DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE
MIUR
Immersive experiences through augmented, virtual and mixed reality: uses, challenges and opportunities
Enzo Pasquale Scilingo
CROSSLAB
Innovation for industry 4.0

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Overhead view of the downtown

IN SUPREMÆ DIGNITATIS 1343

Centro E. Piaggio
bioengineering and robotics research center

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

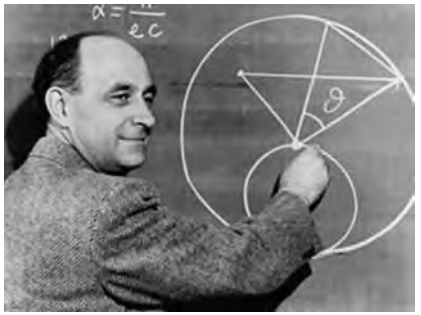
University of Pisa

- 20 departments – 17 libraries – 13 museums
- 60 Bachelor Degrees
- 66 Master Degrees
- 5 Long Cycle Degree Programmes
- 21 PhD programmes
- 68 Third cycle specialisation/Residency programmes
- 55 Special shorter programs (including an MBA)
- 28 Summer Schools

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

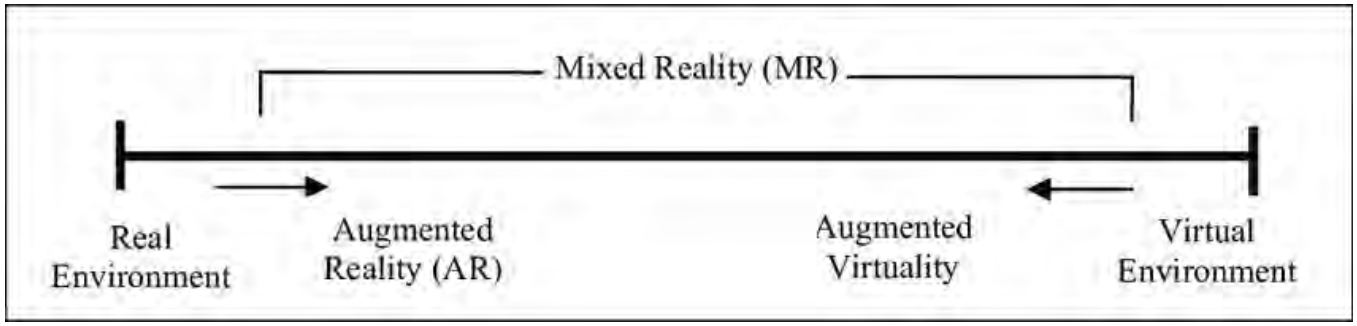
Excellence in research

- Past glories
  - ✓ Galileo Galilei,
  - ✓ Antonio Pacinotti (Physicist),
  - ✓ Ulisse Dini (Mathematician and Politician)
- Nobel prizes
  - ✓ Giosuè Carducci (Literature)
  - ✓ Enrico Fermi (Physics)
  - ✓ Carlo Rubbia (Physics)
- Fields Medal
  - ✓ Enrico Bombieri
  - ✓ Alessio Figaldi (2018)



- An Excellence Center in the University of Pisa for Research and Higher Education in the field of Information and Communication Technology (ICT)

Milgram's Reality-Virtuality Continuum (1994)



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

What is Virtual Reality?

The Virtual Reality is a technology that use software to generate realistic images, sound and other sensations that replicate real world environment.

