each other:
  - Accomodation of the eye: Focus on the display so that we can see the image clearly
  - Convergence of the eyes on the virtual object in front of or behind the projection screen [brain superimposes the images of the eyes on top of each other]

→ contradiction
Cyber Sickness

- **Reason 2:** Vestibular perception (sense of position) and visual perception contradict each other
  - Example projection system:
    - multiple viewers
    - only one viewer tracked
    - tracked user moves
  - Example HMD:
    - even slight latencies between head movement and image reaction
  → contradictory movement information
Application fields HMDs: Interior inspections

Motivation

- Virtual hedging of environments in which the sense of space and its subjective evaluation are relevant
- Visibility conditions (orientation and view)
- Application examples:
  - in the car
  - in the cockpit
  - in the cabin
  - inside the building
Application fields HMDs: Interior inspections

Examples interior design
- Architecture
- Bathroom planning
- Similar: airplane cabin

Hardware set up for the virtual house inspection with Inreal: further persons (such as spouses) can follow the scene on the monitor.

Virtual bathroom inspection with 6D-tracked HMD

Virtual house inspection
Application fields HMDs: Interior inspections

Seat box and distributed 3D environment for two persons. On the left: physical set up; right: corresponding 3D scene.

Image: Bauhaus-Universität Weimar
Application fields HMDs: Virtual hedging engineering / ergonomics

Editing 3D scenes from the first person perspective

- Inspection of technical facilities, installations, workplaces, operating interfaces with regard to
  - Usability
  - Comprehensibility
  - Visibility
  - Reachability
  - Moving spaces
  - …

- General validity possibly limited, because the results are user-specific
Application fields HMDs: Training

Motivation

- 360° simulation required
- Detailed haptic interaction with a view to your own hands is relevant (accommodation conflict in front of Powerwall difficult)
Application fields data glasses

- Data glasses: Natural view is largely not restricted
- In general smaller display surfaces (compared to HMDs)
- In general smaller display resolution (compared to HMDs)
- Mostly different intended use compared to HMDs: additional display of computer-generated content when staying in natural environments (e.g. work, leisure time, travel)
- Content often symbolic, pictogram, alphanumeric because of resolution and size of displays
- Regarding high-end-products AR-applications are possible
- Advantages compared to tablet PCs: hands-free
Application fields data glasses: Process support

Additional information during working process

Approaches:
- Active retrieval of content; interaction with handheld, such as logistics pad
- Location-based (e.g. RFID reference)
- Location-sensitive annotations
- Display of measured data
- Display of process parameters
- „X-ray view“: display of hidden objects

Attempts to AR-based cable assembly in the early 1990s

Superimposition of online-process data on tool

View of a spaceman on maintenance work in front of him; AR support via local annotations

AR- X-ray view on hidden infrastructure such as electric lines
Application fields data glasses: Teleservice / Tele-Operations

Connection of service staff and central technology

- Service staff shares perspective (camera) with central technology
- Central technology provides hints and can locate these (present on display with AR)

Early idea of remote controlling a robot by means of its virtual counterpart, which in turn is manipulated via VR (early 1990s)
Application fields data glasses: Model consistence checks vs. Reality

Checking digital model
- Accurate simulation?
- Accurate construction?
Application fields data glasses: Model consistency checks vs. Reality

Inspection of real environment
- Realised as planned?
- Documented as realised?
- Quality control
- Prototyping

Planning new production facilities (constructed, colored) in existing factory

Checking of welding studs: realised as planned?

Checking of welding studs: realised as planned?

Inspection of an industrial workplace: everything reachable in gripping are (red)?

Inspection of arrangement and conveyor technology: collision-free for new parts?
Application fields data glasses: Collaborative workplaces

- By corporate tracking a joint AR-workplace can be created
- Individual perspective
- Support of local cooperation
- Natural view on the respective person (gesture, facial expression, discussion, …)

Image: TU Wien

Joint AR-workplace by means of Head Mounted Displays
Directions of development: Used display types

- In previous HMDs (until 2012) starting from SXGA-resolution: main application of micro displays from only two manufacturers
- Virtual Retinal Displays (projection on retina)
- Since 2012: smartphone displays as an additional image source

