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ieeta

An Introduction to Virtual (and other) Realities

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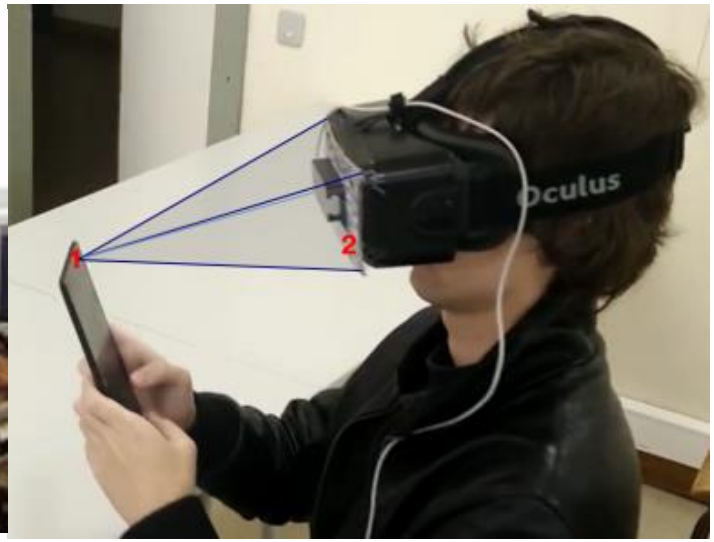
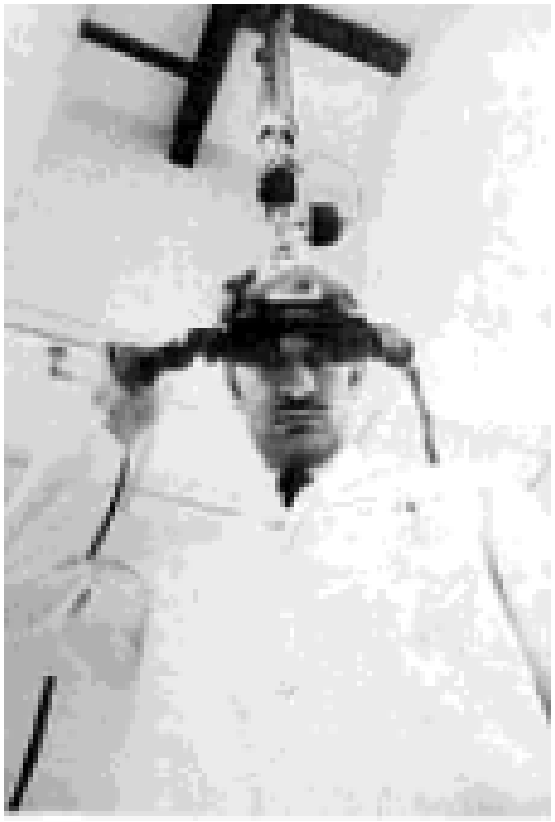


Beatriz Sousa Santos, Junho/2017

- What is?
- Timeline and Applications
- Supporting technologies
- Challenges
- Latest work by the Visualization and Interaction group IEETA/DETI/UA

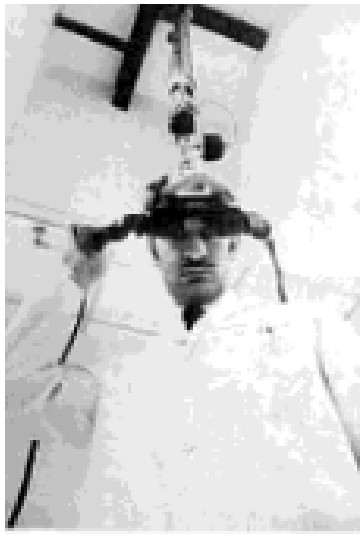
Ivan Sutherland's 1965 Vision



"Don't think of that thing as a screen, think of it as a window, a window through which one looks into a virtual world.

The challenge to computer graphics is to make that virtual world look real, sound real, move and respond to interaction in real time, and even feel real."

Ivan Sutherland's 1965 Vision



"Display as a *window* into a *virtual world*

Improve image generation until the picture *looks real*

Computer maintains world model in *real time*

User *directly manipulates* virtual objects

Manipulated objects *move realistically*

Immersion in virtual world via *head-mounted display*

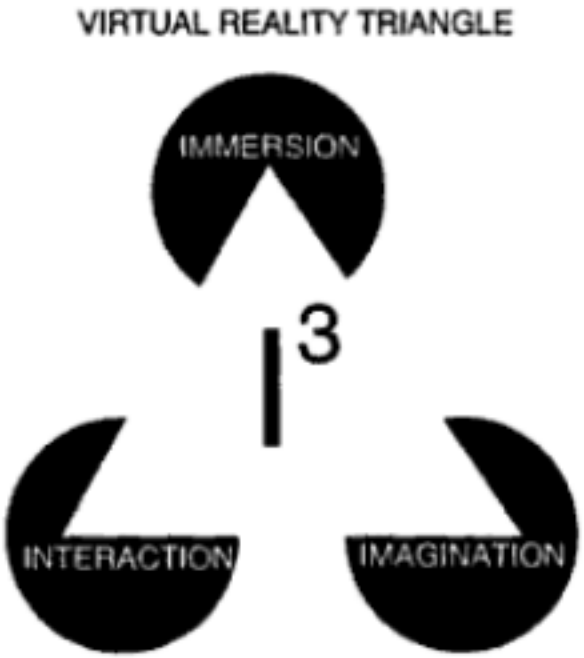
Virtual world also *sounds real, feels real*"

https://www.youtube.com/watch?v=NtwZXGprxag

The Virtual Reality Triangle

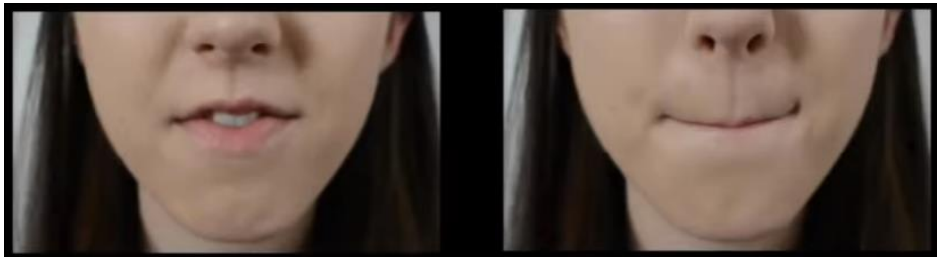
VR is:

- Immersive
- Interactive
- Imagination
  (to perceive non existing things)



(Burdea et al., 2004)

Virtual reality, explained with some visual illusions:
https://www.youtube.com/watch?v=qD3w3cAhEYU



What is VR?

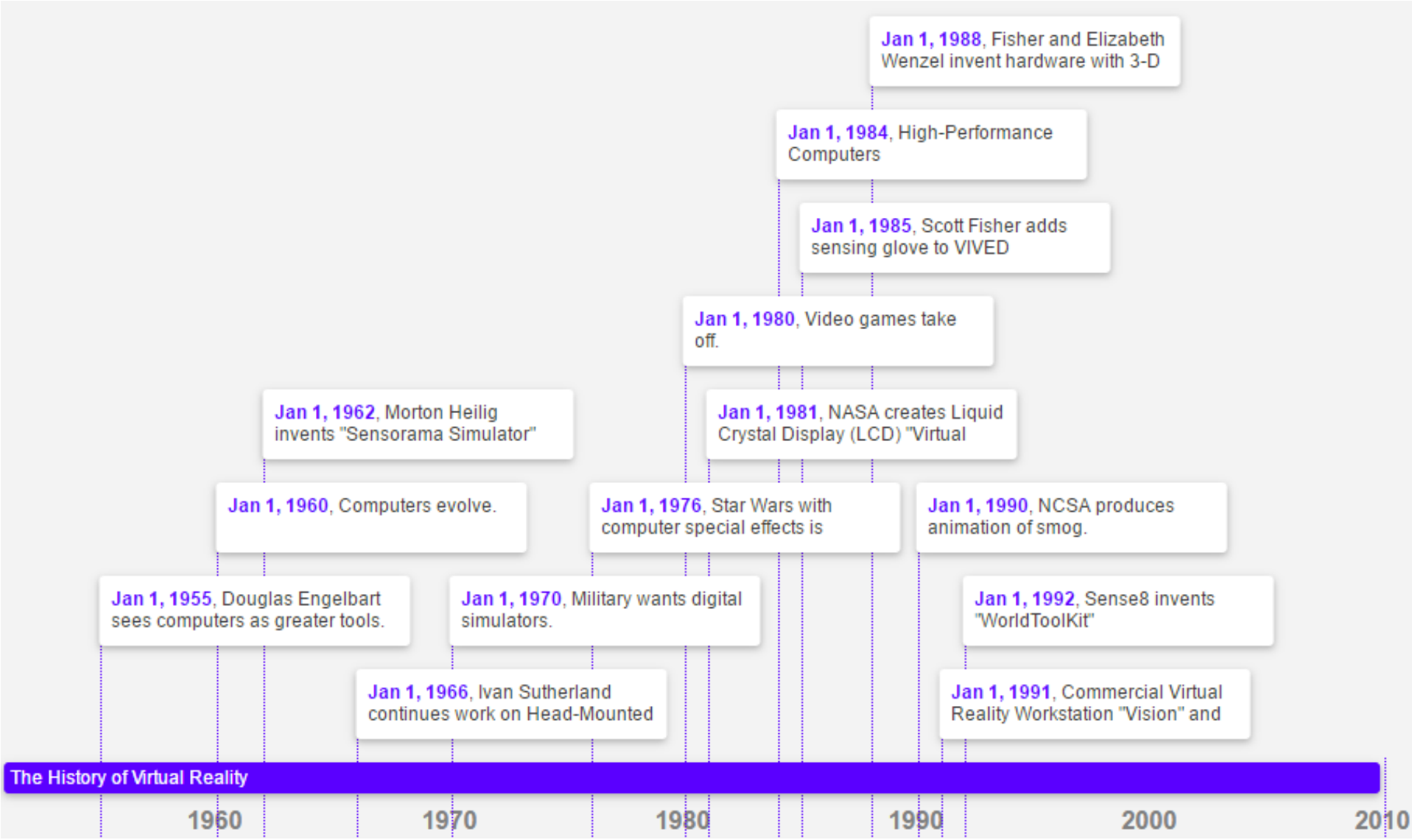
"I define a *virtual reality experience* as any in which the user is effectively immersed in a responsive virtual world. This implies user dynamic control of viewpoint." (Fred Brooks, 1999)

"A high-end user-computer interface that involves real-time simulation and interaction through multiple sensorial channels (vision, sound, touch, smell, taste)". (Burdea et al., 2004)

VR barely worked in 1999

and now?

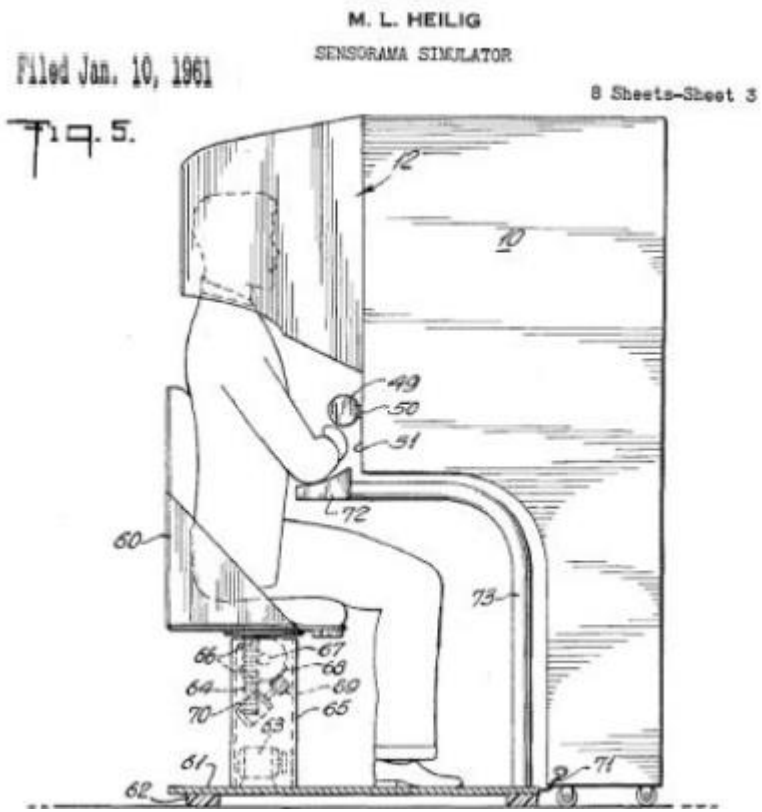
VR Timeline



http://www.timetoast.com/timelines/32116

Sensorama
(Morton Heilig, 1962)