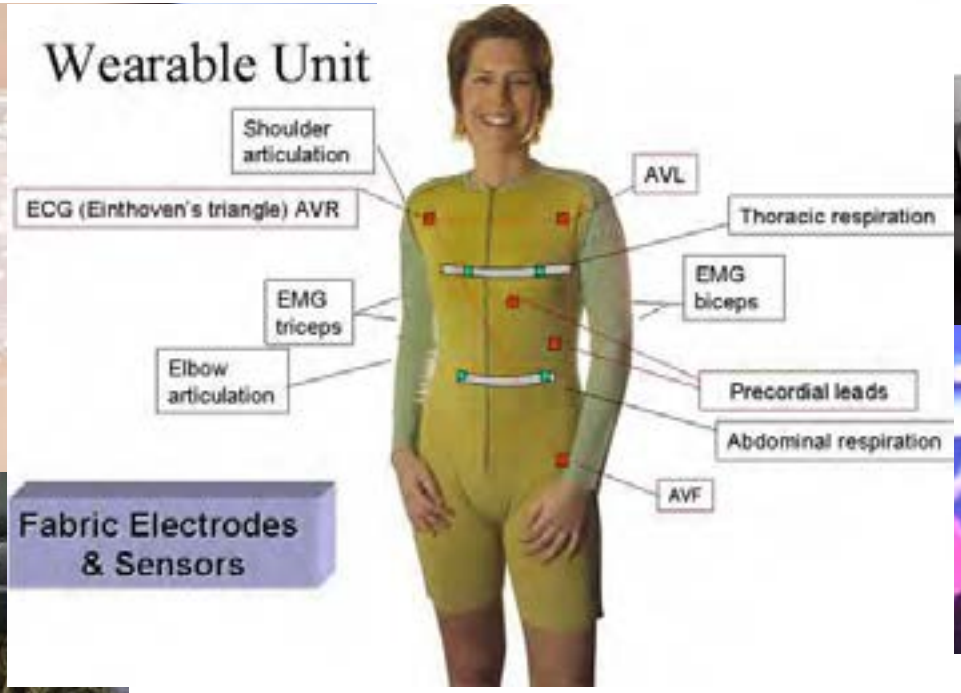
A user can interact and manipulate with the virtual objects of virtual world with the help of specialized devices like display screens or other devices.

What is AR?

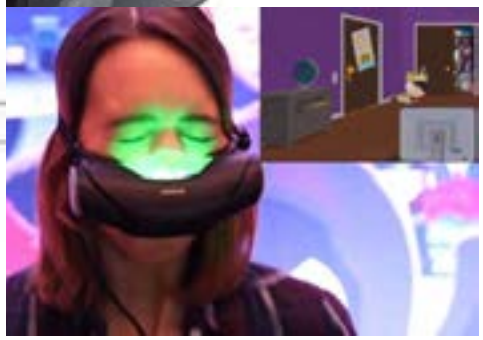
Augmented reality definition

Augmented Reality (**AR**) is an interactive experience with a real-world environment whereby the objects in the real-world are "augmented" by computer-generated perceptual information, sometimes across multiple sensory modalities, including

Visual a



Olfactory



Augmented reality

Augmented Reality is a field of computer research which deals with the combination of real-world and computer-generated data.

An augmented reality system can be defined as one that:

- Combines real and virtual world aspects
- Is interactive in real-time
- Is registered in three dimensions

Common example of augmented reality

What is Mixed Reality?

It is the merging of Real and Virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time.

AUGMENTED REALITY VS. VIRTUAL REALITY

- Augmented Reality (AR)

