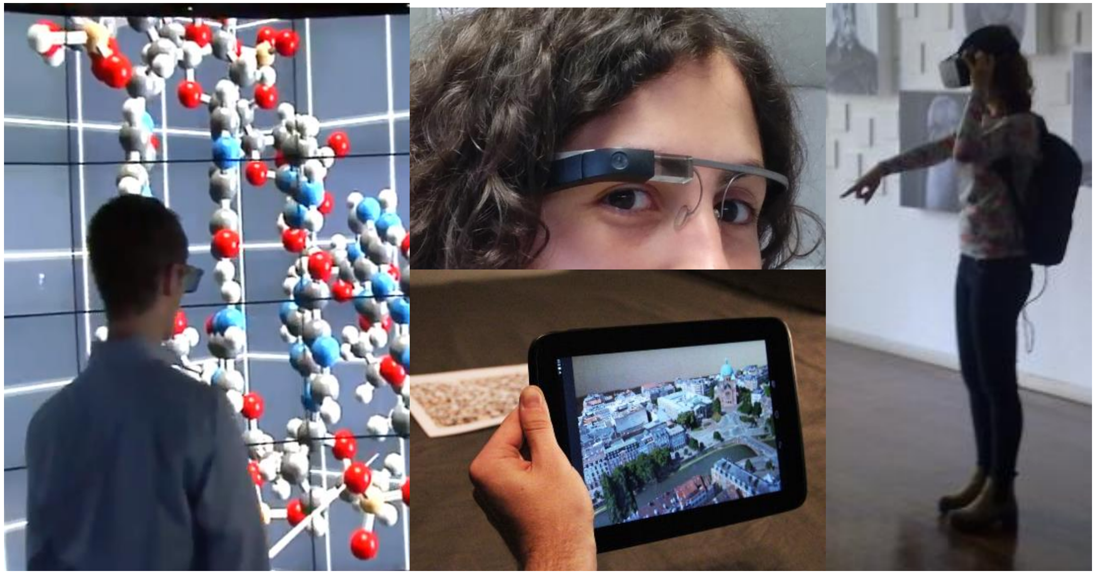
Universidade de Aveiro
Departamento de Electrónica,
Telecomunicações e Informática