- 3D, wide vision, motion, color, stereo sound, aromas, wind, vibrations



http://en.wikipedia.org/wiki/Sensorama

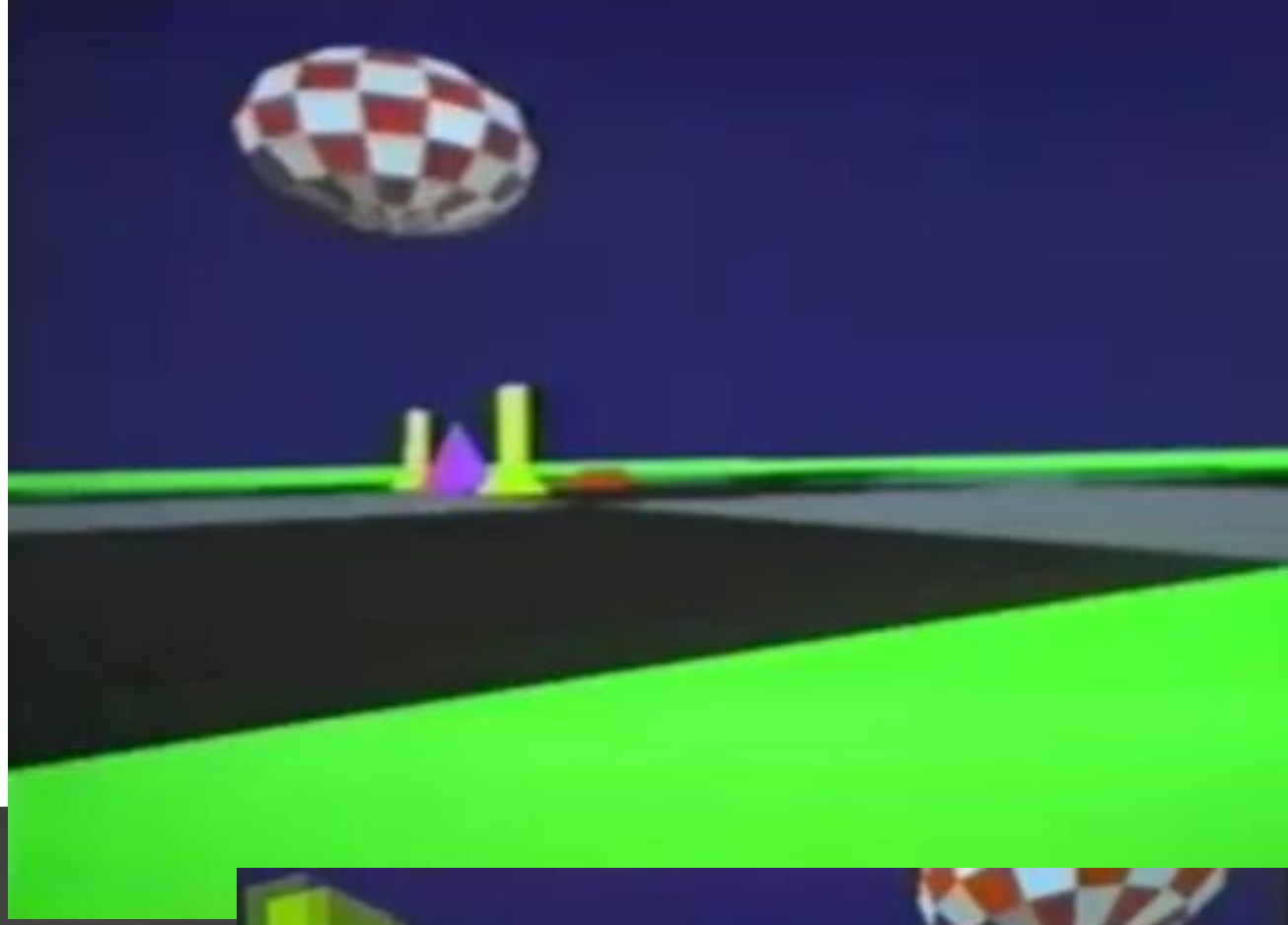
NASA was pioneer:

“Virtual Visual Environmental Display” (VIVED early 80s)

“Virtual Interface Environment Workstation” (VIEW) 1989

Early VR Demo by Sense8

http://www.youtube.com/watch?v=yQgn6u60290



Applications

- Education and training (e.g. military, medical, hazardous industries…)
- Ergonomics evaluation, project review (automotive industry, architecture…)
- Medicine (physical and psychic therapy, surgery planning, pain relief …)
- Culture, entertainment (museums, games, …)
- Data visualization (e.g. science, oil industry)
- Sales and marketing
- …

Applications in Medicine

- Application areas that went beyond the prototype phase:
  - Radiation Treatment, Planning and Control
  - Interactive 3D Diagnostic Imaging
  - Rehabilitation and Sports Medicine
  - Psychiatric and Behavioral Healthcare
  - Neurological Evaluation
  - Pre-Surgical Planning
  - Pain Mitigation
  - Medical Education
  - Surgical Training
  - …

https://www.voxel-man.com/simulators/dental/
http://journals.lww.com/neurosurgery/Fulltext/2015/03002/Virtual_Reality_Cerebral_Aneurysm_Clipping.9.aspx

Examples: Automotive industry

- VR makes possible to:
  - multiply the number of innovative hypotheses studied
  - limit the number of physical mock-ups
  - cut development time and cost

New models can be analysed even before any physical prototype exists

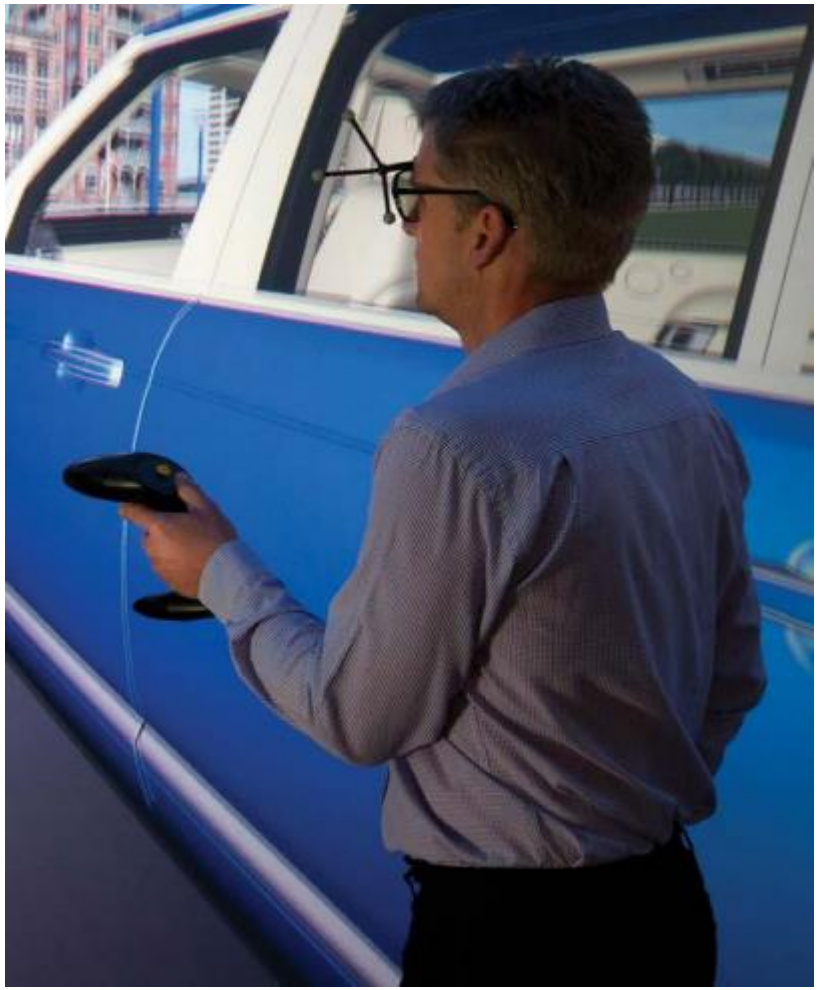
http://www.youtube.com/watch?v=umD0IemkXLc&feature=related
https://www.youtube.com/watch?v=j3qcnvgVlNk

Automotive industry
(Jaguar Land Rover)

- State-of-the-art virtual and high-end visualization technologies

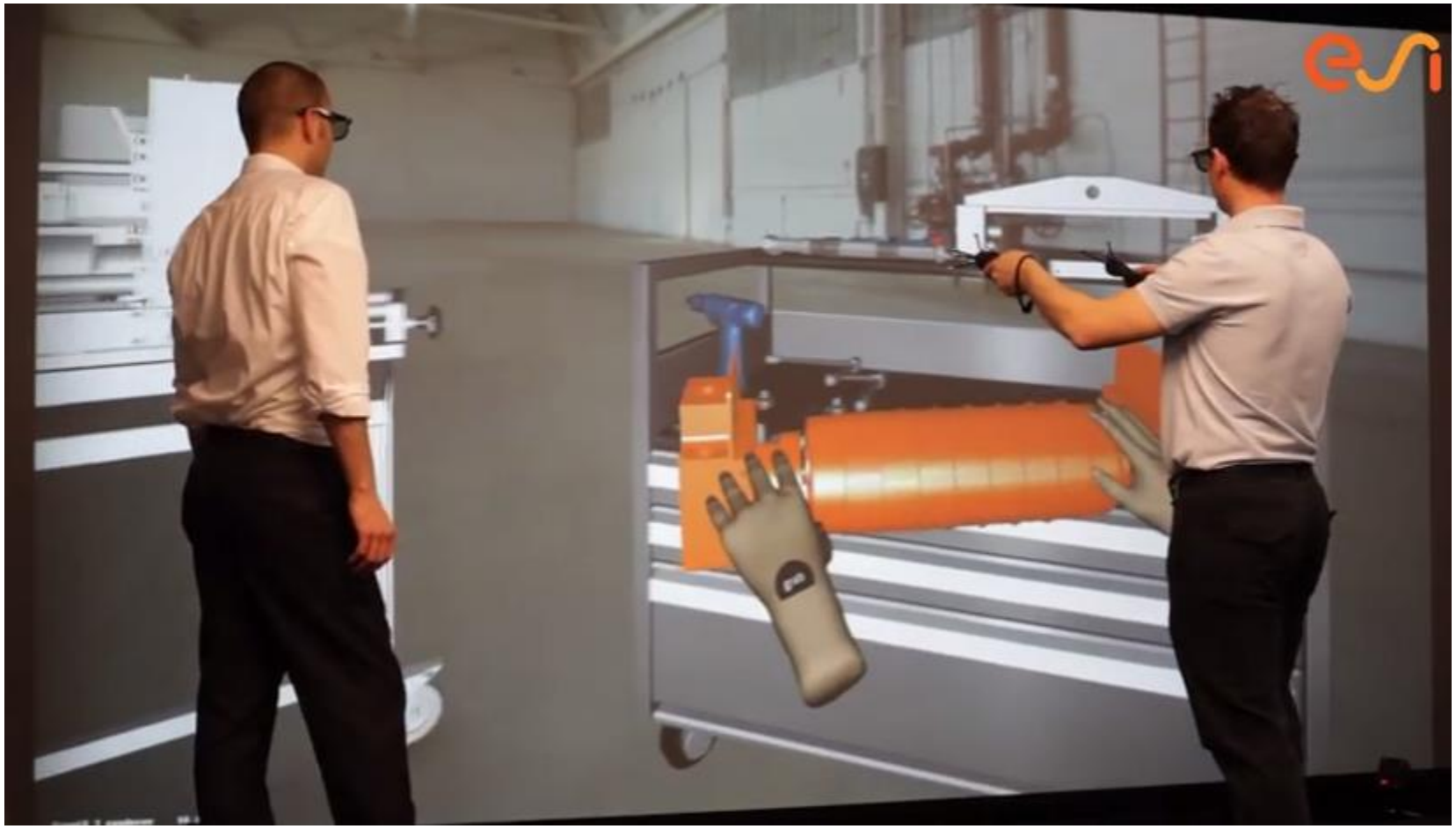
- Increasing efficiency of the product development:
  - faster time to market
  - less investment in physical prototypes
  - helps achieving more robust results

- Virtual Reality Ergonomics laboratory optimize vehicle interior ergonomics and manufacturing or dealer servicing processes.
- Driving simulator (driving dynamics, noise, vibration)



http://www.jaguarlandrover.com/media/23076/jlr_company_information.pdf

Manufacturing lines development



https://www.youtube.com/watch?v=GiX29mcPymY

Sports training

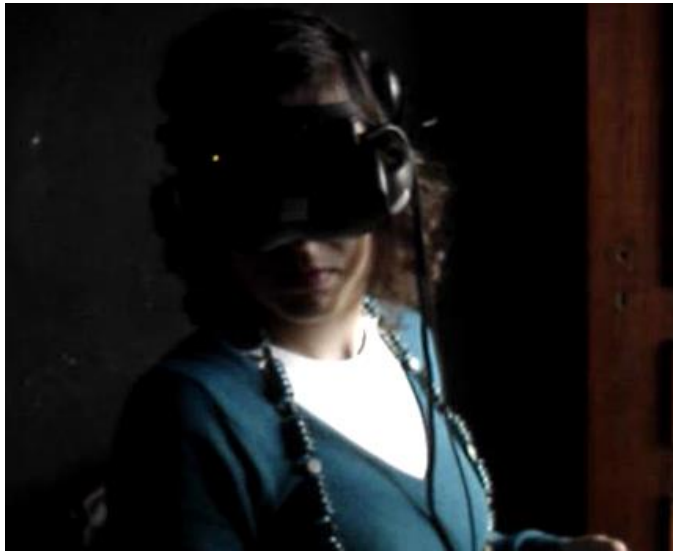
http://strivrlabs.com/press/

Training: Coal mining industry

http://www.3ds.com/fileadmin/PRODUCTS/3DVIA/3DVIAVirtools/demoshowcase/html/demo.html?br=1&rub=2&srub=8&de=245#

Several degrees of immersion

- Desktop VR
- Semi-immersive VR
- Fully immersive VR



(S.H. Choi and H.H. Cheun, 2008)

Potential benefits of Immersion

- Immersion can offer benefits beyond a realistic experience:

- Spatial understanding can result in greater effectiveness in:
  - scientific visualization,
  - design review,
  - virtual prototyping

- Decrease in information clutter and increase the environment's comprehensibility (increased FOV, FOR, and display resolution)

(Bowman and McMahan, 2007)

- May help attain "**presence**"