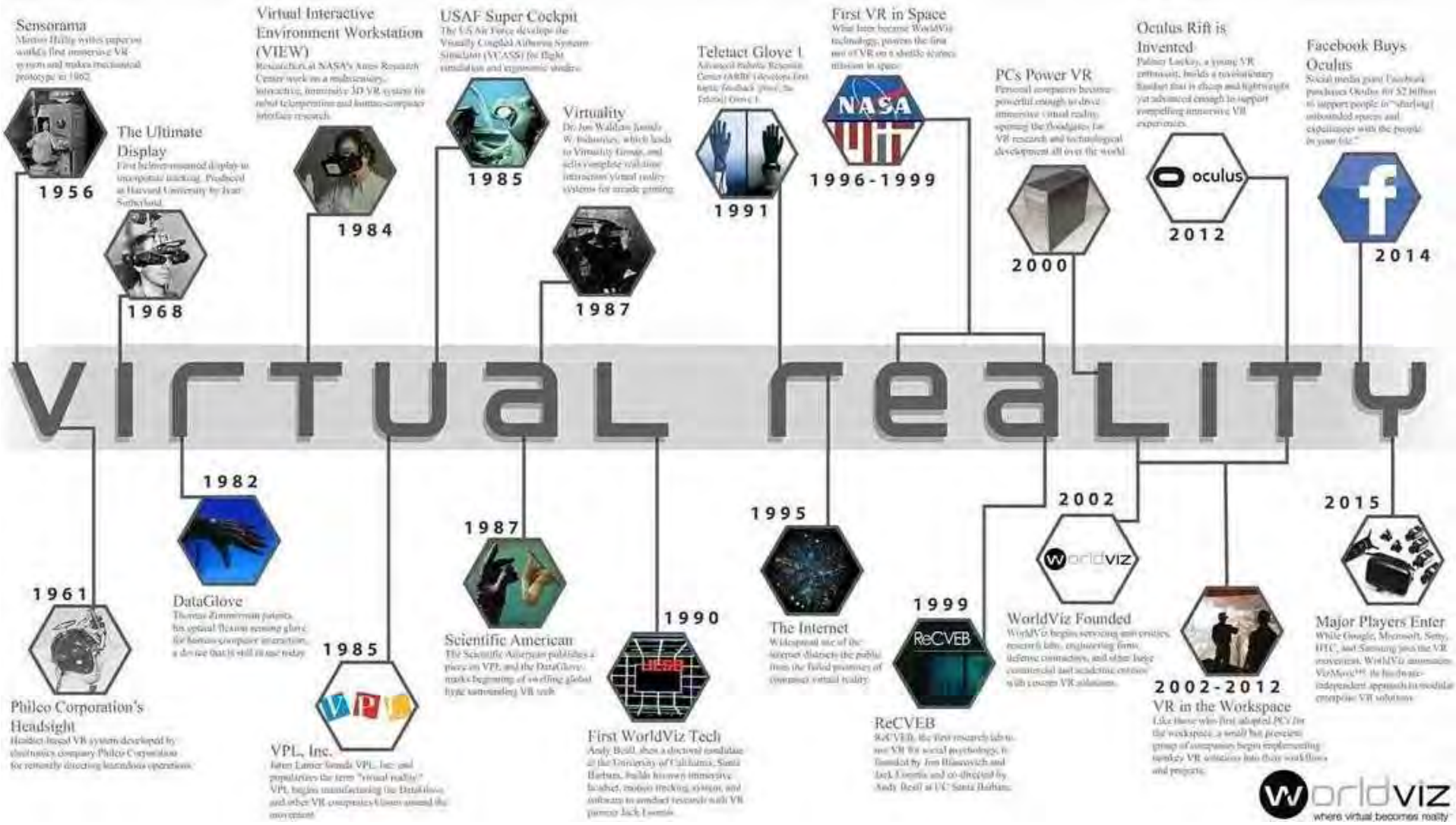
  Supplements the real world with the virtual(computer generated) objects that appear to coexist in the same space as the real world.

- Virtual Reality (VR)

  a computer generated, interactive, 3D environment in which a person is immersed : virtual, interactive and immersive