Output Devices – I
Visual Displays



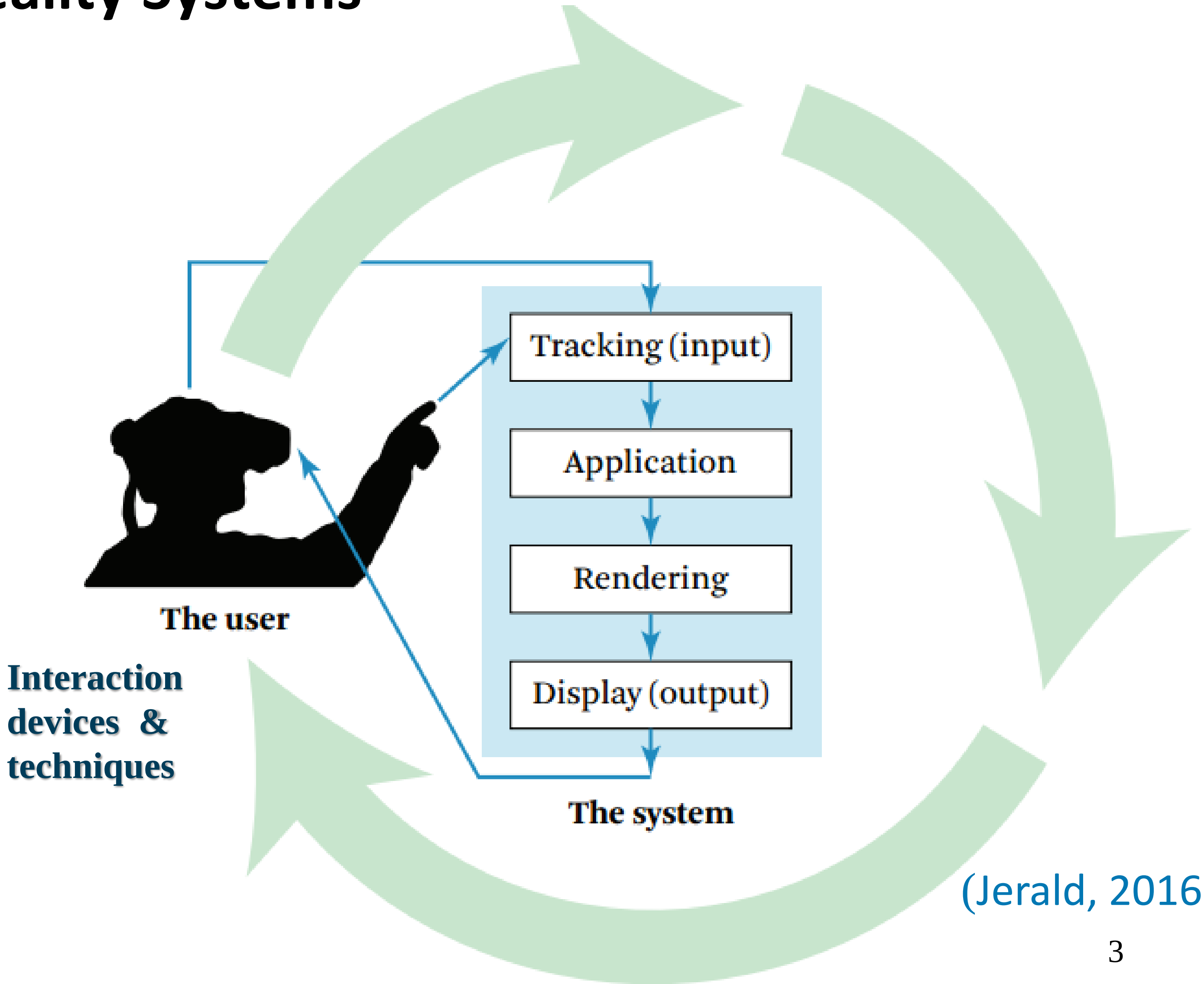
Realidade Virtual e Aumentada 2023

Beatriz Sousa Santos

What is Virtual Reality?

“A high-end user interface that involves real-time simulation and ***interaction*** through **multiple *sensorial channels***.” (**vision, sound, touch, …**) (Burdea and Coiffet., 2003)

Virtual Reality Systems



(Jerald, 2016)

The human senses need specialized interfaces

- **Graphics displays for visual feedback**
- 3-D audio hardware for localized sound
- Haptic interfaces for force and touch feedback

Olfactory feedback has been increasingly researched lately

Some experiments with taste feedback do exist

The ultimate display?

"The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal." (Ivan Sutherland, 1965)

Visual Displays

"is a computer interface that **presents synthetic world images** to one or several users interacting with the virtual world."

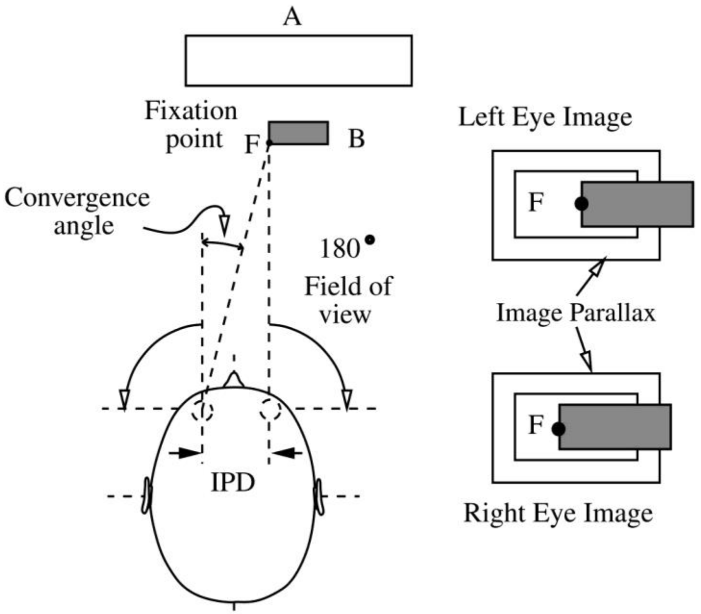
(Burdea and Coiffet., 2003)

• Personal displays:	Main technologies:
- HMDs (VR/AR)	
- Binoculars	LEDs/OLEDs
- Monitor-based displays/active glasses	LCDs
- Autostereoscopic displays	lenticular/barrier

- Large volume displays:
  – Caves — projectors
  – Walls, domes

…

Human Visual System and depth perception



(Burdea and Coiffet., 2003)

- Vision is the dominant sensorial channel
- Depth perception in mono images is based on:
  - occlusion (one object partially covering another)
  - perspective (point of view)
  - familiar size (we know the real-world sizes of many objects)
  - shadows (casted on objects)

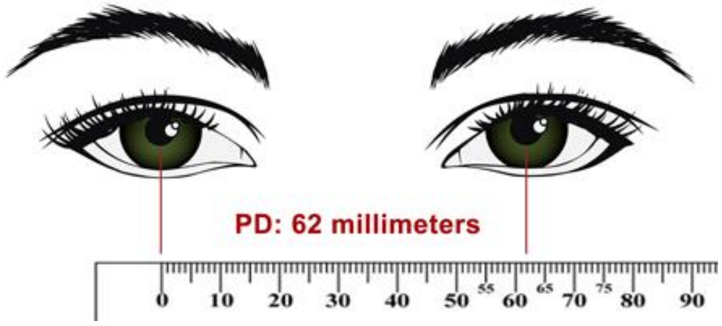
- Depth perception in stereo is based on stereopsis
  (when the brain registers and fuses two images)

- Image parallax means that the two eyes register different images
  (horizontal shift)