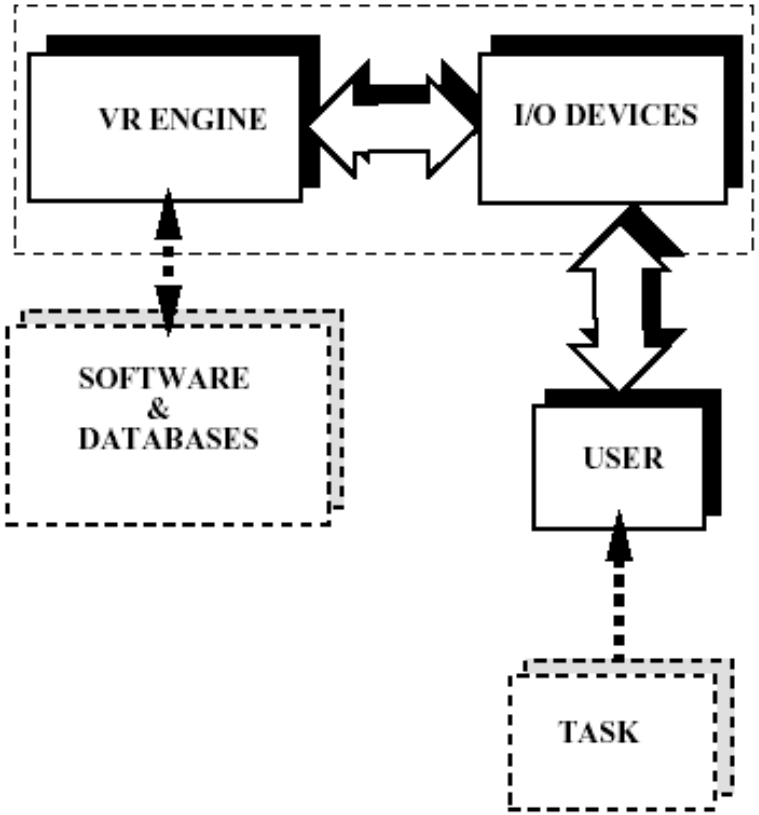
Crucial technologies for VR

- Visual displays that immerse the user in the virtual world and block out from the real world
- Graphics rendering system that generates images (20+ frames/s)
- Tracking system that continually reports user’s position and orientation
- Database construction and maintenance system for building and maintaining models of the virtual world

Important technologies

- Synthesized sound including directional sound and simulated sound fields
- Display of synthesized forces and other haptic sensations
- Interaction devices allowing users to interact with virtual objects
- Interaction techniques that substitute for the real interactions possible with the physical world

VR System



- I/O devices:
  - trackers, interaction devices, ...
  - displays (visual, sound, haptics,…)
- Virtual Reality engine (architecture)
- Software for virtual object modeling:
  - geometry, texture,
  - intelligent behavior
  - physical modeling (inertia, hardness,...)
- Users and their tasks (human factors)

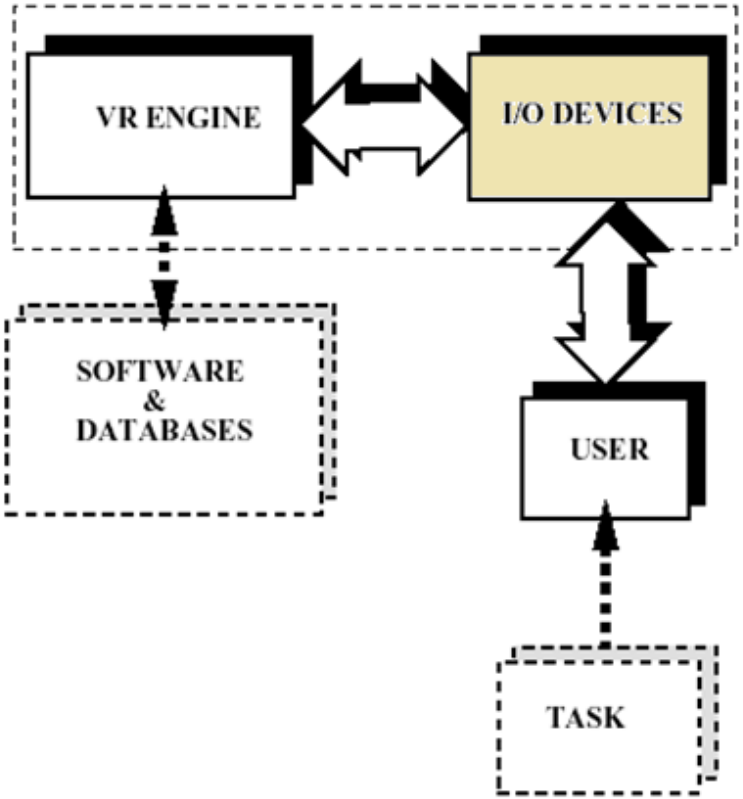
(Burdea et al., 2004)

Input devices

- Trackers:
  - Mechanical
  - Magnetic (AC, DC)
  - Optical
  - Ultrasonic
  - Hybrid inertial

- Navigation and manipulation interfaces:
  - Tracker-based
  - Trackballs
  - 3D probes

- Gesture interfaces:
  - Didjiglove
  - Cyberglove
  - ...



- Navigation and manipulation devices:
  - Tracker-based
  - Trackballs
  - 3D probes, *...

http://www.inition.co.uk/

- Gesture interfaces:
  - Cyberglove *
  - Leap motion, ...

https://www.neurodigital.es/gloveone/

https://www.leapmotion.com/

* May be also output

http://www.cyberglovesystems.com/

And other input devices you know from other contexts:

- Wiimote – remote controller
- Kinect - depth camera

(developed for gaming platforms)

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

http://www.microsoft.com/en-us/kinectforwindows/

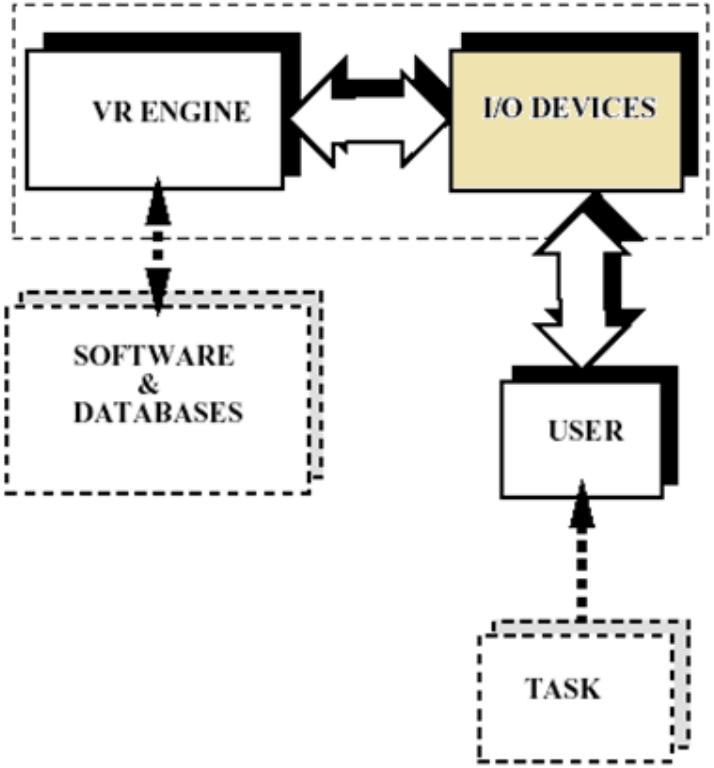
Speech recognition is also an interesting possibility:

- Frees hands
- Allows multimodal input
- Issues: recognition, ambient noise, training, false positives

Input/ output
CyberTouch Glove

http://www.cyberglovesystems.com/cybertouch/

Output devices



- Graphics displays:
  - Personal
    (HMDs, HSD, DSD, ...)
  - Large volume displays
    (monitor-based, projector-based)

- Sound displays:
  - Convolvotron
  - Speaker-based 3D sound

- Haptic feedback:
  - Tactile feedback interfaces
    (mouses, gloves, ...)
  - Force feedback interfaces
    (force-feedback joysticks, haptic arms, ...)

Speech and brain interfaces?

Graphics Displays

https://www.inition.co.uk/extraordinary-technology/head-mounted-displays/

- HMDs
  - single user; very immersive
  - small field-of-view
  - poor ergonomics
    (weight, cables)

Graphics Displays

- Projection systems (CAVE like sysmems)
  - wide, surrounding field of view
  - shared experience to a small group

  - cost of multiple image-generation
  - space requirements
  - reduced contrast and color saturation
  - brightness limitations
  - corner and edge effects

Sound

- In addition to the visual and tactile displays, sound:
  - enhances the presence
  - enhances the display of spatial information
  - can convey simulated properties of elements of the environment (e.g. mass, force of impact...)
  - can be useful in designing systems where users monitor several communication channels (selective attention)

Haptic interfaces

- From Greek *Hapthai* meaning the sense of touch

- Disadvantages:
  - high cost
  - take workspace of desktop
  - large weight
  - safety concerns
  - high bandwidth requirements

Haptic devices

– Tactile feedback interfaces
  (mice, gloves, ...)

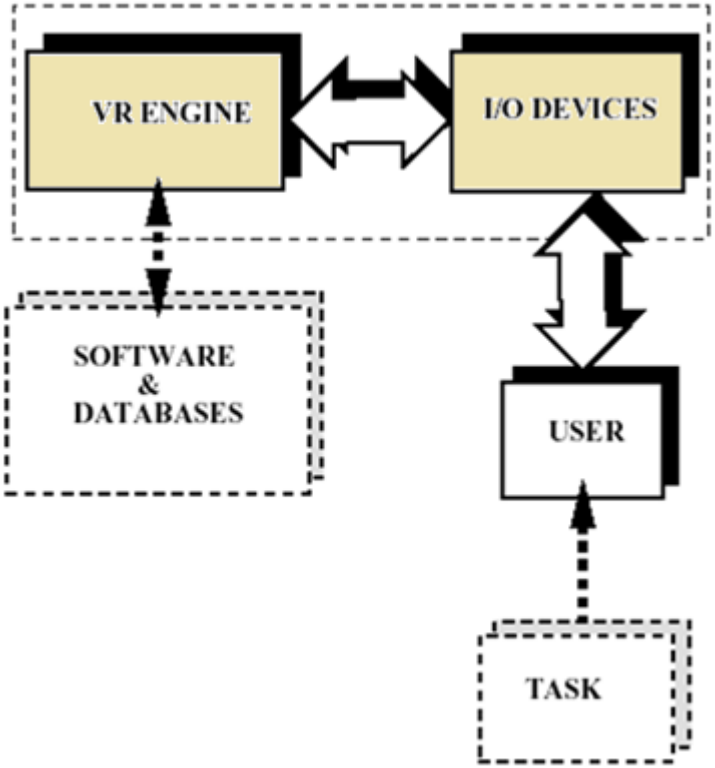
https://steelseries.com/gaming-mice/rival-700

– Force feedback interfaces
  (force-feedback joysticks, phantom-omni, CyberGrasp...)

http://www.sensable.com/haptic-phantom-omni.htm

http://www.cyberglovesystems.com/cybergrasp/

VR Engine



- Creating a Virtual Environment
  - Cost (Time & Money)
  - Specific knowledge
- Several frameworks/tools
  - Specific implementation
  - Particular architecture
- How to ease?
  - Tools for ‘laymen’
  - Flexible yet simple

Which framework is more suitable?

- How to interact/use the tool
- Documentation Availability
- Extensibility
- Which Modules/Interfaces it provides
- Users

Which framework is more suitable?

Several possibilities:

- Graphic Engines (OpenSceneGraph; openSG; VTK …)
- Physics Engines (Bullet; Newton Dynamic; PhysX …)
- 3D computer Graphics Software (Blender; OpenSpace3D; 3D Studio Max …)
- Game engines (Unreal; Unity …)

Virtual Environment Frameworks - not desktop

- inVRs
- VRJuggler
- Vizard
- 3DVIA
- Many others …

Which framework is more suitable?

- Difficult choice, many solutions
- Complex Architecture, many Abstractions
- Often not trivial to Install / Configure
- Game engine emerging as alternative to expensive frameworks

Virtual realities
Schloss Dagstuhl – Leibniz Center for Informatics, 2011

- Challenges:
  - Latency
  - Augmented reality
  - Experience Design (leave certain details to the imagination …)
  - Virtual humans
  - Perception (and simulation sikness)

Augmented *versus* Virtual Reality

- AR is a natural evolution from VR technology
- The major limitation of VR is that it is not easy to fully and accurately model the actual environment
- Does not need to model the entire real world
- AR enhances an existing environment rather than replacing, reduces the high cost of fully immersive VR environments and avoids time-consuming remodeling of complex real objects

Reality Virtuality “Continuum”

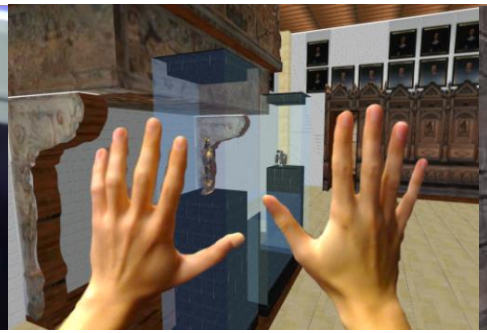
“Augmenting natural feedback to the operator with simulated cues”

(Milgram et al., 1994)

Mixed Reality (MR)

Real Envinoment | Augmented Reality | Augmented Virtuality | Virtual Reality

http://www.youtube.com/watch?feature=endscreen&v=UgQfo7eNFdw&NR=1



(Steinicke et a., 2009)

- Azuma (1997) defines AR as systems that has the following three characteristics:
  - 1) Combines real and virtual
  - 2) Interactive in real time
  - 3) Registered in 3-D