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<th>Manufacturer micro displays</th>
<th>Technology</th>
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<tr>
<td>eMagin Corp.</td>
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<tr>
<td>Epson</td>
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<td>Forth Dimension Displays</td>
<td>fLCOS, ForthDD</td>
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<table>
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<tr>
<th>OLED (eMagin Corp.)</th>
<th>fLCOS (Forth Dimension Displays)</th>
<th>Smartphone-Displays</th>
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</thead>
<tbody>
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<td>No electronic control circuits</td>
<td>External LEDs create color</td>
<td>Partly very high resolution</td>
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<tr>
<td>Small setup</td>
<td>Fast circuit times</td>
<td>Affordable because of mass production</td>
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<tr>
<td>Low current consumption</td>
<td>No subpixels</td>
<td>Used display technologies:</td>
</tr>
<tr>
<td>Fast circuit times</td>
<td>Good grey values</td>
<td>• Samsung: AMOLED</td>
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<tr>
<td>Real “black”</td>
<td></td>
<td>• Microsoft/ Nokia: Nokia: AMOLED with Clear-Black-extension</td>
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<tr>
<td></td>
<td></td>
<td>• Apple: LCD with high resolution</td>
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<td></td>
<td></td>
<td>• LG: LCD and AMOLED</td>
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<td></td>
<td></td>
<td>• HTC: S-LCD by Sony and Samsung</td>
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<td></td>
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<td>• Sony Ericsson: Technology by Sony</td>
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## Technical specifications of previous „old“ HMDs

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<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Resolution horizontal</th>
<th>Resolution vertical</th>
<th>Angle-resolution</th>
<th>Field of view horizontal</th>
<th>Field of view vertical</th>
<th>Price</th>
<th>Updated</th>
<th>Weight</th>
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<td>kA</td>
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<td>FLG0S</td>
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</tbody>
</table>
Technical specifications of previous „old“ HMDs

Common features

- Average field of view: 60°
- Resolution: SXGA (1280x1024)
- Average weight: 1kg
- Only available in the form of glasses (would be customer's request)
- Average price: € 15.000,- (from € 500,- to € 160.000,-)

Highly divergent HMD systems:

Resolution

- Sensics piSight: 2600 x 1200 Pixels
- Sensics xSight: 1680 x 1050 Pixels
- Virtual Realities HMD pro 3D WUXGA-60 : 1920 x 1080 Pixels

Field of view

- Rockwell Collins Sim Eye SR 100: 100°
- Sensics piSight: 180°
- Sensics xSight: 104°
- SEOS HMD 120/40: 120°
Recent and announced HMDs (April 2015)