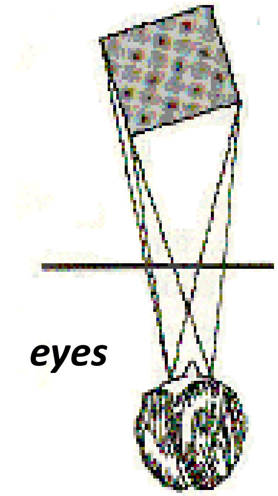
- The amount of shift depends on the “inter-pupillary distance”
  (PD) (varies for each person in the range of 53-73 mm)

- 3-5% of people are stereoblind

(Jerald., 2016)



Stereopsis



Stereo ="solid" or "three-dimensional“

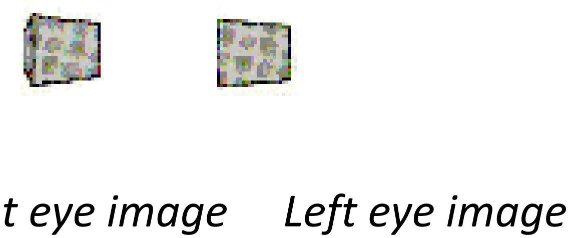
opsis = appearance or sight

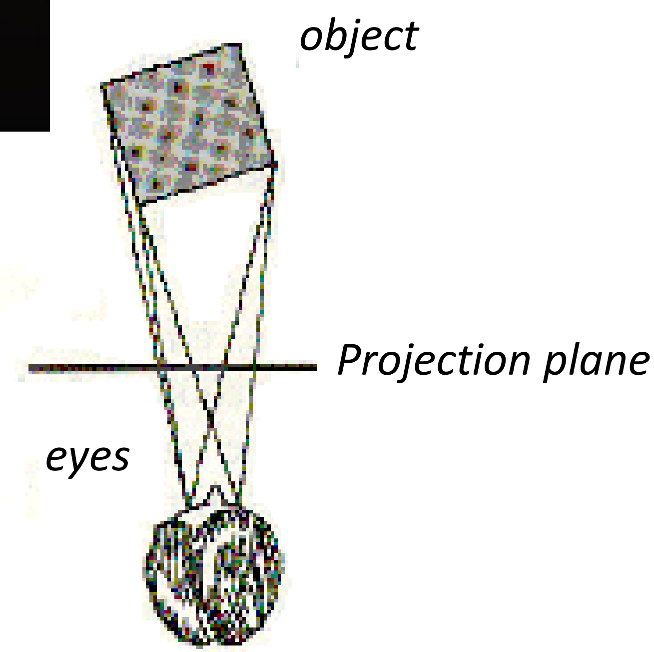
'binocular vision‘ , 'binocular depth perception' , 'stereoscopic depth perception'

- Stereopsis is the impression of depth that is perceived when a scene is viewed with both eyes by someone with normal binocular vision

- **Binocular disparity is due to the different position of our two eyes**

https://en.wikipedia.org/wiki/Stereopsis

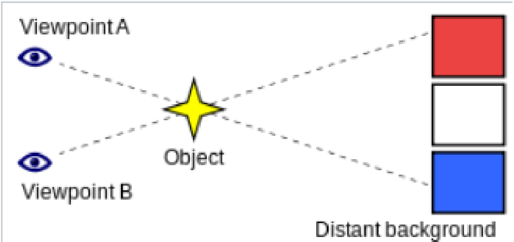

Right eye image
Left eye image

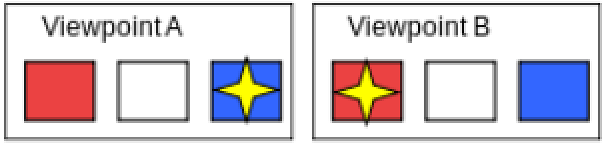

object
Projection plane
eyes

- Many of the perceptual cues we use to visualize 3D structures are available in 2D projections

- We have seen that cues include:
  - occlusion (one object partially covering another)
  - perspective (point of view)
  - familiar size (we know the real-world sizes of many objects)
  - Shadows

- Four cues are missing from 2D media:
  - stereo parallax—seeing a different image with each eye
  - movement parallax—seeing different images when we move the head
  - accommodation—the eyes' lenses focus on the object of interest
  - convergence—both eyes converge on the object of interest