Pertinent issues in AR

- Registry
- Latency
- Calibration
- Human factors

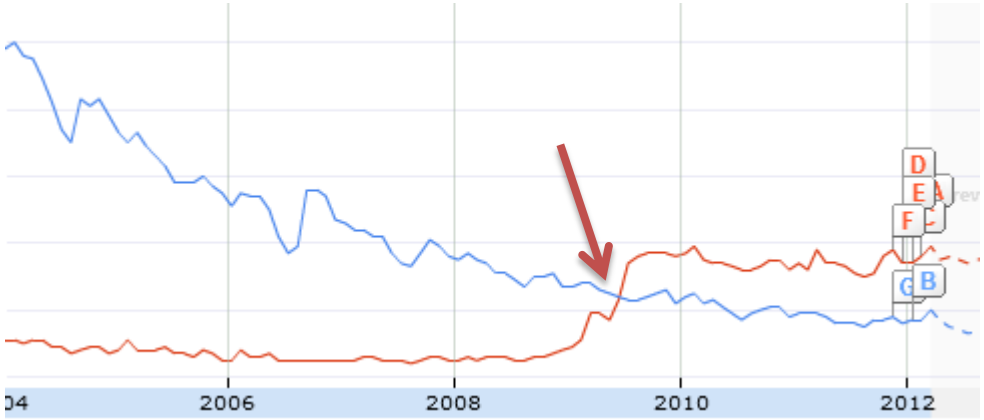
VR/AR popularity

- Google searches for:
  - Virtual Reality
  - Augmented reality

since 2004

- AR became more "popular" around June 2009 (Google insight)

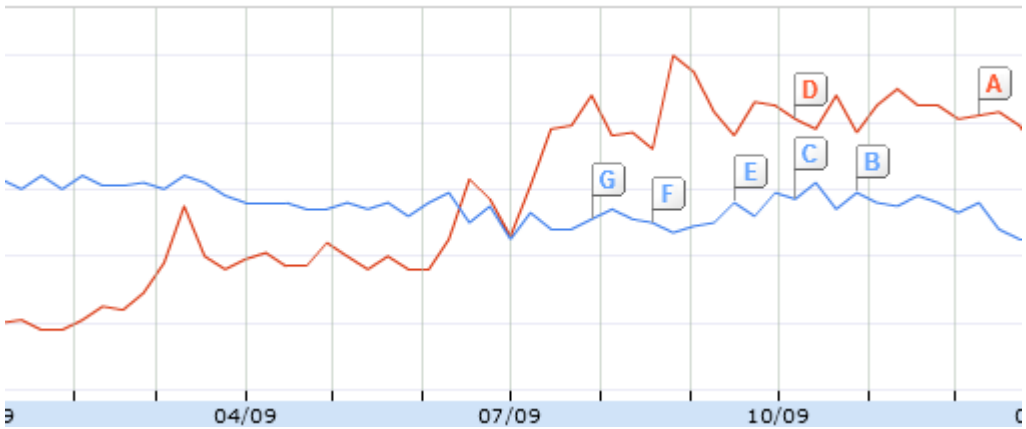
- VR had peak in April 2014 (Oculus Rift and Facebook)



virtual reality
augmented reality

A Google's Augmented-Reality Glasses Confuse and Frighten Inhabitants of Regular Reality
B The case for virtual reality on grandma's stationary bike
C Aurasma debuts 3D augmented reality at CES
D Layar rolls out consumer app for augmented reality
E Waitrose uses augmented reality app for Christmas Magic
F Total Immersion, the Global Leader in Augmented Reality, Optimizes D'Fusion(R) Software to Maximize TI's OMAP(TM) Platform for Faster, Unparalleled AR Experiences at Ultra-Low Power
G Virtual Reality Meets Reality for New Homebuyers

- Looking closer: 2009
- The news near the cross point

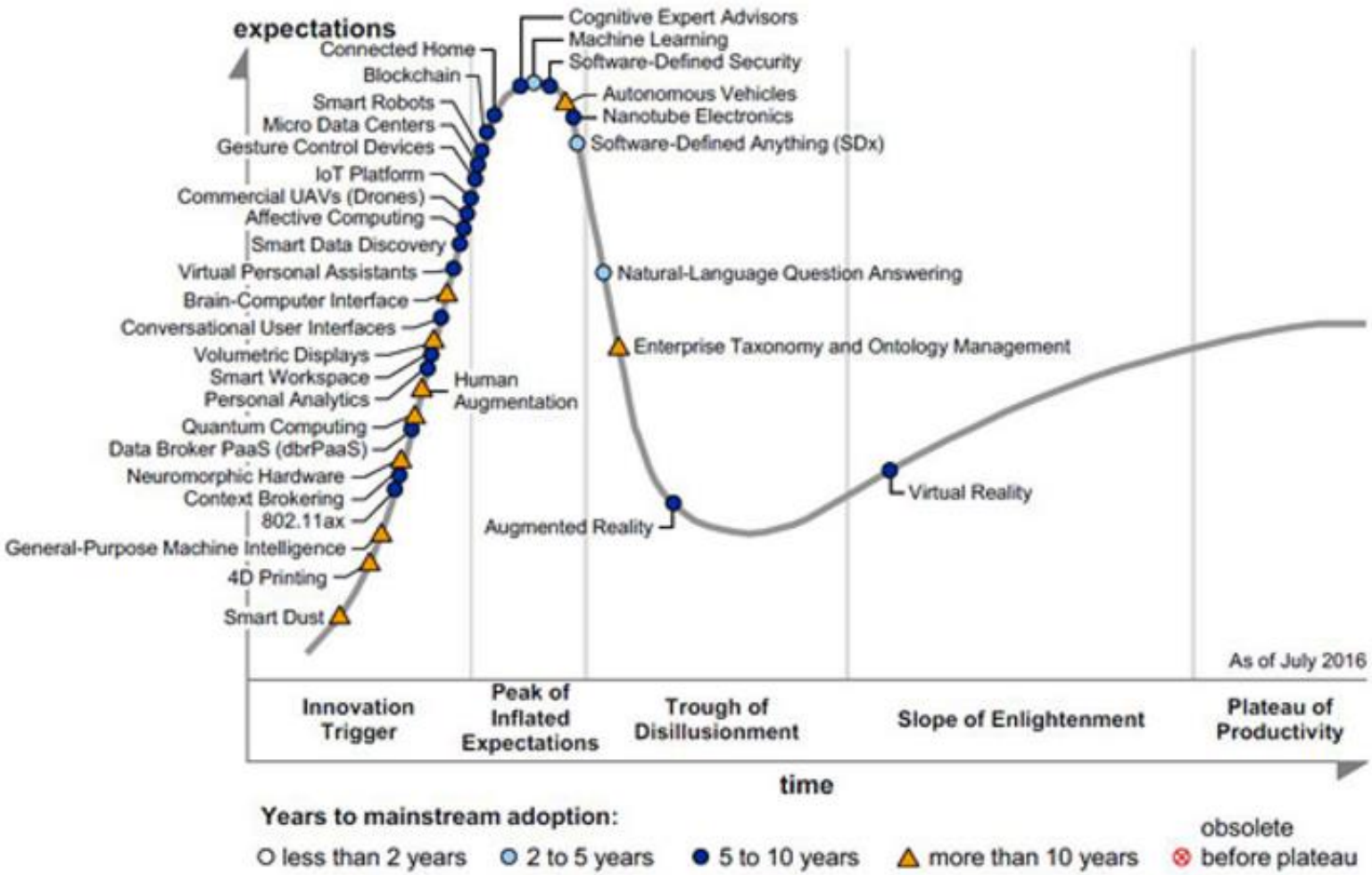


A Augmented Reality Start-Up Tonchidot Moves Beyond Buzz
B Butting out in virtual reality may have real-life results
C Ars Electronica Center Chooses Dassault Systemes 3DVIA to Develop State-of-the-Art Virtual Reality Applications
D Another use for your phone: 'augmented reality'
E Scientists find virtual reality helps relieve pain
F Halifax surgeon removes brain tumour using virtual reality simulator
G Stanford's virtual reality experiments transport knowledge to new vistas

The Gartner Hype cycle

- 1. A new technology creates expectations; it is investigated and its potential explained
- 2. Expectations peak; the technology becomes overestimated
- 3. Failures and high cost lead to disappointment
- 4. Technology is consolidated and expectations rise again
- 5. Mainstream productivity is attained

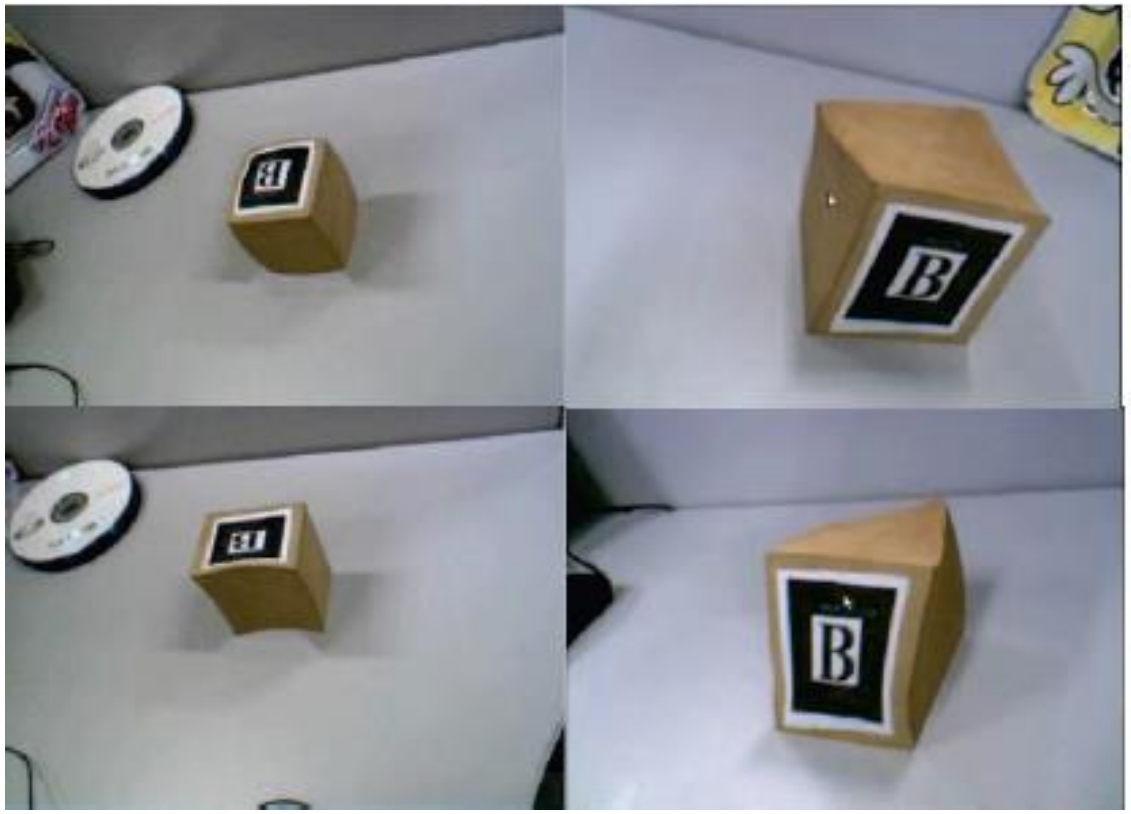
Hype Cycle for Emerging Technologies, 2016



http://www.gartner.com/newsroom/id/3412017

Other Realities: Altered Reality (Augmented + Diminished)

- Leao, C.W.M. Lima, J.P. Teichrieb, V., Albuquerque, E.S., Kelner, J. , "Demo — Altered reality: Augmenting and diminishing reality in real time," *IEEE Virtual Reality Conference, 2011,* pp.259-260



Applications: Commerce: Ray Ban Virtual Mirror

http://www.youtube.com/watch?v=Ag7H4YScqZs

Now it is a App

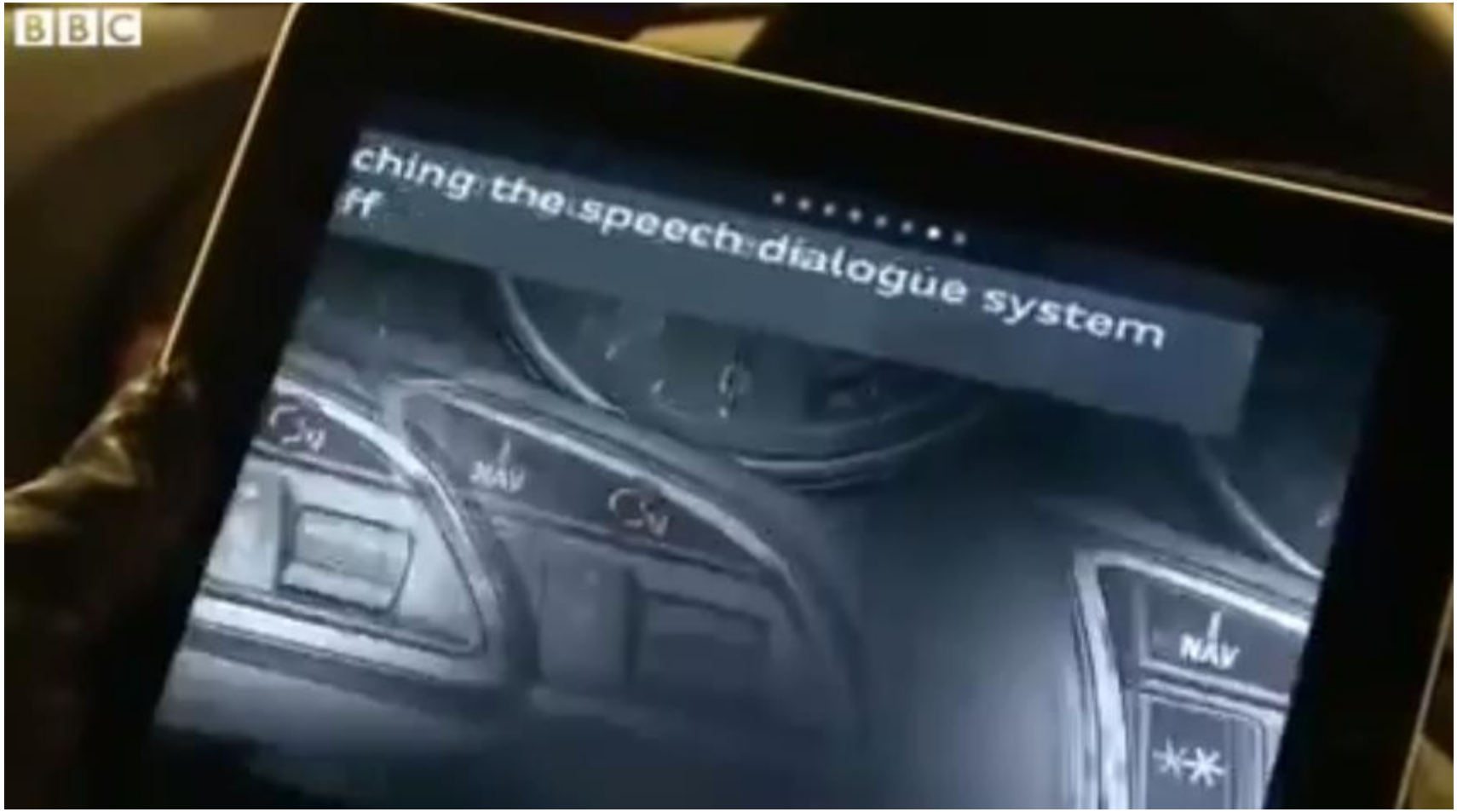
http://www.ray-ban.com/usa/virtual-try-on