- Altergaze
- AntVR
- Archos VR Glasses
- Avegant Glyph
- Carl Zeiss VR One
- Durovis Dive
- FOVE VR Headset
- GameFace
- Google Cardboard
- InfinitEye
- Oculus Rift 2
- Samsung GearVR
- Sony Morpheus
- Sulon Cortex
- Technical Illusions CastAR
- Valve HMD
- vrAse
- VRVANA Totem
### Recent and announced HMDs (April 2015)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Resolution horizontal</th>
<th>Resolution vertical</th>
<th>Angle-resolution</th>
<th>Field of view horizontal</th>
<th>Field of view vertical</th>
<th>Price</th>
<th>Weight</th>
<th>Tracking</th>
<th>Comment</th>
</tr>
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<td>AntVR</td>
<td>960</td>
<td>1080</td>
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<td>Archos</td>
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<td></td>
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<td>€ 25,-</td>
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<td>Smartphone</td>
<td>Fixing type of headphones, pixel-free image by retinal display</td>
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<td>Glyph</td>
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<td>800</td>
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<td>29</td>
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<td>Carl Zeiss</td>
<td>VROne</td>
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<td></td>
<td></td>
<td></td>
<td>€ 100,-</td>
<td></td>
<td>Smartphone</td>
<td>Only for iPhone 6, Samsung Galaxy S5</td>
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<td>Durovis</td>
<td>Dive</td>
<td>Smartphone mount with optics</td>
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<td></td>
<td></td>
<td></td>
<td>€ 60,-</td>
<td></td>
<td>Smartphone</td>
<td></td>
</tr>
<tr>
<td>FOVE</td>
<td>VR Headset</td>
<td>kA</td>
<td>kA</td>
<td>kA</td>
<td>45</td>
<td>kA</td>
<td>kA</td>
<td>kA</td>
<td>kA</td>
<td>Integrated Eye Tracking</td>
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<td>1440</td>
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<td>kA</td>
<td>kA</td>
<td>$ 500,-</td>
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<td>integrated</td>
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<td>Google</td>
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<td>Smartphone mount with optics</td>
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<td></td>
<td></td>
<td></td>
<td>$ 10,-</td>
<td></td>
<td>Smartphone</td>
<td>Cardboard housing</td>
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<td>InfinitEye Gründerteam</td>
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<td>800</td>
<td>9,8</td>
<td>210</td>
<td>150</td>
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<td>490</td>
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<tr>
<td>Liviu Berechet Antoni</td>
<td>Altergaze</td>
<td>Smartphone mount with optics</td>
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<td></td>
<td></td>
<td>€ 60,-</td>
<td></td>
<td>Smartphone</td>
<td></td>
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<tr>
<td>Oculus / Facebook</td>
<td>Rift 2</td>
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<td>1080</td>
<td>6,9</td>
<td>110</td>
<td>90</td>
<td>$ 350,-</td>
<td>400</td>
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<td>OLED, rich colors, Low-Persistence technology</td>
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<td>Samsung</td>
<td>GearVR</td>
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<td></td>
<td></td>
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<td>$ 200,-</td>
<td></td>
<td>Smartphone</td>
<td></td>
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<tr>
<td>Sony</td>
<td>Morpheus</td>
<td>960</td>
<td>1080</td>
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<td>68</td>
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<td>LCD</td>
</tr>
<tr>
<td>Sulon</td>
<td>Cortex</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>integrated</td>
<td>Augmented-Reality capable</td>
</tr>
<tr>
<td>Technical Ilusions</td>
<td>Cast AR</td>
<td>1280</td>
<td>720</td>
<td>4,2</td>
<td>90</td>
<td>68</td>
<td>$ 200,-</td>
<td></td>
<td>integrated</td>
<td>Augmented-Reality capable</td>
</tr>
<tr>
<td>VRVANA</td>
<td>Totem</td>
<td>960</td>
<td>1080</td>
<td>5,6</td>
<td>90</td>
<td>68</td>
<td>kA</td>
<td></td>
<td>integrated</td>
<td>OLED, Augmented-Reality capable, Low-Persistence technology</td>
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<tr>
<td>Valve</td>
<td>HMD Prototyp</td>
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<td></td>
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<td>kA</td>
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<td>announced</td>
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<tr>
<td>vrAse</td>
<td>vrAse</td>
<td>Smartphone mount with optics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>€ 60,-</td>
<td></td>
<td>Smartphone</td>
<td>Augmented-Reality capable</td>
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</table>
Recent and announced HMDs: Companies

- Announced HMD manufacturer:

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Company</th>
<th>Location</th>
<th>Country</th>
<th>Website</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>AntVR Technology</td>
<td>Peking</td>
<td>China</td>
<td><a href="http://www.antvr.com">http://www.antvr.com</a></td>
</tr>
<tr>
<td>2</td>
<td>Avegant</td>
<td>Ann Arbor</td>
<td>USA</td>
<td><a href="http://www.avegant.com">http://www.avegant.com</a></td>
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<tr>
<td>3</td>
<td>Durovis</td>
<td>Münster</td>
<td>Germany</td>
<td><a href="http://www.durovis.com">http://www.durovis.com</a></td>
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<tr>
<td>4</td>
<td>FOVE</td>
<td>Japan</td>
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<tr>
<td>5</td>
<td>GameFace Labs</td>
<td>San Francisco</td>
<td>USA</td>
<td><a href="http://gamefacelabs.com">http://gamefacelabs.com</a></td>
</tr>
<tr>
<td>6</td>
<td>InfinitEye-Gründerteam</td>
<td>Toulouse</td>
<td>France</td>
<td><a href="https://www.facebook.com/InfinitEyeVR">https://www.facebook.com/InfinitEyeVR</a></td>
</tr>
<tr>
<td>7</td>
<td>Liviu Berechet Antoni</td>
<td>London</td>
<td>Great Britain</td>
<td><a href="https://www.facebook.com/altergaze">https://www.facebook.com/altergaze</a></td>
</tr>
<tr>
<td>8</td>
<td>Meta</td>
<td>Los Altos</td>
<td>USA</td>
<td><a href="https://www.spaceglasses.com/">https://www.spaceglasses.com</a></td>
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<td>9</td>
<td>Oculus / Facebook</td>
<td>Irvine</td>
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<tr>
<td>10</td>
<td>Sulon</td>
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<td>Canada</td>
<td><a href="http://sulontechnomogies.com">http://sulontechnomogies.com</a></td>
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<td>11</td>
<td>Technical Illusions</td>
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<tr>
<td>12</td>
<td>True Player Gear</td>
<td>Outremont</td>
<td>Canada</td>
<td><a href="http://www.trueplayergear.com">http://www.trueplayergear.com</a></td>
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<tr>
<td>13</td>
<td>Valve</td>
<td>Bellevue</td>
<td>USA</td>
<td><a href="http://www.valvesoftware.com">http://www.valvesoftware.com</a></td>
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<tr>
<td>14</td>
<td>vrAse</td>
<td>Edinburgh</td>
<td>Great Britain</td>
<td><a href="http://www.vrase.com/">http://www.vrase.com</a></td>
</tr>
</tbody>
</table>

Kick starter:

- Oculus: 2,4 million $
- Avegant: 1,5 million $
- Technical Illusions: 1,0 million $
- Meta: 0,2 million $
- Oculus was acquired by Facebook in March 2014 for $ 2 billion
Data glasses – Products (April 2015)

- Atheer One
- Epson Moverio BT100
- Epson Moverio BT200
- Google Glass
- ION Glass
- Lumus OE-32
- Meta One
- Meta Pro
- Microsoft HoloLens
- OptInvent ORA-1
- Recon Jet
- Samsung Galaxy Glass
- Vuzix M100
- Vuzix M100 Safety
- Vuzix M2000AR
## Data glasses – Products (April 2015)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Number of displays</th>
<th>Resolution horizontal</th>
<th>Resolution vertical</th>
<th>Angle-resolution</th>
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<th>Field of view vertical</th>
<th>Price</th>
<th>Weight</th>
<th>Tracking</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>Atieer</td>
<td>One</td>
<td>2</td>
<td>1024</td>
<td>768</td>
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<td>52.0</td>
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<td>GlassUp</td>
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<td>320</td>
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<td>No information.</td>
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<td>No information.</td>
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<td>Audio, LCoS.-Display, touchpad, microphone, camera, brightness sensor</td>
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<tr>
<td>Google</td>
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<td>1</td>
<td>640</td>
<td>360</td>
<td>1.2</td>
<td>12.5</td>
<td>9.4</td>
<td>$ 1500</td>
<td>54g</td>
<td>Acceleration, Gyro, compass, Eyetracker, proximity sensor, position sensor</td>
<td>Audio, LCoS.-Display, touchpad, microphone, camera, brightness sensor</td>
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<td>ION</td>
<td>Glass</td>
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<td>No information.</td>
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<td>Camera, developer module</td>
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<td>Lumus</td>
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<td>26g</td>
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<td>720</td>
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<td></td>
<td></td>
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<td></td>
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<td>Only announcement until now</td>
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<tr>
<td>Optinvent</td>
<td>ORA-1</td>
<td>1</td>
<td>640</td>
<td>480</td>
<td>3.6</td>
<td>19.2</td>
<td>14.4</td>
<td>[presales]</td>
<td>80g</td>
<td>9DOF-IMU, GPS</td>
<td>Audio</td>
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<tr>
<td>Recon</td>
<td>Jet</td>
<td>1</td>
<td>432</td>
<td>240</td>
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<td>17.1</td>
<td>9.6</td>
<td>$ 599</td>
<td>60g</td>
<td>Acceleration, Gyro, magnetometer, GPS</td>
<td>Audio, altimeter, barometer, thermometer</td>
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<td>Samsung</td>
<td>Galaxy Glass</td>
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<td></td>
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<td></td>
<td>Only announcement until now</td>
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<tr>
<td>Vuzix</td>
<td>M100, M100 Safety</td>
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<td>432</td>
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<td>13.1</td>
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<td>9DOF-IMU, GPS, proximity sensor</td>
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<td>m2000AR</td>
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<td>720</td>
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<td>26.1</td>
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<td>$6,000</td>
<td>No information.</td>
<td>9DOF-IMU</td>
<td>1 x 5MP camera</td>
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</tbody>
</table>
Low persistence technology