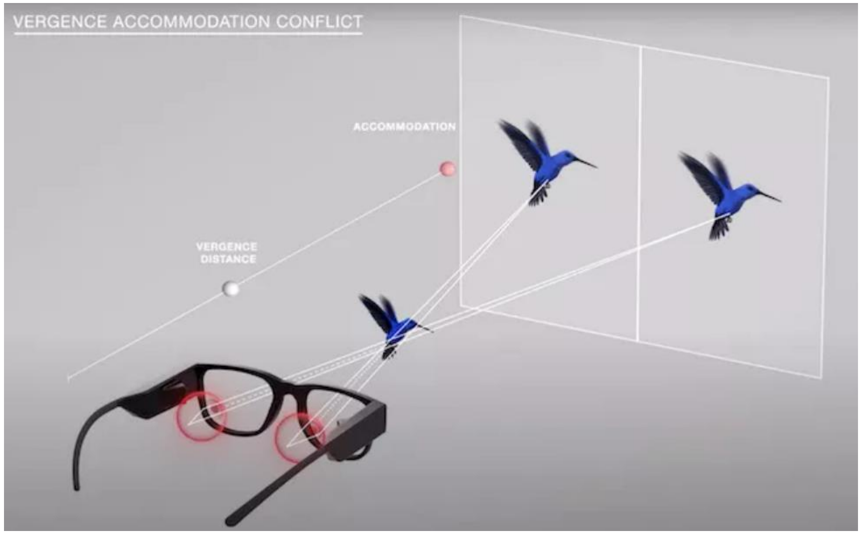
The Vergence Accommodation conflict

- Occurs when your brain receives **mismatching cues** between:

  - the **distance of a virtual 3D object** (vergence),

  and

  - the **focusing distance** (accommodation) required to focus on the object



- It can contribute to:
  - **focusing problems,**
  - **visual fatigue,**
  - **eyestrain,**

  while looking at stereoscopic imagery,
  effects last after ceasing looking

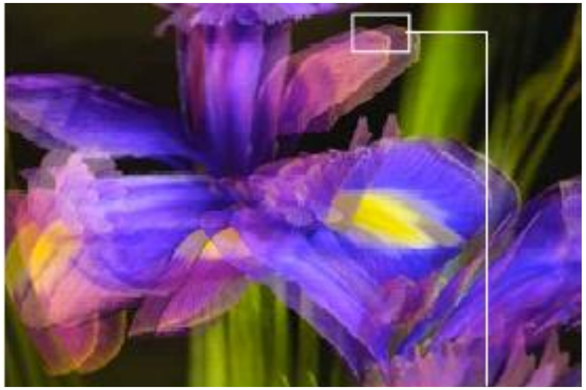
- It is less severe when properly taken into account in content creation and display

https://xinreality.com/wiki/Vergence-Accommodation_Conflict

Implications for Stereo Viewing devices

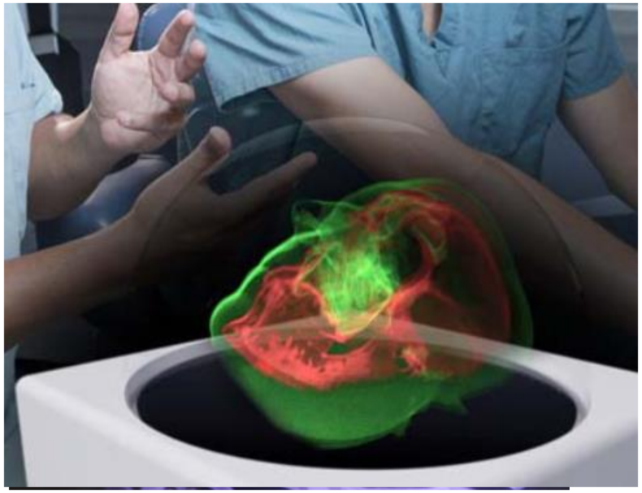
- Need to present **two images** of the same scene (one for the **right eye** and another for the **left eye**)

- The two images can be presented:
  - **at the same time** on two displays (HMD)
  - **time-sequenced** on one display (active glasses)
  - **spatially-sequenced** on one display (auto-stereoscopic displays)



Left eye, right eye images
(Burdea and Coiffet., 2003)

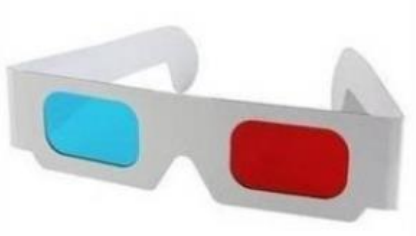
- All stereoscopic displays provide at least stereo parallax
- Autostereoscopic displays do not need any eyewear
- Volume displays provide a “real” 3D image
- VR systems use the first type (stereoscopic displays)



https://voxon.co/technology/

https://www.gartner.com/en/information-technology/glossary/volumetric-displays

Common ways to produce a 3D sensation



- Anaglyphs: two colored images and color coded glasses (red/cyan(green))
- Two images with different light polarization and polarizing glasses
  - Linear and circular

- Double frame-rate displays combined with LCD shutter glasses

- Autostereoscopic displays
  - Parallax barrier and lenticular lens
- Head Mounted Displays (HMDs)

https://3dvision-blog.com/4124-anaglyph-shutter-polarized-glasses-or-autostereoscopic-3d-solution/

Show the right image to the right eye and the left image to the left eye!