Maintenance/ repairing

BMW's working to create augmented reality maintenance tutorials for service technicians seen through a pair of AR goggles - with narration (2009)

http://www.youtube.com/watch?v=Y5ywMb6SeGc

Audi uses AR : Google Glass Metaio Project - Augmented reality turns drivers into a car mechanic



https://www.youtube.com/watch?v=nx-dqZ21NlU

Marketing

Prettify yourself in Panasonic's AR mirror

http://www.wired.co.uk/news/archive/2014-09/05/panasonic-augmented-reality-mirror

HMD for Augmented Reality

- Google Glass
- Meta
- HoloLens
- …

https://www.metavision.com/

https://www.vuzix.com/Products/m100-smart-glasses

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

wikitude
See more.

OPTIMIZED FOR GOOGLE GLASS

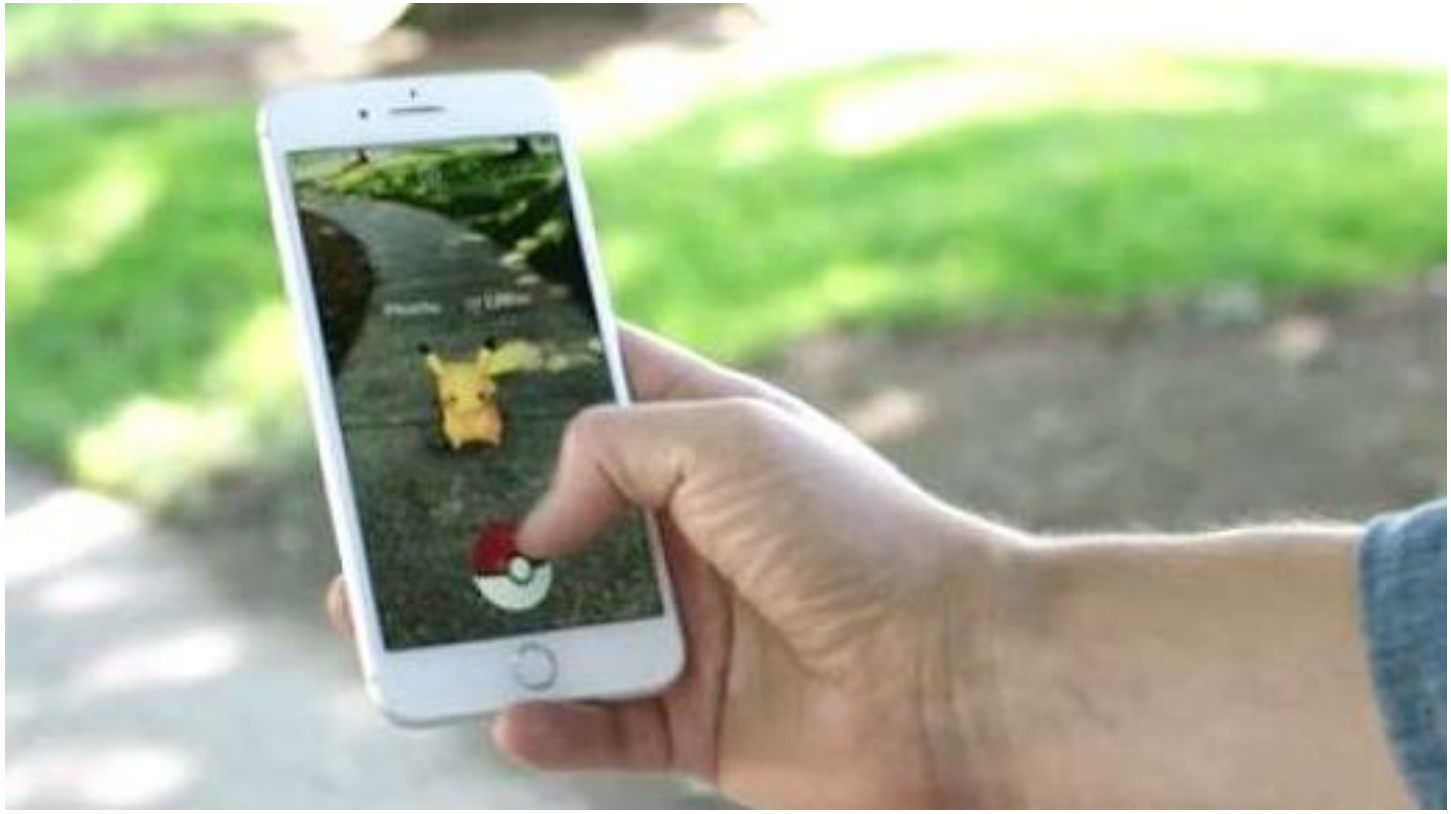
The Wikitude SDK is fully optimized to take advantage of the unique user-interface of Google Glass.

http://www.wikitude.com/products/eyewear/google-glass-augmented-reality-sdk/

Hololens will be used to help repairing Thyssenkrupp elevators

http://www.digitaltrends.com/virtual-reality/thyssen-krupp-hololens-partnership/

Mobile Augmented Reality



More and more popular

What future for AR?

- A successful AR application should ideally:
  - be accurate, small, light, fast and cheap
  - have efficient and suitable UIs allowing users easily operate the virtual and real objects in the 3D environments, such as using their hands to freely interact with the things in their daily life
- Fast and stable Internet-based collaborative AR systems will be ideal for some scenarios (e.g. manufacturing, maintenance)

To keep up with the latest developments: Conferences

- IEEE Virtual Reality (VR) (since 1993)
- ACM Symposium on Virtual Reality Software and Technology (VRST) (since 1994)
- Eurographics Workshop on Virtual Environments (since 1995)
- IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (since 2002)
- IEEE World Haptics Conference (WHC) (since 2005)
- IEEE 3D User Interfaces (3DUI) (since 2006)
- IS&T/SPIE Electronic Imaging
- SIGGRAPH Emerging Technologies
- …
- http://vgtc.org/wpmu/conferences/
- http://www.vrst.org
- http://spie.org/x16218.xml
- http://www.wikicfp.com/cfp/call?conference=virtual%20reality

(Fred Brooks, 1999)

"VR barely worked in 1999"

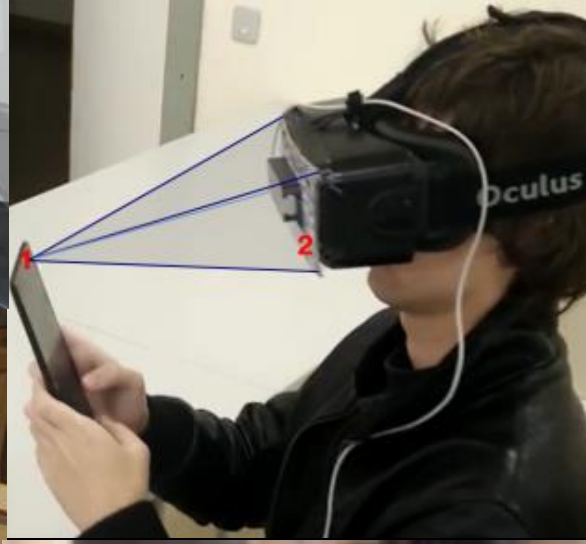
and now?

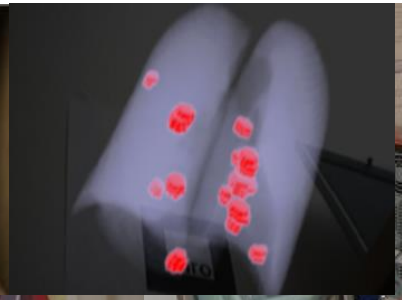
Don't forget AR!

In my opinion:

- There is a continuum of realities
- It is **more consolidated and much more affordable**
- It has passed the "hype and disappointment phases"
- There is a range of VR settings with very different costs
- **It works and is useful in specific applications**
- It is still not easy to integrate a complete solution (**improving**…)
- It still has **human factors challenges**

Interaction in Virtual and Augmented Reality





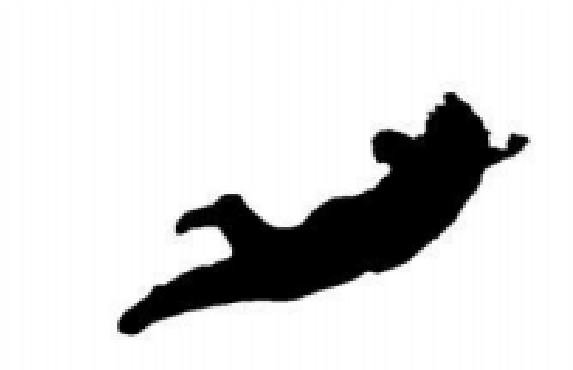
Visualization and Interaction group @DETI/IEETA:

- Interaction and Usability in VR/AR

- Low cost VR/AR platforms:
  - PC based, mobile
  - HMD, desktop, large display
  - 3D sound, auralization
  - Kinect, Leap motion, Wiimote...
  - VRML, OGRE, VTK, VRJuggler, Unity …
  - “Home made” input devices

- Applications/demos:
  - Physical Rehabilitation
  - Museum installations
  - Psychophysics studies
  - Data Visualization
  - Augmented books

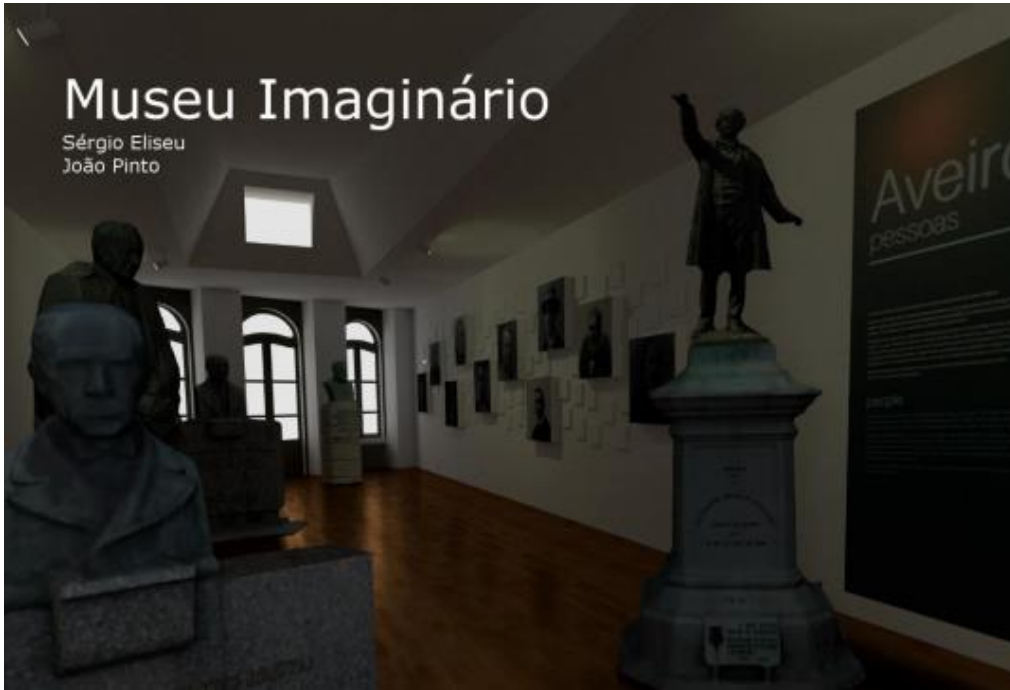
“The world as a C.A.V.E.”
Sérgio Eliseu, PhD dissertation, 2016
Faculdade de Belas Artes, Universidade do Porto



“Virtual Reality Environment for immersive walkthroughs and interaction”
João Pinto, MSc dissertation, 2015
Universidade de Aveiro

“… increasingly configuring a new artistic production paradigm where the distinction between virtual and real diluted.”

