Virtual Reality Systems

EPFL Immersive Interaction Group
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Outline

First Part:

• Head Mounted Display (HMD)
• Display Interface (Screen, Mura, God Ray, Screen Door Effect, Contrast, FOV, Resolution)
• Tracking System
• Input Devices (Controller, Camera, Suit, Voice, Eye Tracking, BCI)
• Standalone vs Wireless vs Tethered vs Backpack
Head Mounted Display (HMD) Virtual Reality (VR)

• Oculus Rift
  • 1 Display
  • 2 IR cameras
  • 2 Wireless controllers
  • Active trackers
Head Mounted Display (HMD) Virtual Reality (VR)

- HTC Vive
  - 1 Display
  - 2 Laser emitters
  - 2 wireless controllers
  - Active trackers
Head Mounted Display (HMD) Virtual Reality (VR)

• Windows Mixed Reality
  • 1 Display
  • 2 RGB cameras (Attached)
  • 2 Wireless controllers
  • Active trackers
Head Mounted Display (HMD) 
Virtual Reality (VR)

• PSVR (PS4 Pro/PS4 Sony)
  • One Display
  • 1 External Camera
  • 2 wireless controllers
  • Active trackers
Head Mounted Display (HMD)
Virtual Reality (VR)

• Gear VR
  • One Display Stand-alone
  • No wireless controllers
  • No positional tracking
<table>
<thead>
<tr>
<th>Features</th>
<th>GearVR</th>
<th>Oculus</th>
<th>HTC Vive</th>
<th>Mixed Reality</th>
<th>PSVR</th>
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<tbody>
<tr>
<td>PC requirements</td>
<td>Smartphone Galaxy S7</td>
<td>Nvidia GTX970 AMD 290 I5, 8G+DDR3</td>
<td>Nvidia GTX970 AMD 290 I5, 4G+ DDR3</td>
<td>GPU NVidia GTX 960 AMD RX 460 I5, 2G+ DDR3</td>
<td>CPU x86-64 AMD “Jaguar”, 8 cores GPU 1.84 TFLOPS,AMD</td>
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<td>Connection</td>
<td>HDMI+USB</td>
<td>HDMI 1.3 3USB 3.0</td>
<td>HDMI 1.3+ 2USB 3.0</td>
<td>HDMI 2.0+ USB 3.0</td>
<td>HDMI+USB 3.1</td>
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<tr>
<td>Sensor Types</td>
<td>Acc, Gyro, Mag</td>
<td>Acc, Gyro, Mag, Tracking Sensor Array</td>
<td>Acc, Gyro, Front-Facing Camera, Laser sensor</td>
<td>Acc, Gyro, Inside-out Tracking</td>
<td>Acc, Gyro, External Camera</td>
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<tr>
<td>Field of View</td>
<td>Appr. 90 degrees</td>
<td>Appr. 110 degrees</td>
<td>Appr. 110 degrees</td>
<td>Appr.105 degrees</td>
<td>Appr.110 degrees</td>
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<td>Resolution</td>
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<td>2160*1200</td>
<td>2160*1200</td>
<td>2880*1 440</td>
<td>1920x1080</td>
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<td>Refresh Rate</td>
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<td>90hz</td>
<td>90hz</td>
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<td>99€ +699€</td>
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<td>799 €</td>
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</table>
Head Mounted Display (HMD) 
Augmented Reality (AR) Optical See Through 

- Meta 
  - 1 Display LCD 
  - 2 Depth cameras (Attached) 
  - Finger Tracking 
  - 1 RGB Camera
Head Mounted Display (HMD) Augmented Reality (AR) Optical See Through

• Hololens
  • 1 Display Wave Guide
  • 4 Monochrome cameras
  • 1 Depth camera
  • 1 Photo / HD video camera
Head Mounted Display (HMD)  
Augmented Reality (AR) Optical See Through