- All these technologies provide:
  - stereo parallax

  (apparent displacement of an object when seen from two different positions)

- When combined with head tracking, they can provide:
  - movement parallax for a single viewer

  (objects moving at a constant speed across the frame will appear to move a greater amount if they are closer to an observer)

- Virtual Reality uses:
  - Different light polarization and polarizing glasses
  - Double frame-rate displays and LCD shutter glasses
  - Two images in two screens (HMDs)

Polarized glasses for stereoscopic displays
(also used in 3D movies)

- Advantages of polarized glasses:
  - are generally inexpensive
  - don't require any power
  - do not suffer from flicker
  - don't require synchronization with the display

- Disadvantages:
  - The images for polarized glasses may have to share the screen simultaneously, and therefore cannot have full resolution
  - There are incompatible polarized systems (circular or linear polarized)
  - The head should not be tilted to maintain the 3D effect with linear polarization

Shutter glasses for stereoscopic displays

- Active-shutter glasses are small LCD screens that alternately dim the left and right "lenses" in succession
- They are synchronized with the display usually through IR or radio signals
- Each eye can see the image intended for it
  - Can be bought for < 50€
  - Need a battery

Passive (polarized) *versus* active (shutter)?

- Passive
  - cheaper
  - lighter
  - batteryless
  - syncless glasses
- Active
  - Better image quality

Main Properties of Visual Displays

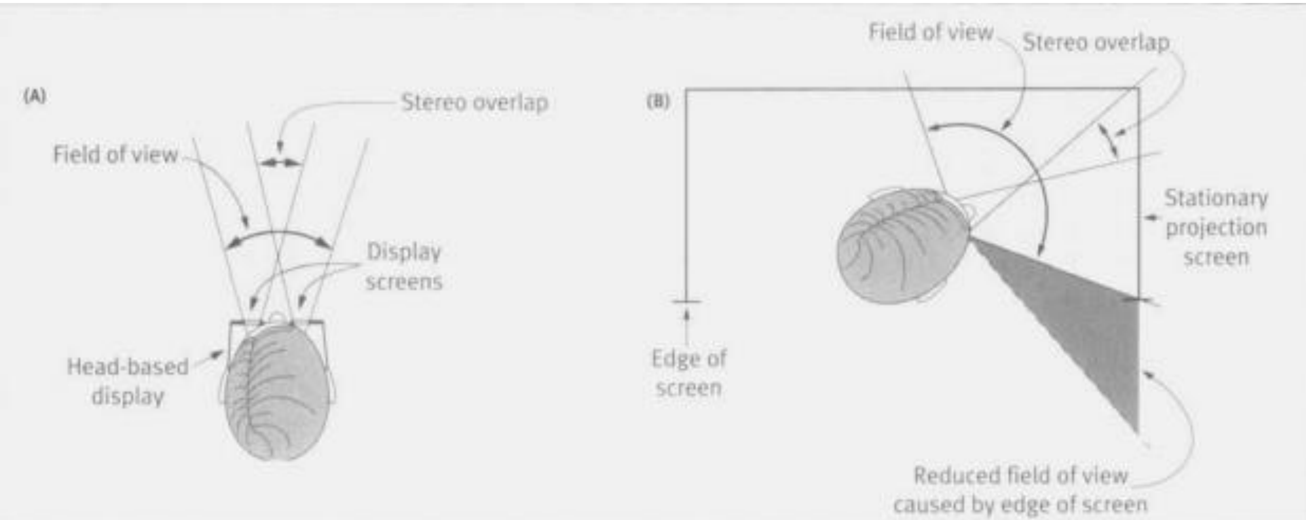
Visual presentation properties:

- Color
- Spatial resolution
- Contrast
- Number of display channels
- Focal distance
- Opacity
- Masking
- **Field of view (FOV)**
- **Field of regard (FOR)**
- Head position information
- Graphics latency tolerance
- Temporal resolution

Logistic Properties:

- User mobility
- Interface with tracking
- Environment requirements
- Associability with other sense displays
- Portability
- Throughput
- Encumbrance
- Safety
- Cost

Field of view (FOV) and Field of regard (FOR)



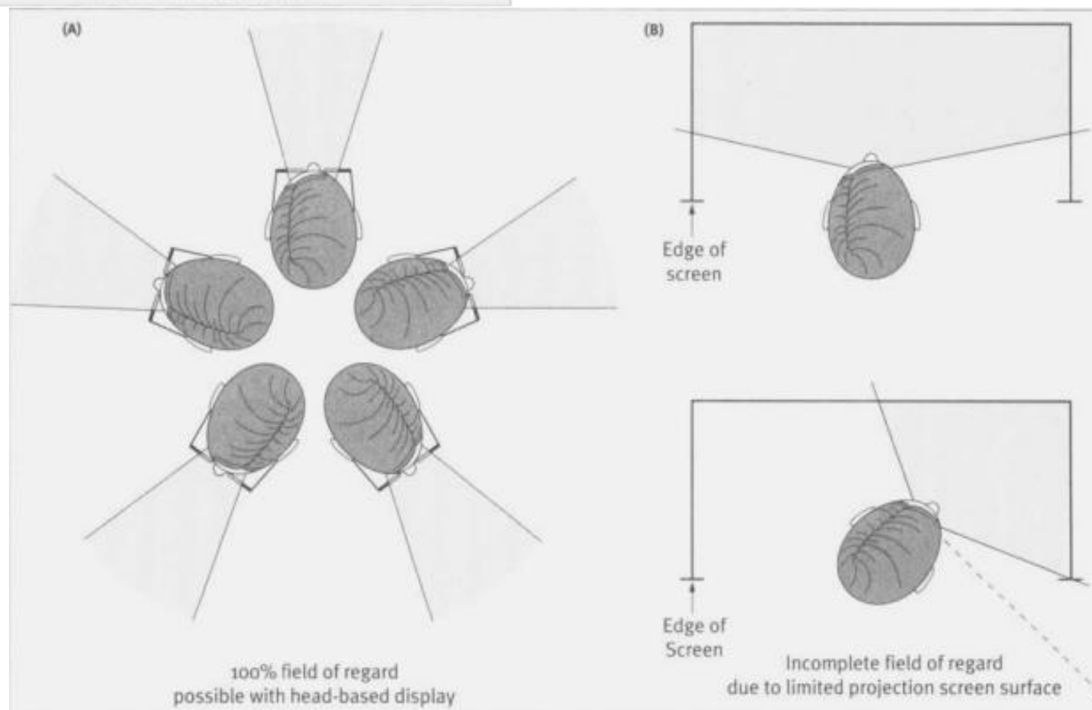
FOV is the amount of the viewer's visual field covered by a display.