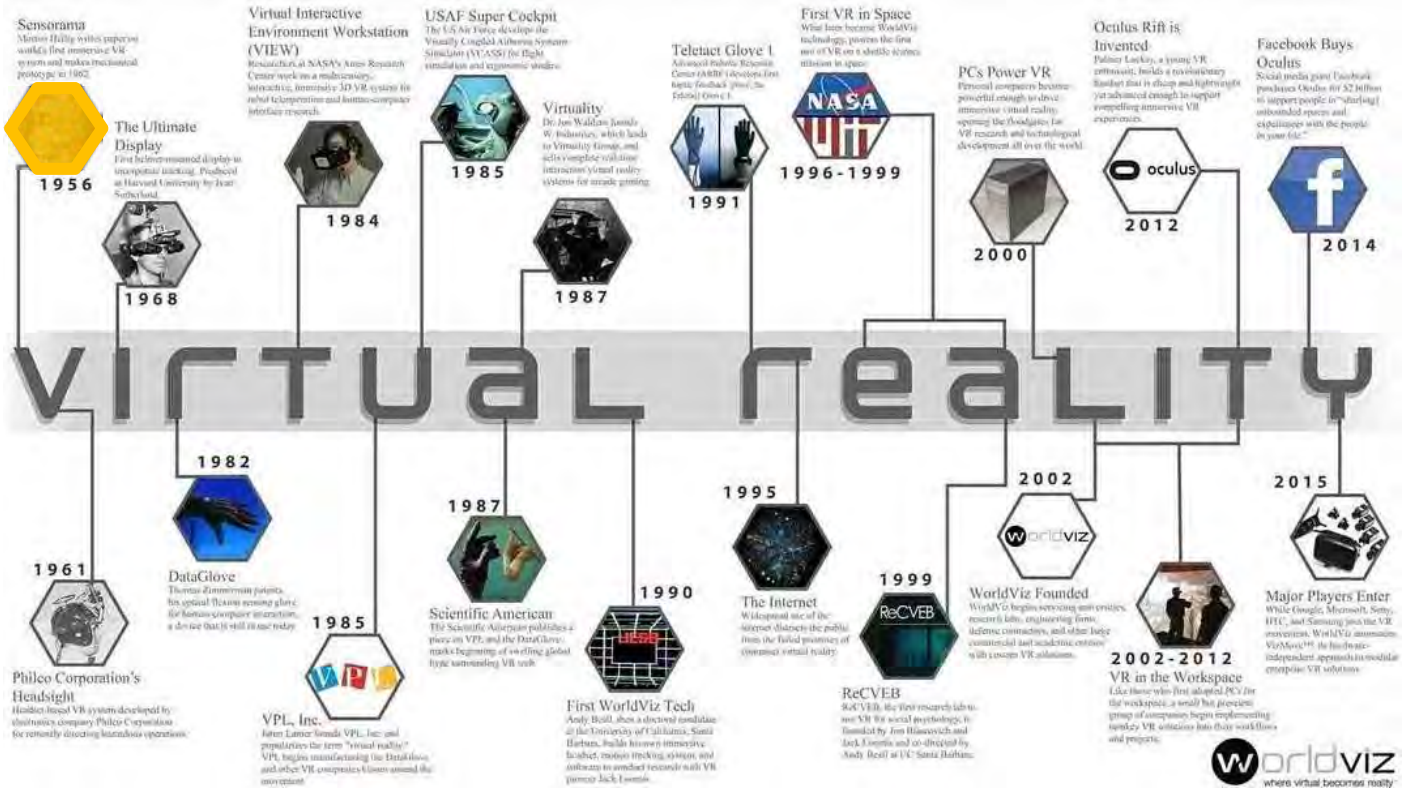
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Timeline 1956 - 2015



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Sensorama (1956)