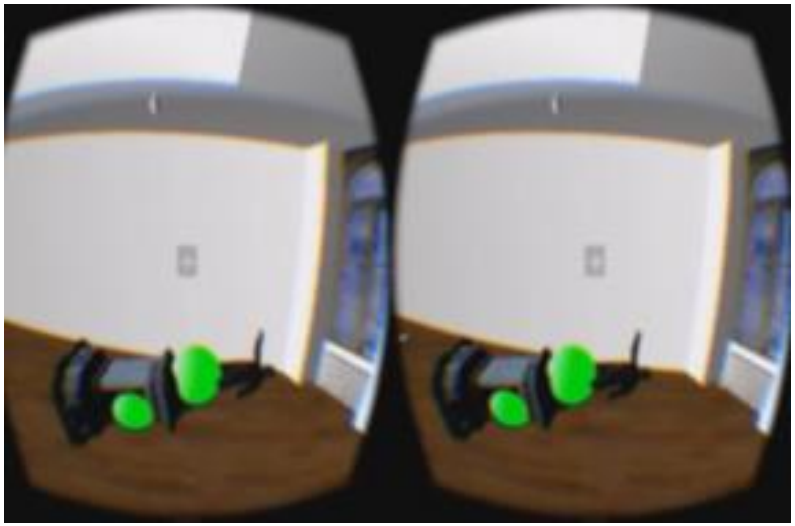
Imaginary Museum:
A museum where the visitor may navigate by physically walking and set up their own exhibit manipulating objects with space hand gestures



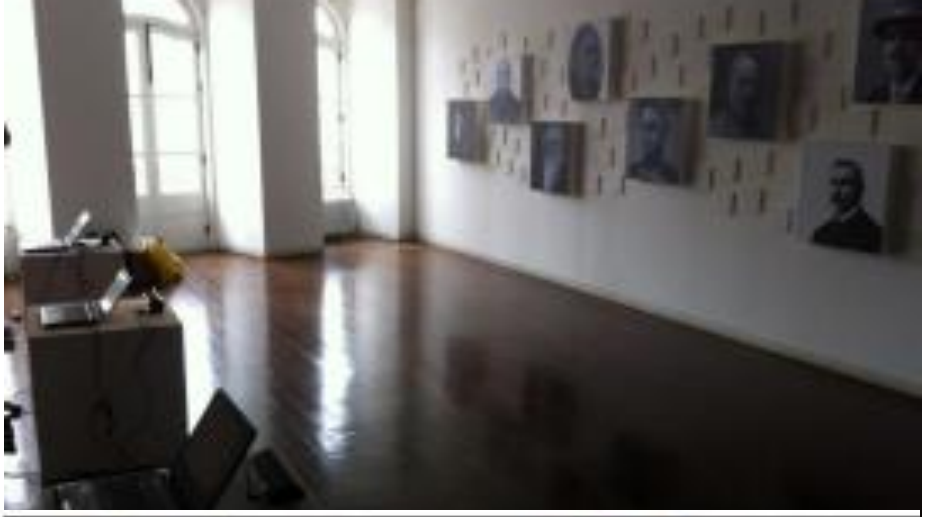
“Gesture interactions for Virtual Immersive Environments: navigation, selection and manipulation”

P. Dias, J. Pinto, S. Eliseu, B. Sousa Santos,
HCII, Toronto, July 2016

- A framework allowing the creation of an interactive virtual world in a specific room
- Gestures are used to manipulate the objects in the room (as in the Imaginary Museum)



Real Museum Room



Virtual Museum Room

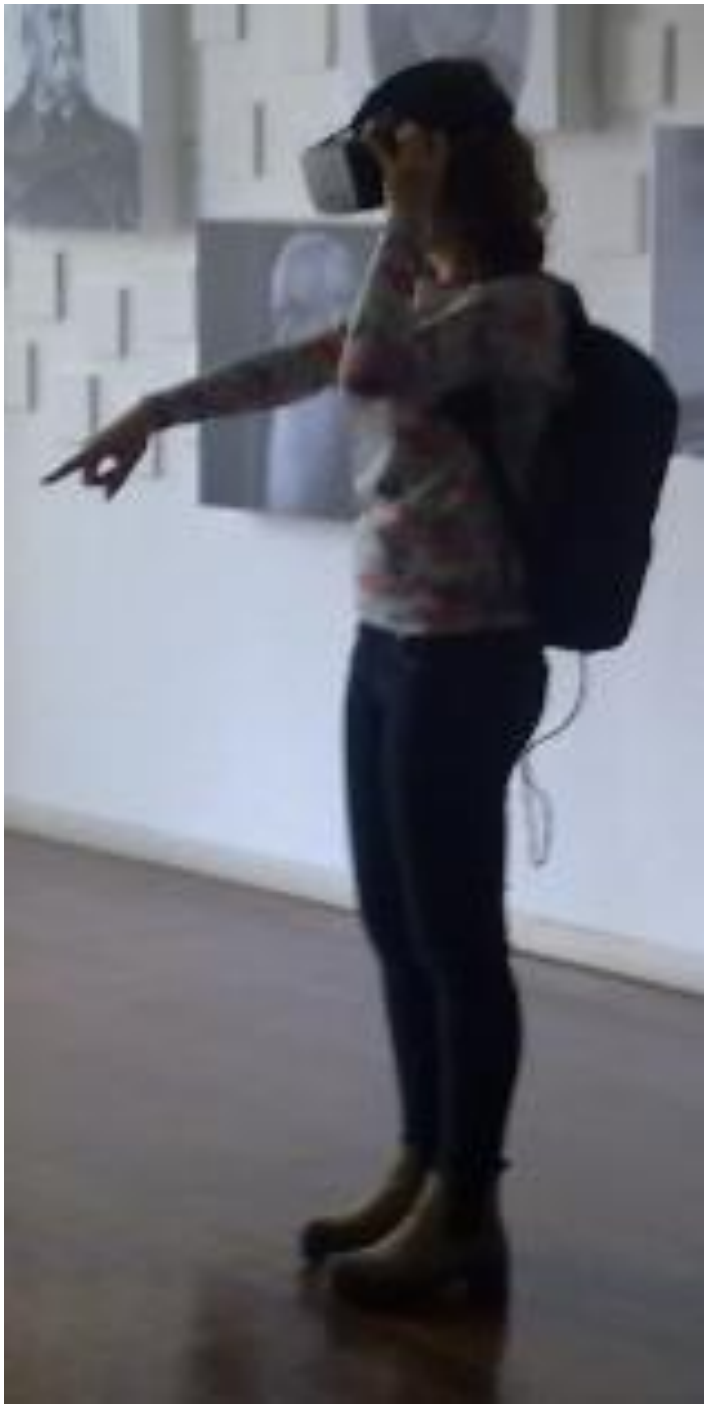
Visitor setting an exhibit

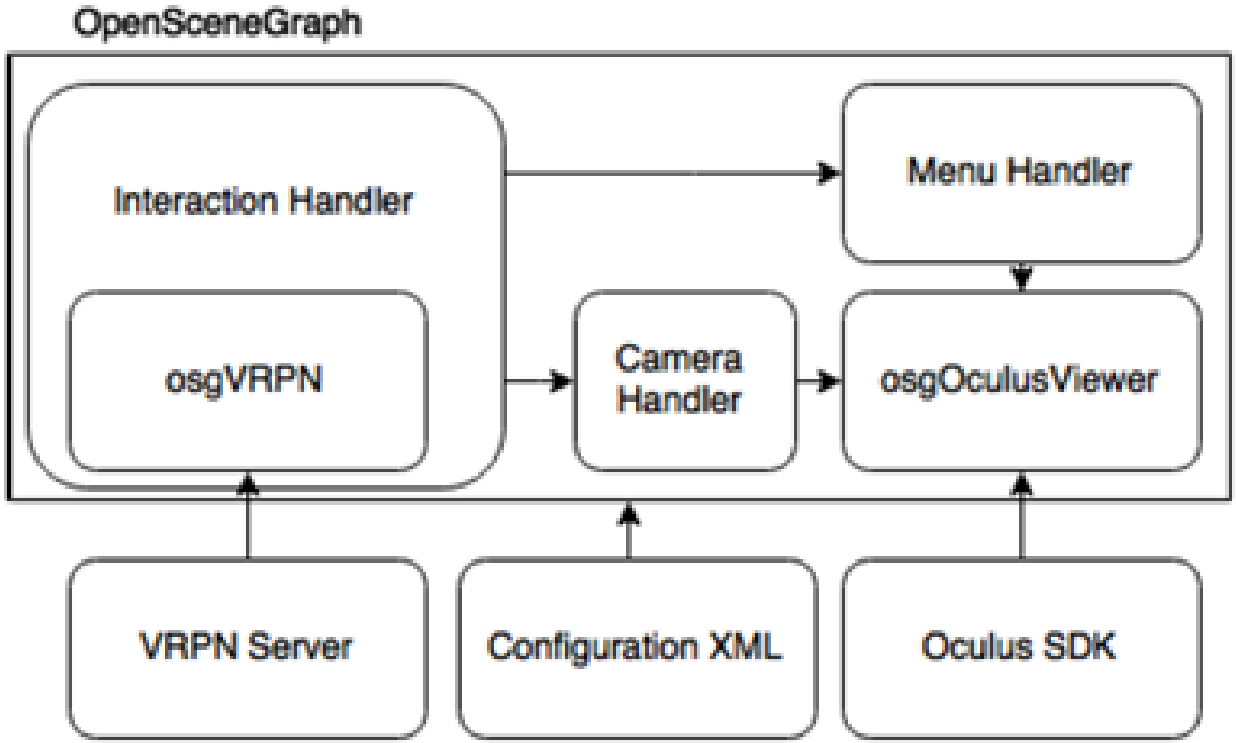
Set-up

- The Museum room was modeled

- And had depth cameras to tack the user
(one to one navigational input and hand gestures)

- The user had a HMD and a backpack with a laptop





Framework architecture

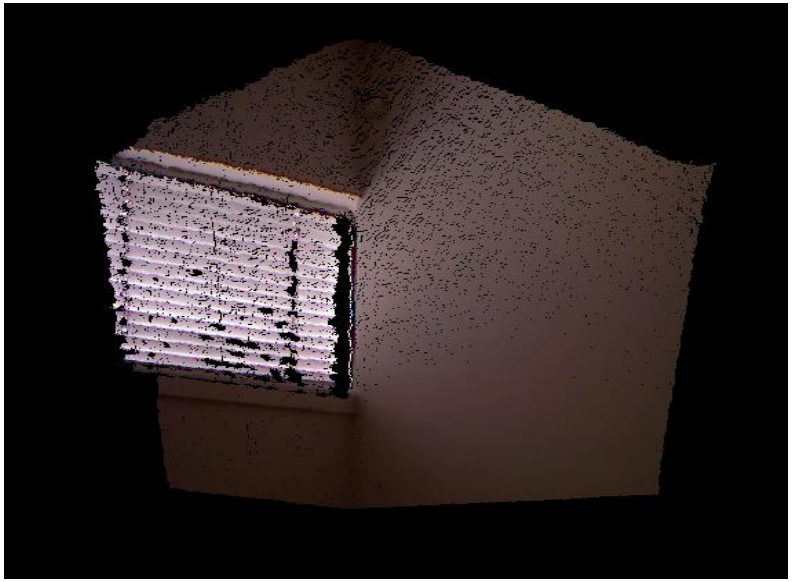
Adjusting to a specific room

- One to one navigation implies calibrate the Depth camera position regarding real world
- a calibration tool was developed:

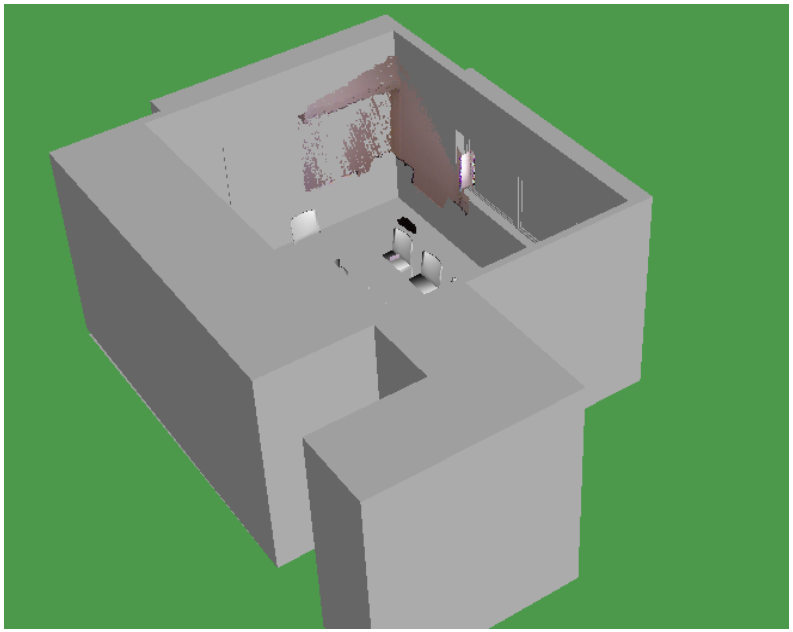
  VTK - Visualization Toolkit

  ICP - Iterative Closest Point

- the transformation matrix is exported into a file ready to be used as input to the custom VRPN server for a given room with given camera positions