(Sherman and Craig, 2003)

FOR is a measure of the amount of coverage a given display provides when head motion and other factors are considered

(A) Head-based displays can easily provide a 100% FOR,

(B) stationary displays are limited to the area of the screens

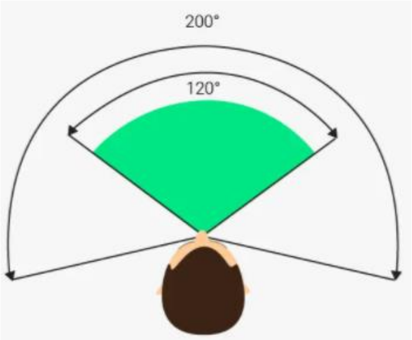


Field of View comparison

Pimax Vision 8K X	156°×104°
Pimax 5K+	140°×101°
Valve Index	**108°×105°**
Samsung Oddysey+	103°×107°
HP Reverb (G1)	98°×92°
Oculus Quest	**96°×94°**
HTC Vive Cosmos	95°×86°
HTC Vive (2016)	86°×86°
Oculus Rift (2016)	86°×86°
Oculus Rift S	**86°×85°**

https://uploadvr.com/field-of-view-tool-database/

The FOV of a given headset is notoriously difficult to consistently measure, because it actually changes depending on the distance between your eye and the lens. That distance is determined by the shape of your face and the fit of the headset.



Human FOV is ~ 210°×150°.

Visual Displays: two possible taxonomies

(Burdea and Coiffet, 2003)

- **Personal displays:**
  - HMDs (VR/AR)
  - Binoculars
  - Monitor-based displays/active glasses
  - Autostereoscopic displays
- **Large volume displays:**
  – Caves
  – Walls, domes
  – …

…

(Sherman and Craig, 2003)

- Head-based (occlusive)
- Non-occlusive head-based
- Handheld
- Monitor- based (Fishtank)
- Projection Displays

Stationary displays

Personal Displays

A Visual display that outputs a virtual scene destined to be viewed by a single user. Such image may be monoscopic or stereoscopic, monocular (for a single eye) or binocular (displayed on both eyes).

- Head Mounted Displays (HMDs)

- 3-D Binoculars (hand supported)

- Auto-stereoscopic displays
  (desk supported)

The low cost Head-Mounted Displays have evolved e.g.:

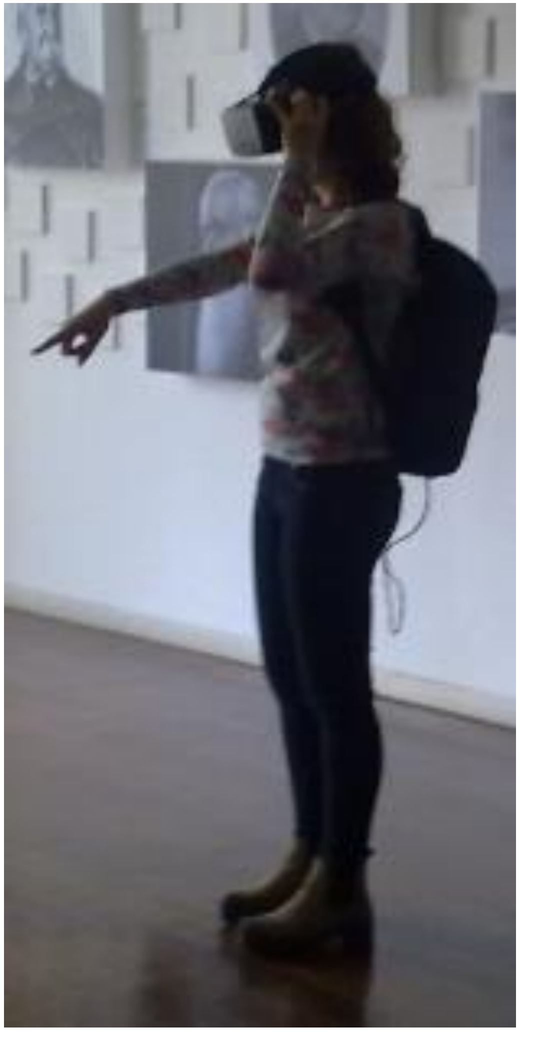
Oculus Rift

2014, DK2:

- low persistence OLED display to eliminate motion blur and judder (two of the biggest contributors to simulator sickness)
- It also makes the scene appear more visually stable, increasing the potential for presence
- 960×1080 pixels per-eye display improves clarity, color, and contrast.