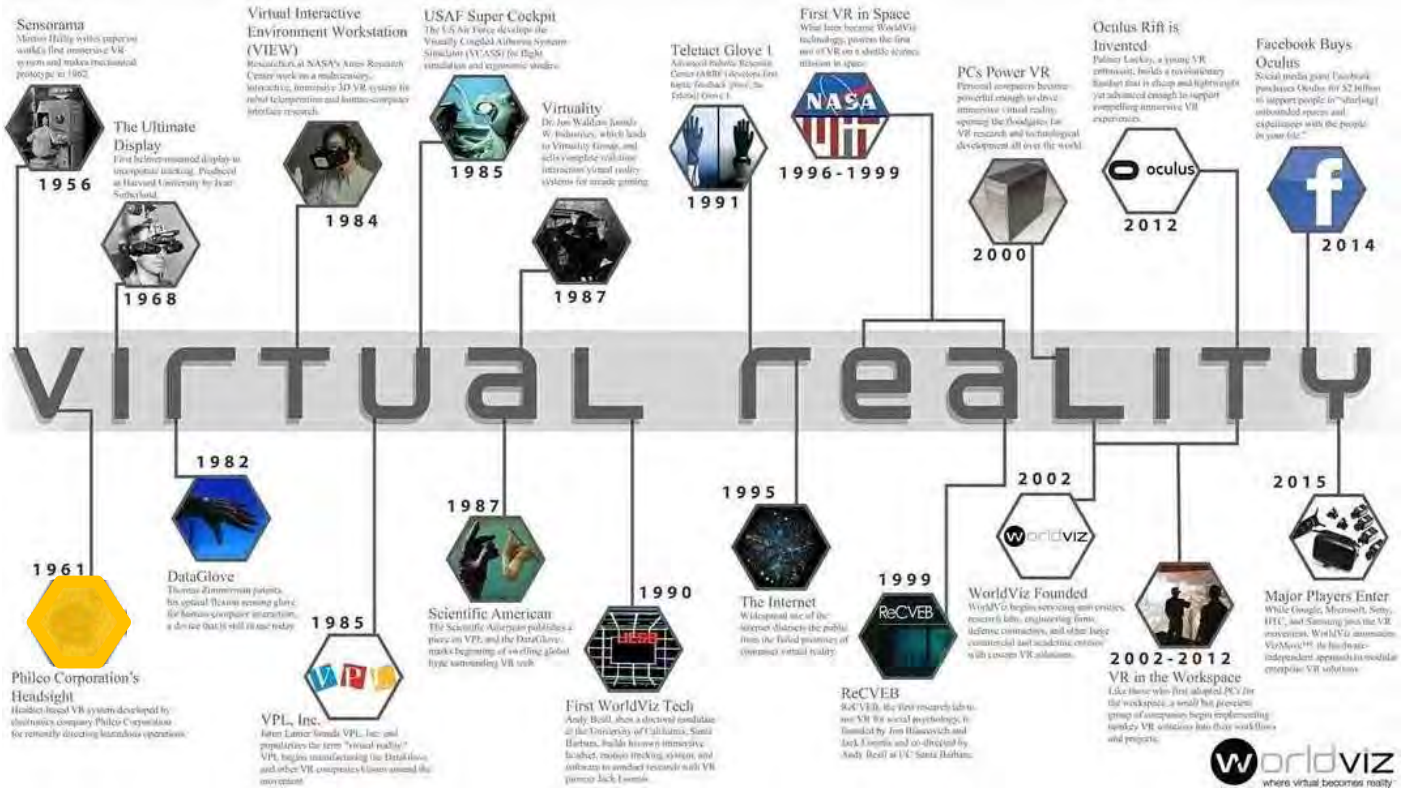


Morton Heilig
Sensorama - 1956-1962

The Sensorama was able to display stereoscopic 3-D images in a wide-angle view, provide body tilting, supply stereo sound, and also had tracks for wind and aromas to be triggered during the film.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