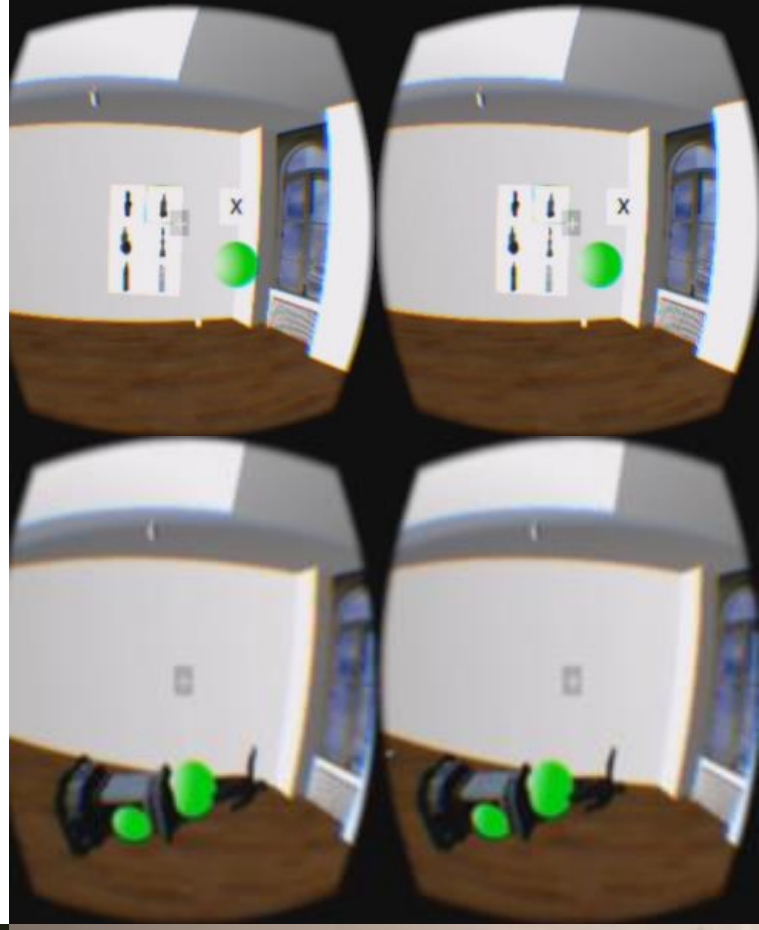


Point cloud and final alignment with 3D model after ICP



Gesture interactions

- select an object model from a menu
- manipulate the objects
- set them up in the exhibit



Interaction methods

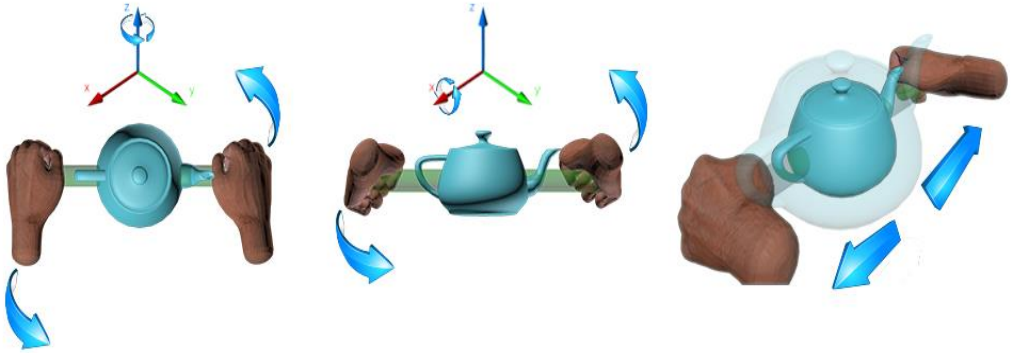
- Navigation: one to one navigation - the user just walks

- Menu selection – grip gesture

- To position, rotate and scale the objects:

Modified handle-bar metaphor

scale - distance between the user's hands
rotation - angle
position - midpoint between the user's hands in the world



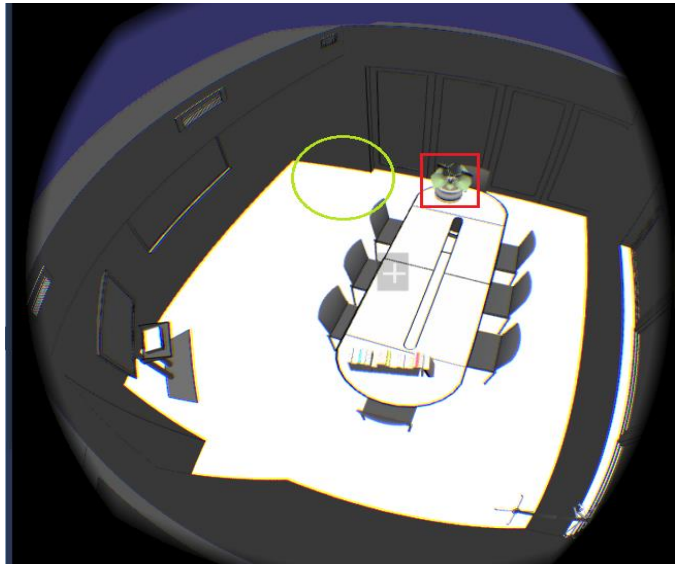
User Studies

To compare:

hand space gestures

button commands (wiimote)

- A preliminary study with 12 volunteers
- A controlled experiment with 28 participants
- input variables: navigation methods
  selection methods
  manipulation methods
- Output variables: times , errors, satisfaction
- Experimental design : within groups



Meeting room: model and real

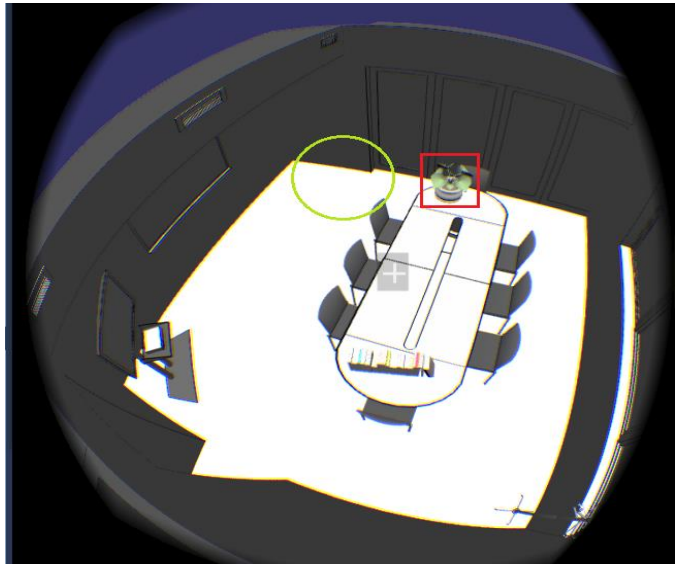
Main results

- Most users preferred:
  gesture-based navigation
  and
  gesture-based interaction

despite some learning difficulties and tracking problems

Manipulation - the gesture-based method was significantly faster to use with similar accuracy

Rotations,- the controller-based method was faster



Meeting room: model and real

“Interaction in Virtual Reality using Mobile Devices.”
Luís Afonso, MSc dissertation, 2016
Universidade de Aveiro

Is the interaction using mobile devices
viable in Immersive Virtual Environments?

Mobile Virtual Museum:

Two viewing modes:

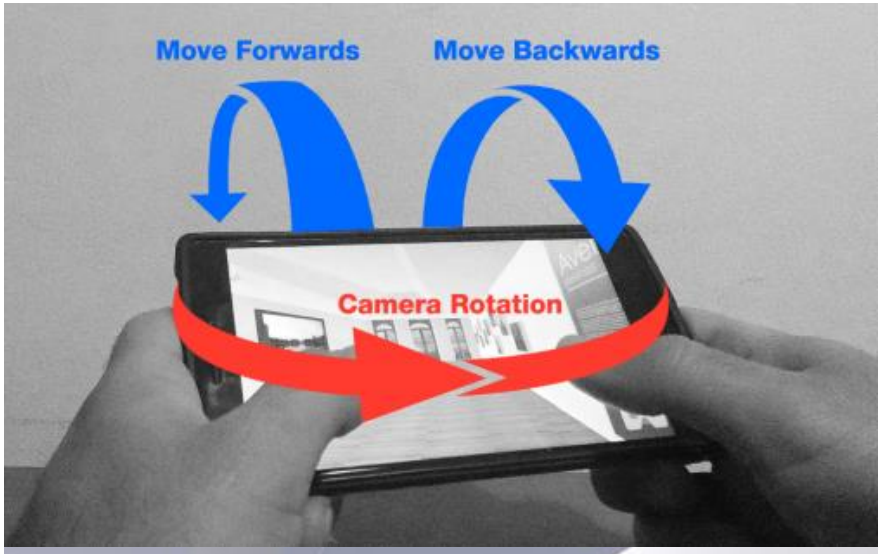
Regular – user holds the phone

HMD – user wears Cardboad

Using on board sensors

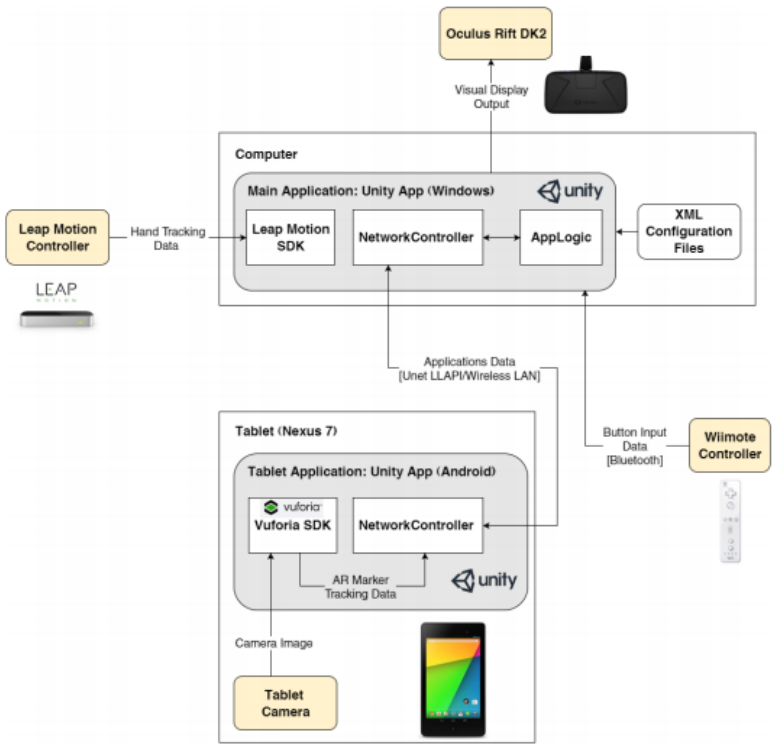
Interaction methods

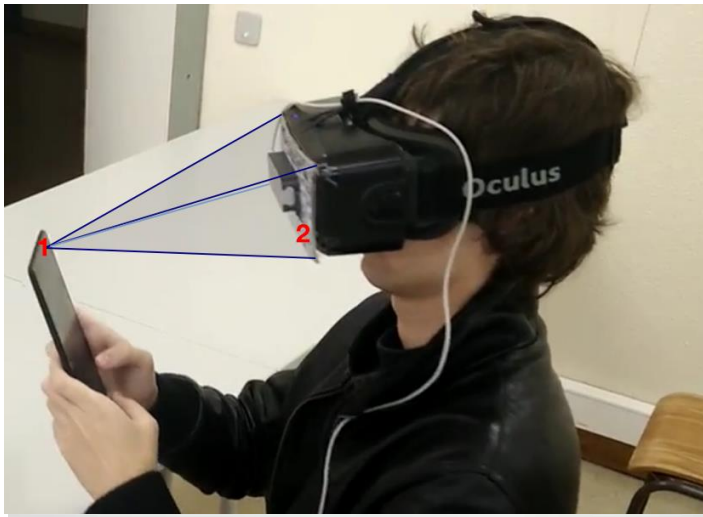
- Navigation – tilting the phone
- Menu selection - touching the screen
- Manipulation – tilting the phone



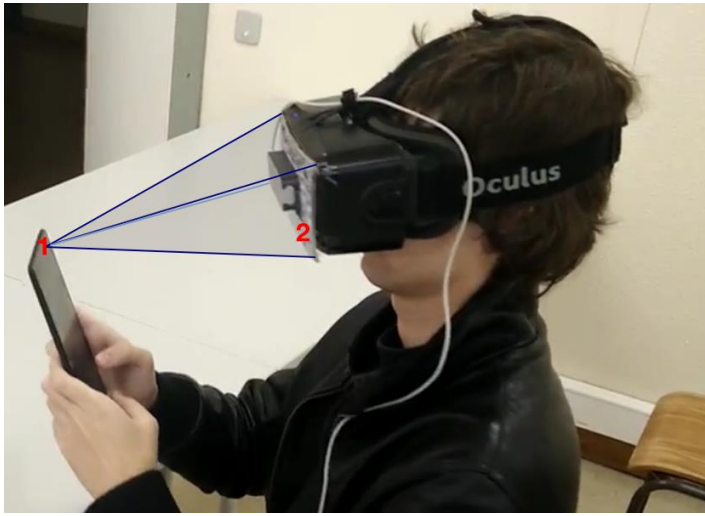
Immersive Virtual Reality System with Tablet-Based Interaction

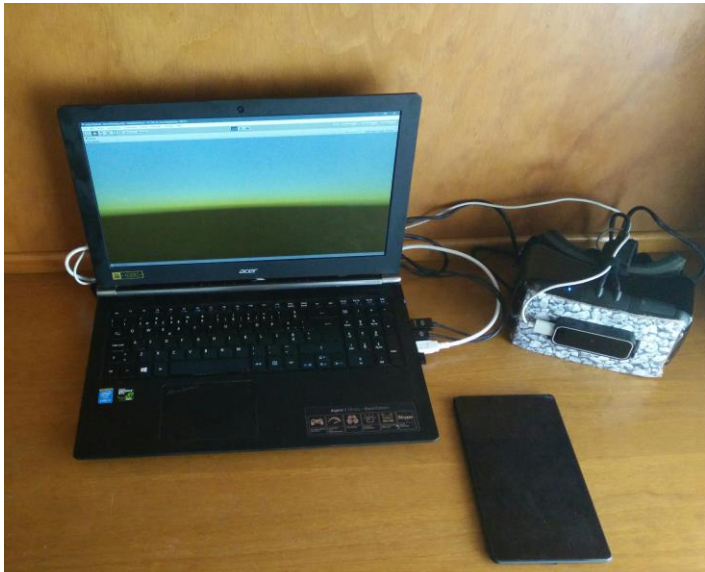
- Immersive virtual reality system easily configured
- Using tablet for interaction with the virtual content





- Laptop running the main application (in Unity)
- HMD (Oculus Rift DK2) providing head tracking
- Tablet (Google Nexus 7) as input device running the controller application (in Unity)
- Leap Motion (mounted on the HMD) to track the user's hands
- Tablet camera (1) tracking the position and orientation of an AR marker (2) on the HMD to map tablet position in the virtual world (using Vuforia)





“Effect of Hand-Avatar in a Selection Task using a Tablet as Input Device in an Immersive Virtual Environment”

L. Afonso, P. Dias, C. Ferreira, B. Sousa Santos
IEEE 3D UI, Los Angeles, March 2017

- Research question: How does the virtual representation of the user's hands influence the performance on a button selection task performed in a tablet-based interaction within an immersive virtual environment?