Price: ~~$400

http://www.oculusvr.com/



To standalone (all in one) systems…

Oculus Quest 2 specs:

Smaller, lighter, and higher resolution than Oculus Quest

- Display panel: LCD
- VR Gaming without Cables or a PC
- 256GB Storage Capacity
- 1832 x 1920 Resolution Per Eye
- Qualcomm Snapdragon XR2 Platform
- Built-In IPD Adjustment with 3 Settings
- Cinematic 3D Positional Audio
- Headset Casting
- Two Touch Controllers Included

~500USD – Sep/2022

Example of different HMDs from the same maker

GAMER

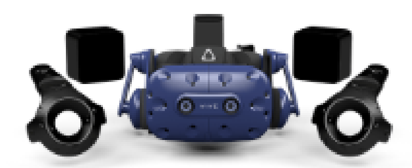
VIVE VR System

- Everything needed to enter the world of VR gaming.
- Experience full immersion with 360-degree controller and headset tracking.
- Play seated, standing or room-scale with SteamVR™ Tracking.

€599.00

PROFESSIONAL

VIVE Pro Starter Kit

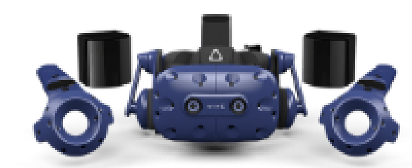


- Designed for pro-level users and a wide-range of business usages.
- Includes VIVE Pro HMD. Refined fit, balance and comfort for extended usage.
- Spectacular graphics and 3D spatial audio deliver deep immersion.
- Up to 3.5M x 3.5M room-scale stage.

€1,199

ENTERPRISE

VIVE Pro Full Kit



- Elevate your business with cutting-edge innovations in VR.
- Includes VIVE Pro HMD with second-generation controllers & base stations.
- Features SteamVR™ Tracking 2.0
- Up to 7M x 7M room-scale stage.

€1,156.20* (EXVAT)

Headsets using Smartphones: the first project
Google Cardboard

https://en.wikipedia.org/wiki/Google_Cardboard

AR smartglasses in 2021: the devices, apps and new tech coming

https://www.wareable.com/ar/ar-glasses-state-of-the-union-8461

“Some of the current best mixed and augmented reality headsets, as the Magic Leap 1 and the Microsoft Hololens 2 are too bulky for non-enterprise use.”

Hololens 2

Microsoft AR glasses

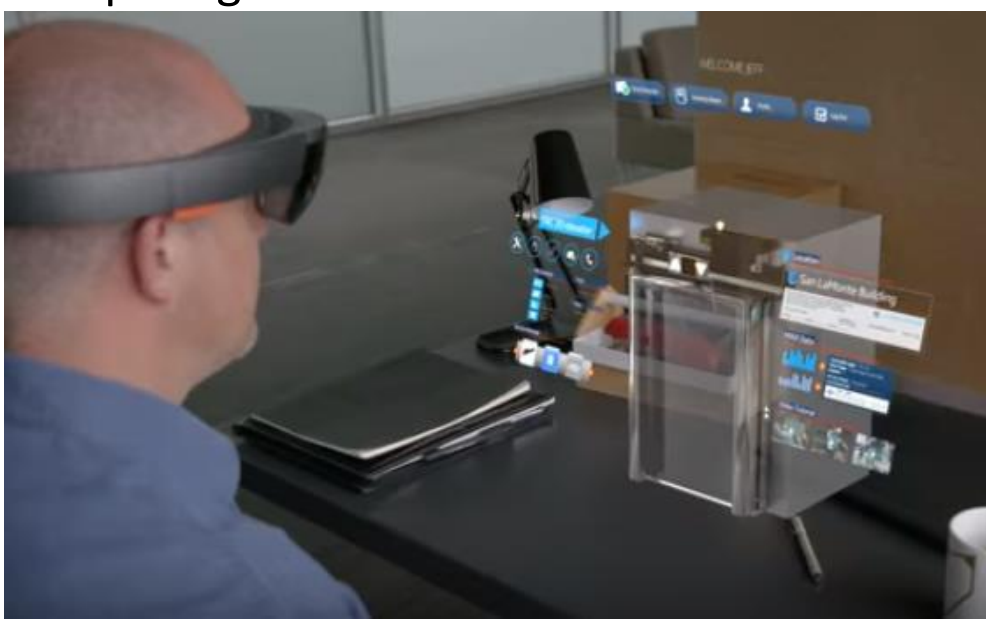
~3500 USD
Include Eyeball and hand tracking