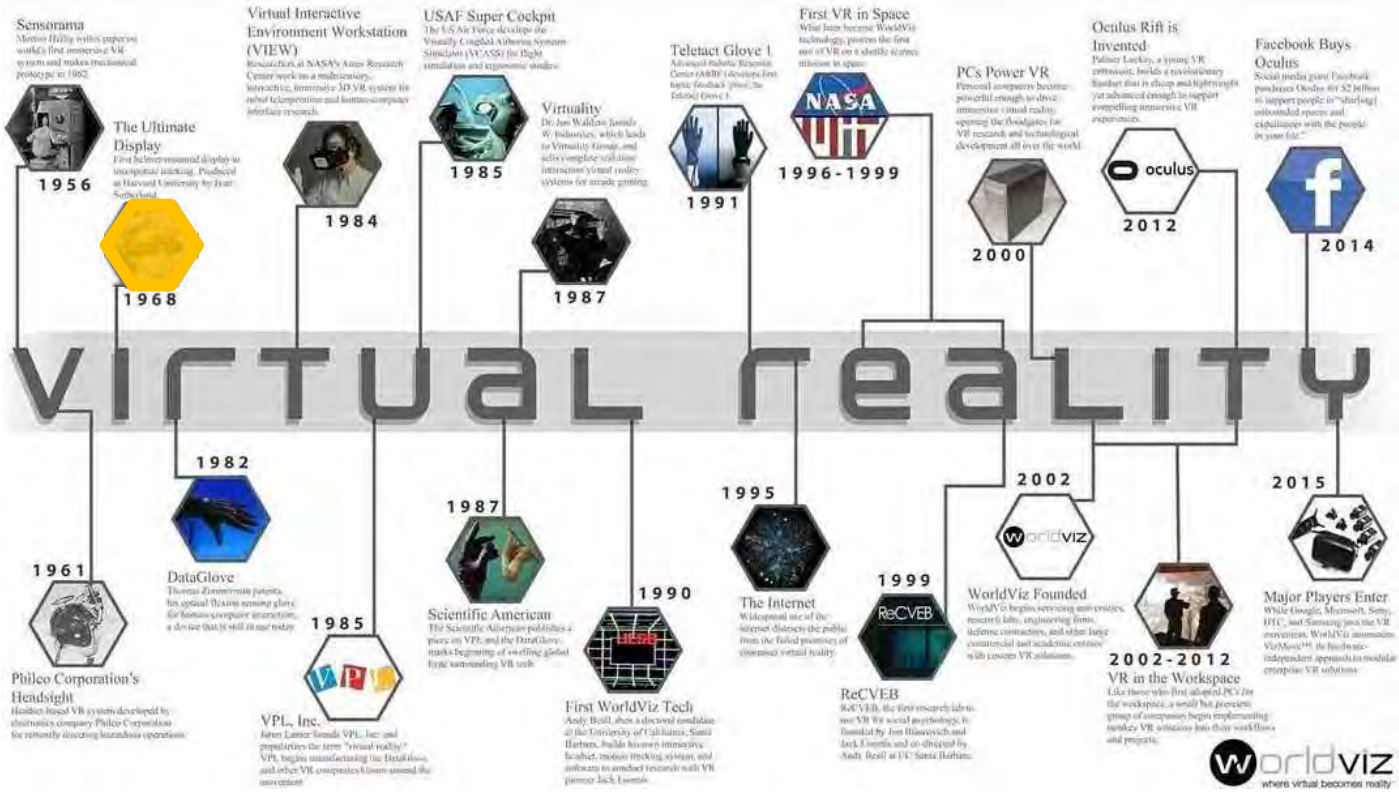
Philco Corporation (1961)



In 1961, devised project 'Headsight' Produced visual stimulation and a tracking system. Also used for military purposes. E.g. Pilots could train under Headsight to simulate flying in complete darkness

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Ultimate display (1968)