- Technology of the company Valve for OLED displays
- Reduction of re-drawing effects of the display (blurring) during movements
- Fast head movements: even with refresh rate of 60 hertz the display can not be updated on time
- User sees the object in the wrong place for a short time (60 hertz: 16 milliseconds).
- Instead of displaying the frame until the next frame is loaded and replaced, the pixels in "low persistence" only light up for a brief moment and remain dark for the rest of the time
- To make this strobing effect not visible to the user, a higher frequency is necessary
- Tests confirmed the increased image quality
Nvidia GameWorks VR

- Collection of hardware and software technologies for stereoscopic real-time rendering

- **VR SLI:** splitting GPUs by eye (not frames)

- **Multi Resolution Shading:** lower resolution in distorted (& shrunken) margins

- **Timewarp:** read head position; based on the head position warping the rendered image → strong latency reduction
Integrated Tracking: 9-DOF-IMUs

- Miniaturization, increase in precision and price decline: increase in importance of the inertial measurement unit (IMU) for tracking

IMU contain the following types of sensors:

- 3 orthogonally arranged acceleration sensors (translation sensors): linear acceleration in the x-, y-, z- axis; translation by integration done twice

- 3 orthogonally arranged rotation rate sensors (gyroscopic sensors): angular velocity about x-, y-, z- axis; rotation by one-time integration

- To determine the integration constants, to improve the accuracy and to correct the drift of the before mentioned sensors: additional sensors, e.g. magnetic field sensors (compass sensors) and GNSS sensors
Integrated Tracking

Several measuring principles and systems in use:

- 9DOF-IMUs
- External cameras that track IR light sources on the HMD
- Cameras on the HMD tracking external IR light sources in the environment
- Camera for deep imaging for scanning the environment, continuous referencing
- Hybrid approaches: mostly 9DOF-IMU in combination with optical methods for fast as well as absolute 6-DOF tracking
## Integrated tracking: HMDs and consoles