- Method: Controlled experiment

- 55 participants used three conditions:
- no-hand avatar,
- realistic avatar,
- translucent avatar.

- Participants were faster but made slightly more errors with no-avatar

- Considered easier to perform the task with the translucent avatar

Experimental Design

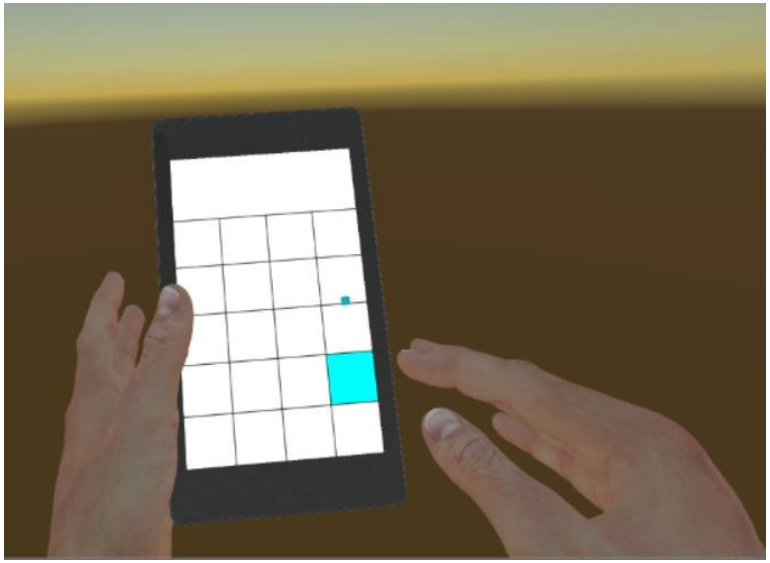
Null Hypothesis: usability is independent of the hands representation

Independent variable (with 3 levels): representation of the hands

Dependent variable: usability (performance + satisfaction)

Within-groups: all participants used all experimental conditions in different sequences (to avoid bias)

Task: selecting as fast as possible a highlighted button from a group of twenty buttons (repeated measures)

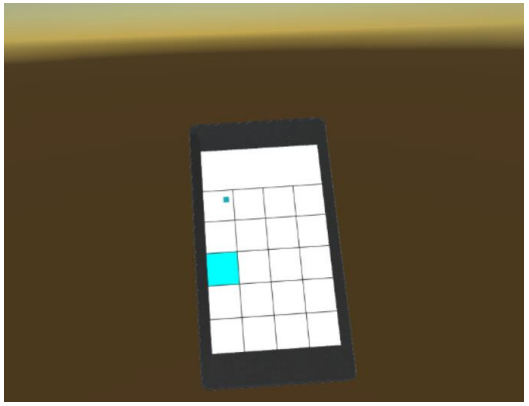


Experimental Conditions

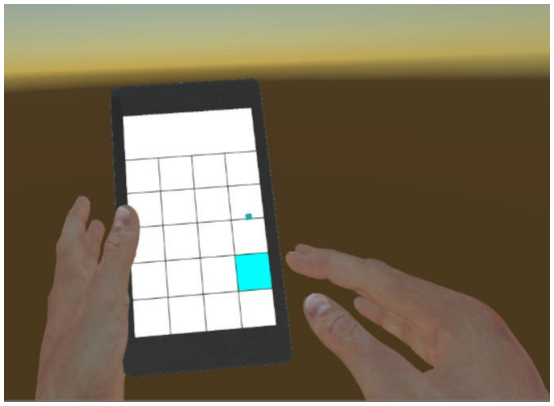
1- No avatar: the user only sees the virtual tablet

2- Realistic avatar: a realistic representation of the hands movement is shown

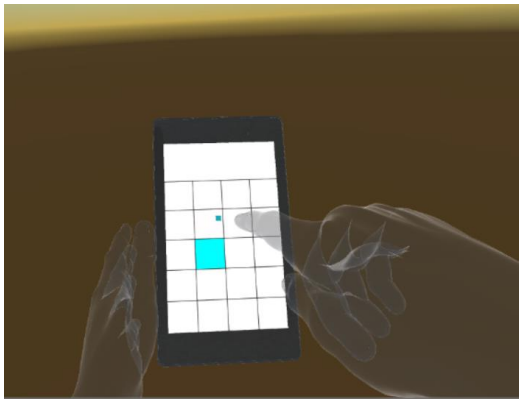
3- Translucent avatar: a translucent hand model is used (to alleviate occlusion)



No-avatar



Realistic avatar



Translucent-avatar

Results

Selection time:

Participants completed the button selections in average faster with no-avatar

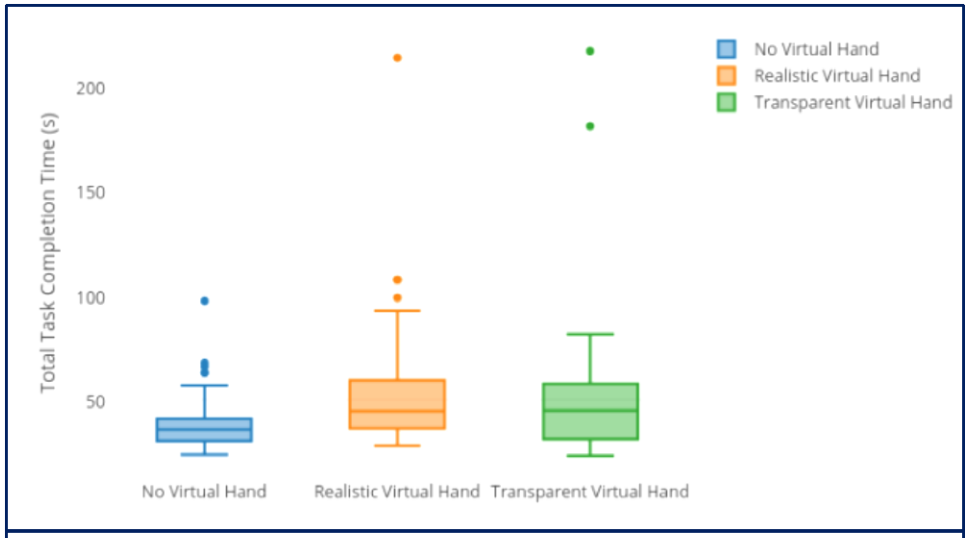
Selection errors:

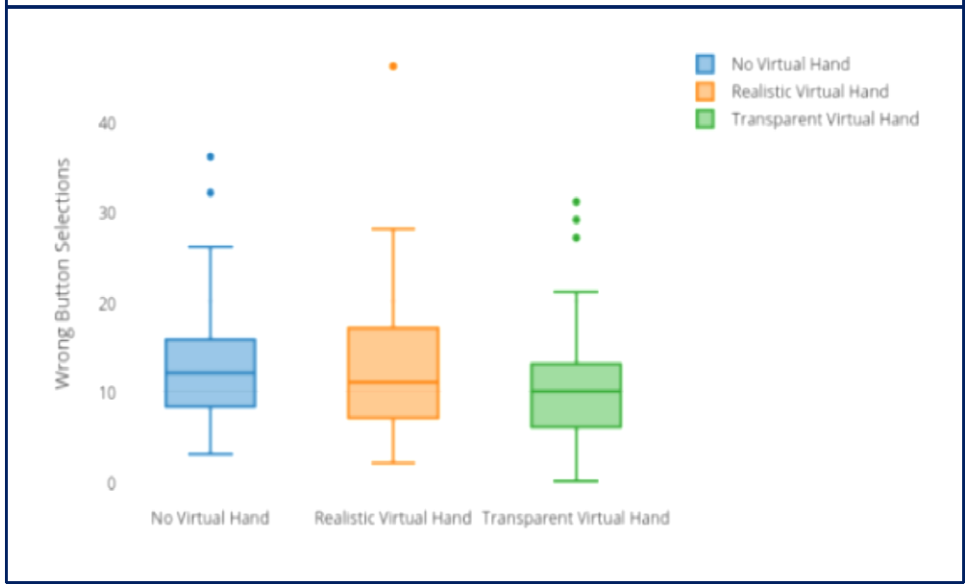
Participants made slightly less errors with avatar (realistic or translucent)

Participants' opinion:

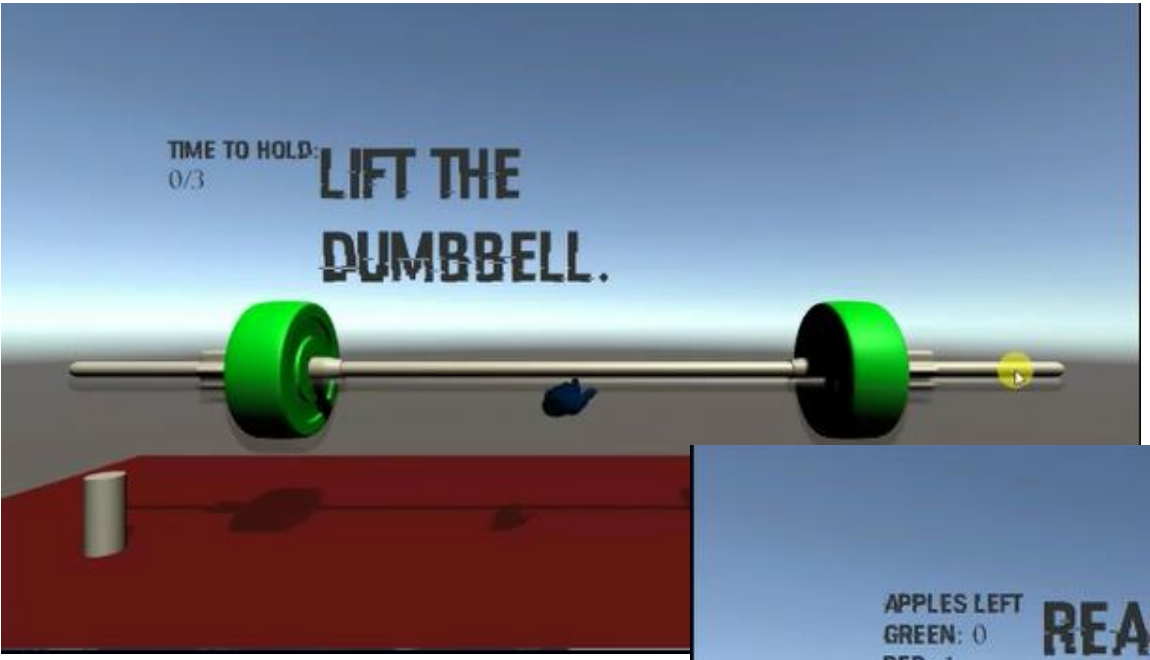
The translucent avatar:

- was more often preferred
- was considered as better than the realistic avatar (statistically significant)





Work in progress: Serious Games for the physical rehabilitation of the upper limb of Stroke patients
In cooperation with Centro Rovisco Pais



VR mini-games:

- Motivate patients to repeat gestures
- Patient customization
- And monitoring
- Two set ups:
  - Desktop + Leap motion
  - HMD + Leap motion

Under evaluation by patients and staff

Thanks to all the People involved:

- Paulo Dias, Carlos Ferreira, Sérgio Eliseu, Guilherme Campos, Joaquim Madeira, Samuel Silva

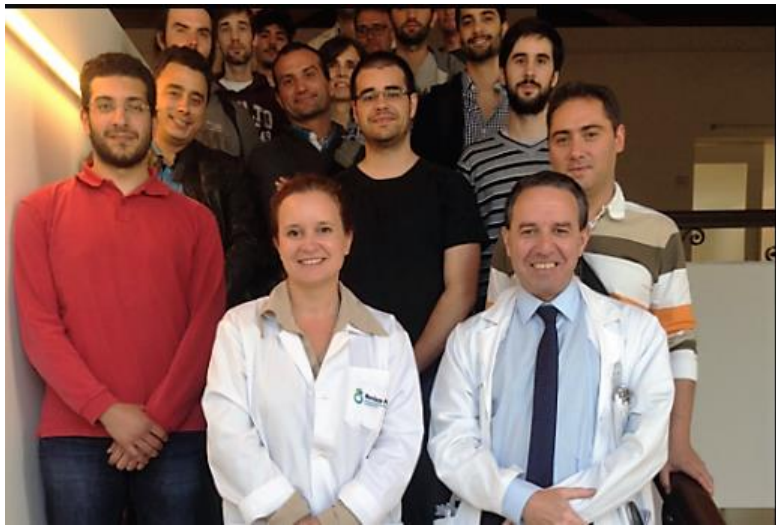
- Students:

Mário Cruz, Paulo Moreira, Ângela Pimentel, Gustavo Corrente, Ana Cantanhede, Jan-Willem Baggerman, Pauline van der Horst, Frank van Huussen, Ricardo Casaleiro, Ricardo Seco, Paulo Nascimento, Mauro Ribeiro, Nuno Veloso, João Parracho, João Cardoso, João Pinto, Danilo Souza, Luís Afonso, Ricardo Silva ...

- Doctors:

Paula Amorim, João Lains …

- And many participants in demos, tests and user studies...



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