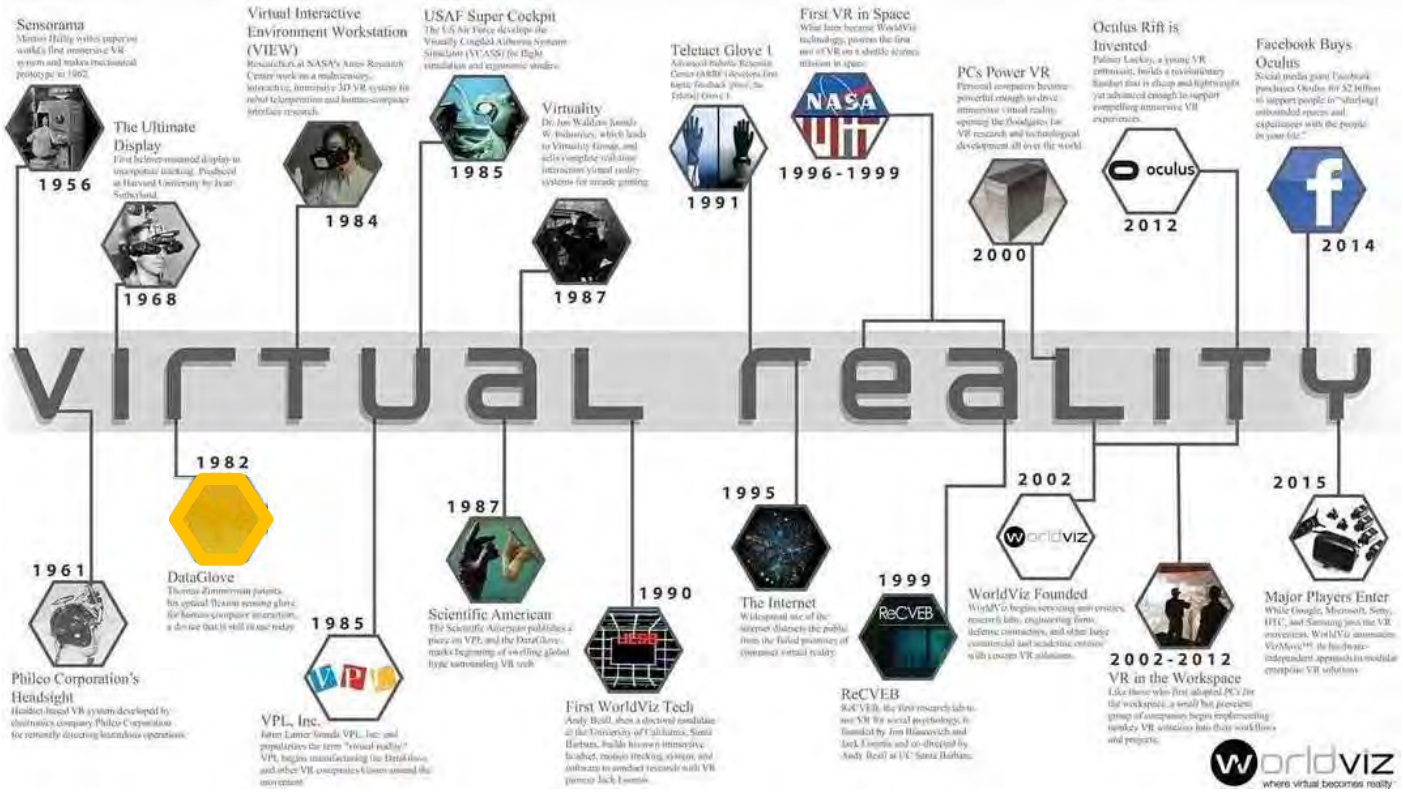


Ivan Sutherland
Head Mounted Display

The Sword of Damocles is widely considered to be the first virtual reality (VR) and augmented reality (AR) head-mounted display (HMD) system. It was created in 1968 by computer scientist Ivan Sutherland with the help of his student Bob Sproull. Before he began working toward what he termed "the ultimate display", Ivan Sutherland was already well respected for his accomplishments in computer graphics.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dataglove (1982)