• Magic Leap
  • 1 Display Wave Guide
  • 4 Monochrome cameras
  • 1 Depth camera
  • 1 Photo / HD video camera
  • 1 Eye Tracking
Head Mounted Display (HMD) Augmented Reality (AR) Video See Through

- ARkit (Apple)/ ARCore (Google)
  - One Display Stand-alone (Iphone/Android Phone)
  - No wireless controllers
  - No positional tracking
## AR HMD comparison

<table>
<thead>
<tr>
<th>Features</th>
<th>Meta2</th>
<th>Hololens</th>
<th>Magic Leap</th>
<th>Smartphone</th>
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<tbody>
<tr>
<td>PC requirements</td>
<td>Nvidia GTX960 AMD R9 280, Intel Core i7</td>
<td>Intel Atom x5-Z8100</td>
<td>NVIDIA Tegra X2 SOC</td>
<td>Smartphone iPhone7 Pixel</td>
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<td>Field of View</td>
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<td>Appr. 30 degrees</td>
<td>Appr. 40 degrees</td>
<td>Appr.73 degrees</td>
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<td>2160*1200</td>
<td>2160*1200</td>
<td>2880*1 440</td>
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<tr>
<td>Refresh Rate</td>
<td>60Hz</td>
<td>60hz</td>
<td>...</td>
<td>60hz</td>
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<tr>
<td>$$$</td>
<td>$949</td>
<td>$3000</td>
<td>$2295</td>
<td>$449</td>
</tr>
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</table>
Display Interface
Screen

• Human Characteristic:
  • Field of View (FOV) ~210 deg (~180 deg horizontal, 130 deg vertical)
  • Retina Resolution 9000x7800 pixels per eye.
  • Accommodation (Infinite Focal Plane Displays)
  • Refresh Rate 120 Hz (Motion Blur)
Display Interface
Screen

- Wave Guide (1280 x 960) at 60Hz
- LCD 8K (7680 × 4320) at 60Hz
- OLED 8K (7680 × 4320) at 60Hz
- LCD 2K (2048×1080) at 90Hz
- OLED 2K (2048×1080) at 90Hz

Wave Guide:
Schematic general diagram of basic principle*

Display Interface

Screen

• Screen Door Effect
  We see the line between pixels.

• Mura Effect
  Issue with Colour consistency

• God Ray Effect/Lens Flare
  Lens diffract the light
Tracking system

• With markers
  • Active
  • Passive
• Markerless
Tracking system (Head tracking)

• With markers: Active motion capture system
  • PhaseSpace optical motion capture
    • Motion tracking
    • Position sensing

LEDs
Dimensions: 20 mm x 14 mm x 3.2 mm
Weight: 4.5 grams
Each LED modulates at a unique frequency resulting in a unique digital ID. LEDs are available in Red visible and Infra-red versions.

Cameras
Dimensions: 108 mm x 92 mm x 57 mm
Weight: 380 grams
Each camera achieves an Optical Resolution of 3600 x 3600 (12 Megapixel) using two linear detectors with 16-bit dynamic range. Onboard processors produce an impressive Subpixel Resolution of 30,000 x 30,000 at 480 Hz.
Tracking system (Head tracking)

- Active motion capture system
  - Only Head Tracking
Tracking System

- Data sent to headset
- Proprietary Protocol

- IR filter on the Camera
- Triangulate its position in the tracking space

Data streaming

Positional Tracking
Tracking System

- Data sent to headset
- Proprietary Protocol

Data streaming

- Laser Emitter
- Triangulate its position in the tracking space

Positional Tracking
Tracking system (Head and hand tracking)

• Passive tracking system
  • Reflect incoming IR radiation back in the direction of the incoming light (ART tracking maxi distance = 7m)
Tracking system

- Passive tracking system architecture
Tracking system

• IMU motion capture
  • Xsens
  • Perception Neuron

https://www.youtube.com/watch?v=LtMfrkRqlRs
Tracking system

- Markerless Motion capture system
  - Kinect sensor
    - Natural user Interface using
      - Gestures
      - and Spoken commands
  - Connectivity: + power cable (for PC)
Tracking system