Review: + ergonomics; - visual effects

https://www.microsoft.com/en-us/hololens/

https://arstechnica.com/gadgets/2019/11/microsofts-hololens-2-tracks-your-eyeballs-to-see-what-youre-looking-at/?amp=1

Preparing the visit:



On site:

https://www.youtube.com/watch?v=8OWhGiyR4Ns

Projector based Large-volume displays

- CAVE type displays
- Wall-type displays
- Domes

…

CAVE
(Cave Automatic Virtual Environment)

- Room in which each of the surfaces – the walls, floor and ceiling – may be used as **projection screens to create a highly immersive VE**

- Users typically wear **stereoscopic eyewear** and

- Interact with visual stimulus via wands, data gloves, joysticks, …

https://steantycip.com/vr-cave/

Benefits of Head-based Displays (Occlusive and Non-occlusive)

- Lower cost (for lower resolution models)
- Complete field of regard
- Greater portability
- Can be used for augmenting reality
- Can occlude the real world
- Less physical space required
- Less concern for room lighting and other environmental factors

Benefits of Hand-based Displays

- Greater user mobility
- Greater portability
- Can be combined with stationary VR displays

Main bibliography

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- LaValle, S., *Virtual Reality - Virtual Reality*. Cambridge University Press, 2023 http://vr.cs.uiuc.edu/

- Bimber, J., R. Hainich, *Displays: Fundamentals and Applications*, CRC Press, 2011https://learning.oreilly.com/library/view/displays/9781439867709/chapter-99.html

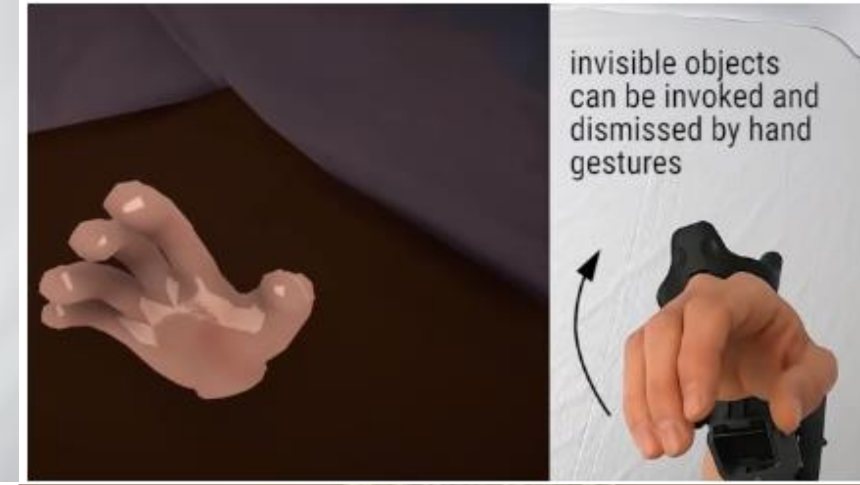
- Craig, A., Sherman, W., Will, J., *Developing Virtual Reality Applications: Foundations of Effective Design*, Morgan Kaufmann, 2009

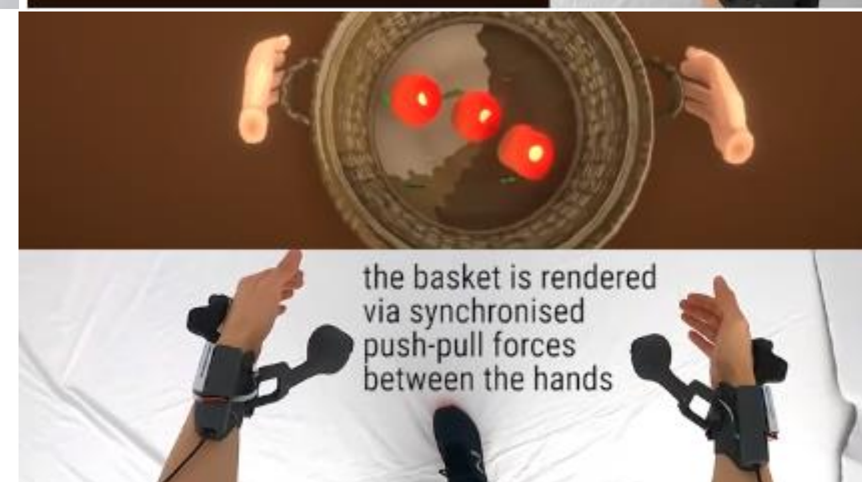
Next episode of Output devices…

Displays to other senses: sound, touch, and smell, …

Haptic PIVOT,

simulates physical forces such as momentum and gravity





https://www.microsoft.com/en-us/research/blog/physics-matters-haptic-pivot-an-on-demand-controller-simulates-physical-forces-such-as-momentum-and-gravity/?OCID=msr_blog_pivot_uist_tw

(October 2020)