<table>
<thead>
<tr>
<th>Company</th>
<th>Website</th>
<th>Product name</th>
<th>Principle</th>
<th>DOF</th>
<th>Working space</th>
<th>Sampling rate</th>
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<tbody>
<tr>
<td>AntVR</td>
<td><a href="http://www.antvr.com">http://www.antvr.com</a></td>
<td>AntVR</td>
<td>2 x 9DOF-IMUs</td>
<td>6</td>
<td>Only relative</td>
<td>1000 Hz</td>
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<tr>
<td>Avegant</td>
<td><a href="http://www.avegant.com">http://www.avegant.com</a></td>
<td>Glyph</td>
<td>9DOF-IMU</td>
<td>3</td>
<td>Only relative</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>Carl Zeiss</td>
<td><a href="http://www.zeiss.com">http://www.zeiss.com</a></td>
<td>Cinemizer</td>
<td>9DOF-IMU</td>
<td>3</td>
<td>Only relative</td>
<td>1000 Hz</td>
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<tr>
<td>GameFaceLabs</td>
<td><a href="http://gamefacelabs.com">http://gamefacelabs.com</a></td>
<td>GameFace</td>
<td>9DOF-IMU</td>
<td>3</td>
<td>Only relative</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>Immersight</td>
<td><a href="http://www.immersight.de/">http://www.immersight.de/</a></td>
<td>Immersight</td>
<td>External camera with pattern detection of the passive tracking target</td>
<td>6</td>
<td>3m</td>
<td>60 Hz, in case of another camera up to 330 Hz</td>
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<tr>
<td>Meta</td>
<td><a href="https://www.spaceglasses.com/">https://www.spaceglasses.com/</a></td>
<td>SpaceGlasses</td>
<td>9DOF-IMU</td>
<td>3</td>
<td>Only relative</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>Microsoft</td>
<td><a href="http://www.microsoft.de">www.microsoft.de</a></td>
<td>Kinect</td>
<td>External camera and depth imaging camera</td>
<td></td>
<td>3.5 m</td>
<td>30 Hz</td>
</tr>
<tr>
<td>Nintendo</td>
<td><a href="http://www.nintendo.de">http://www.nintendo.de</a></td>
<td>Wii</td>
<td>Optic (infrared camera in controller) and acceleration sensor</td>
<td>6</td>
<td>1-3 m</td>
<td>Sensor 100Hz, Bluetooth query but only 50 Hz</td>
</tr>
<tr>
<td>Oculus</td>
<td><a href="http://www.oculusvr.com">http://www.oculusvr.com</a></td>
<td>Rift 2</td>
<td>9DOF-IMU and external camera; IR-LEDs at the front of the HMD, 360° tracking</td>
<td>6</td>
<td>room</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>Sony</td>
<td><a href="http://www.sony.de">http://www.sony.de</a></td>
<td>Morpheus</td>
<td>9DOF-IMU and external camera, IR-LEDs at the front and the back of the HMD, 360° tracking</td>
<td>6</td>
<td>room</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>Sony</td>
<td><a href="http://www.sony.de">http://www.sony.de</a></td>
<td>Playstation Move</td>
<td>Optic (external camera), gyroscope, inclination measurement device</td>
<td>6</td>
<td>5 m</td>
<td>60 Hz or 120 Hz depends on resolution</td>
</tr>
<tr>
<td>Sulon</td>
<td><a href="http://sulontechnologies.com">http://sulontechnologies.com</a></td>
<td>Cortex</td>
<td>9DOF-IMU and depth imaging sensor on HMD scans and references environment</td>
<td>6</td>
<td>room</td>
<td>optic: 50 Hz</td>
</tr>
<tr>
<td>Technical Illusions</td>
<td><a href="http://technicalillusions.com">http://technicalillusions.com</a></td>
<td>CastAR</td>
<td>Tracking camera in glasses, which tracks IR-LEDs in environment</td>
<td>6</td>
<td>room</td>
<td>kA</td>
</tr>
<tr>
<td>True Player Gear</td>
<td><a href="http://www.trueplayergear.com">http://www.trueplayergear.com</a></td>
<td>Totem</td>
<td>2 cameras at the front of the HMD, referencing the environment</td>
<td>6</td>
<td>room</td>
<td>kA</td>
</tr>
<tr>
<td>Valve</td>
<td><a href="http://www.valvesoftware.com">http://www.valvesoftware.com</a></td>
<td>Valve HMD</td>
<td>2 cameras at the front and the back of the HMD for environment and pattern detection</td>
<td>6</td>
<td>room</td>
<td>kA</td>
</tr>
</tbody>
</table>
Integrated Tracking: Eye Tracking

Benefit for:
- Usability checking
- Design decisions
- Attentiveness analysis

HMD-integrated eye tracking solution:
- 2011: Google patent for eye tracking in Google Glass
- Solutions:
  - FOVE VR Headset
  - SensoMotoric Instruments (SMI) for Oculus
  - Arrington Research for HMDs by Sony, Oculus, Sensics, CyberMind, Virtual Realities
Virtual Retina Displays (VRDs)

- Direct projection on retina
- Further development of VRD technology, esp.
- LEDs available in basic colors (red, green, blue)
- Increased light performance of LEDs

Advantages:
- Space requirement
- Brightness (see-through even in daylight)
- Energy consumption
- Eye focussing not necessary
- Suitable for persons with visual impairment
- Example: HMD Avegant Glyph
Light field cameras (plenoptic cameras)

Functionality
- Conventional camera captures 2D image
- Plenoptic camera detects direction
- For light field measurement: grid of several microlenses in front of the image sensor

Advantages
- Maximum depth of field very high
- No focusing process
- Focus plane subsequently customizable
- Depth information can be determined

Disadvantages
- Costs
- 2D resolution 4MP rather low
The Light Field Stereoscope

Immersive Computer Graphics via Factored Near-Eye Light Field Displays with Focus Cues

Fu-Chung Huang
Stanford University

Kevin Chen

Gordon Wetzstein

The Stanford University now uses lightfield technology in Head Mounted Displays to solve the accommodation problem of HMDs.