• Kinect sensors:
  • RGB camera
  • Depth sensor (IR Emitter and IR Depth Sensor)
  • Multi-array microphone

• Functionality:
  • Full-body 3D motion capture
  • Facial recognition
  • Voice recognition
Tracking system

• Kinect sensor features:
  • Sensor outputs video at 30Hz
  • RGB video 8-bit VGA Resolution (640*480 pixels/HD)
  • Depth sensing in VGA resolution (320*240pixels/512*424pixels)
• Ranging limit:
  • Distance 4.5m
  • Angular field of view:
    • 57° horizontally / 70°
    • 43° vertically / 60°
Tracking system

• New Kinect Sensor
  • Improved field of view results in much larger play space.
  • RGB stream is higher quality and higher resolution.
  • See in the dark
  • Biometric scanning
  • Muscle+force
  • Expression engagement

https://www.youtube.com/watch?v=NDTqx1Zi-n0
Tracking System

- Data sent to headset
- Proprietary Protocol

Data streaming

- Visible light Cameras
- Identify features in your environment in visible light.

Positional Tracking
## Tracking system

<table>
<thead>
<tr>
<th></th>
<th>Active</th>
<th>Passive</th>
<th>Markerless (Kinect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Invasiveness</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
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<tr>
<td>Measurement</td>
<td>Marker pos(/ori)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Marker pos(/ori)</td>
<td>Pos</td>
</tr>
<tr>
<td>Preparation</td>
<td>Complex</td>
<td>Complex</td>
<td>Easy</td>
</tr>
<tr>
<td>Battery</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Calibration</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Marker recognition</td>
<td>Yes</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Price</td>
<td>High</td>
<td>Very High (e.g VICON)</td>
<td>Low</td>
</tr>
</tbody>
</table>

<sup>1</sup>: at least, 3 markers are needed for orientation measurement
Input Devices

• Oculus Touch
  • 4* Digital buttons
  • 1*Joystick
  • 3*Passive buttons
  • Haptic vibration motor
  • Ring of infrared LEDs (24 IR LEDs)
  • Gyroscope and Accelerometer

• Constellation
  • Infrared sensor (IR camera + filter)
  • USB 3.0
Input Devices

• Vive Controller
  • 6* Digital Buttons
  • 1*Tactile Pad
  • Haptic vibration motor
  • Ring of photodiodes (24)
  • Gyroscope and Accelerometer

• Lighthouse
  • 2*Laser emitters
Input Devices

- Motions Controller
  - 4* Digital Buttons
  - 1*Tactile Pad
  - 1*Joystick
  - Haptic vibration motor
  - Ring of visible LEDs (32 LEDs)
  - Gyroscope and Accelerometer

- Inside-out Tracking
  - 2*low-resolution black and white cameras
Input Devices

• PlayStation Move for PSVR (PS3 Sony)
  • Motion sensing
    • 3-axis accelerometer
    • 3-axis angular rate
  • Location tracking
    • Magnetometer
    • Object recognition (via PlayStation Eye)
  • 1 * Analog trigger
  • 8 * Button

Range of distance : 25cm - ∞ (in wide angle view)
Field of view 56° (standard view) - 75° (wide angle view)
FOV zoom lens

External dimension : Approx. 200mm × 46mm (height × diameter)
Best range : 0.6-3 meter from camera
Input Devices

• PlayStation Move Navigation Controller:
  • Analog stick (for navigation)
  • D-pad (thumb-operated directional control)
  • 1 * Analog trigger
  • 5 * Buttons

• Connectivity:

• Sony PlayStation Move trailer:
  • http://www.youtube.com/watch?v=KywkIJJJoJ5s
Input Devices

- Leap Motion
- Knuckles
- Perception Neuron
- Manus VR
Vive Pro + Wireless Module
WiGig 60GHz
4.6Gbps

Oculus Quest
Standalone vs Wireless vs Tethered vs Backpack

HTC Vive

Meta2+ Backpack
Questions ?