Figure 1: The light field stereoscope is a near-eye display (top left) that facilitates immersive computer graphics via stereoscopic image synthesis with correct or nearly correct focus cues. As opposed to presenting conventional 2D images, the display shows a 4D light field to each eye, allowing the observer to focus within the scene (center and right). The display comprises two stacked liquid crystal displays (LCDs) driven by nonnegative light field factorization. We implement these factorizations in real-time on the GPU; resulting patterns for front and rear LCDs, including the views for both eyes and inlense lens distortion, are shown (bottom left).
Integration of imaging depth sensors (1/3)

Products and releases
- Microsoft Kinect
- Google project Tango
- Leap Motion
- Intel Real Sense 3D
- Primesense Carmine
- ASUS Xtion Pro Live
- Meta Space Glasses
- PMD
- Sony Playstation 4 Camera
- Softkinetics
- Mantis Vision
Integration of imaging depth sensors (2/3)

Enabling self-awareness
- Detecting one's own body (torso, hands, ...) with imaging depth sensors instead of data gloves and/or motion capturing

Cancellation of the environment isolation
- User can see and interact with the dynamic environment
- Real-virtual mixed scenes possible
Integration of imaging depth sensors (3/3)

Detecting the movements, gestures of the user
- Interaction: running, grasping, moving things, ...

Extraction of objects from scene (near, far)
- Set up of mixed scenes for presentation in the Head Mounted Display

Occultation calculation for Augmented Reality
- Graphical objects that should actually be (partially) hidden by real objects should not be drawn; the occultation calculation required for this needs a current 3D-image of reality

Person with HMD is scanned by Kinect and can thereby interact
Here: operating a setting wheel with one’s hands, walking

Real person in short distance in real-time extracted from 3D-scan

Drawn built-in unit (violet) disappears partially behind metal sheet (black). To do this, the computer has to check the concealment of metal sheet and built-in unit
Final remark: Estimates

- The market for HMDs and tracking systems will change a lot in the next 5 years
- Markets:
  - global HMD market at $12,28 billion in the year 2020
  - annual growth rate 2014-2020: 57%
- Various application possibilities of good HMDs and data glasses (especially support, service, interior inspections, training)
- Restrictions on the ability to cooperate are reducible
Literature

- Li, Hua et. al.: Review and analysis of avionic helmet-mounted displays. In : Optical Engineering 52(11), 110901, November 2013
- N.N.: Head Mounted Display (HMD) Market by Products (Helmet Mounted, Wearable Glass), Components (Micro display, Camera, control unit, Tracker, Accessories), Applications (Defense, industrial, Video Gaming) & Geography - Global Analysis and Forecast to 2020, Markets and Markets, Mai 2014
- N.N.: Global Head-mounted Display Market, TechNavio, Januar 2013
- N.N.: Head Mounted Display (HMD) Market Analysis By Product (Helmet Mounted Display, Wearable Glass), By End-Use (Defense, Consumer), By Application (Imaging, Security, Tracking, Training & Simulation) And Segment Forecasts To 2020, Grand View Research, Oktober 2014
Links

- [http://www.stereo3d.com/hmd.htm](http://www.stereo3d.com/hmd.htm)
  Bungert, Christoph: HMD/headset/VR-helmet Comparison Chart, abgerufen am 20.6.2014

- [http://www.vrbrillen.net](http://www.vrbrillen.net)
  Kovshenin, Konstantin: VR Brillen. Head Mounted Display – Der nächste Quantensprung in Gaming und Film, abgerufen am 20.6.2014

  Road to VR: HMD Comparison. Head Mounted Display (HMD) / VR Headset Comparison Chart, abgerufen am 20.6.2014

- [http://www.vdc-fellbach.de/wissen/vr-hardware/head-mounted-displays](http://www.vdc-fellbach.de/wissen/vr-hardware/head-mounted-displays)
  Runde, Christoph: Head Mounted Displays & Datenbrillen, abgerufen am 20.6.2014

- [http://www.vrnerds.de/hardvr/96-2/](http://www.vrnerds.de/hardvr/96-2/)
VDC members regarding this topic:
Thank you very much for your interest!
You are interested in this topic and you are looking for contact persons/ implementation partners? Please contact us.

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