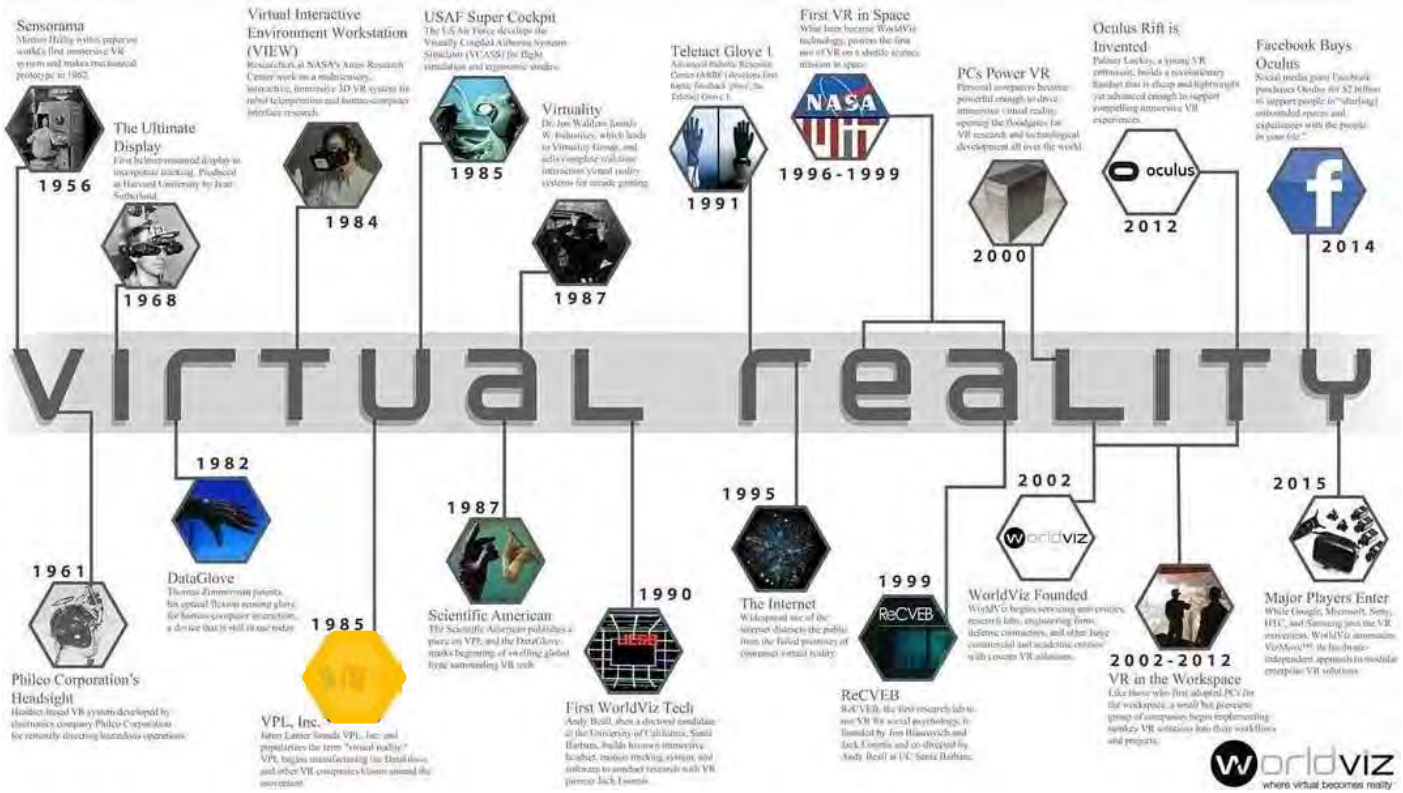


DataGlove
Thomas G. Zimmerman US Patent 4542291

Various sensor technologies are used to capture physical data such as bending of fingers. Often a motion tracker, such as a magnetic tracking device or inertial tracking device, is attached to capture the global position/rotation data of the glove. These movements are then interpreted by the software that accompanies the glove, so any one movement can mean any number of things.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Visual Programming Language (1985)

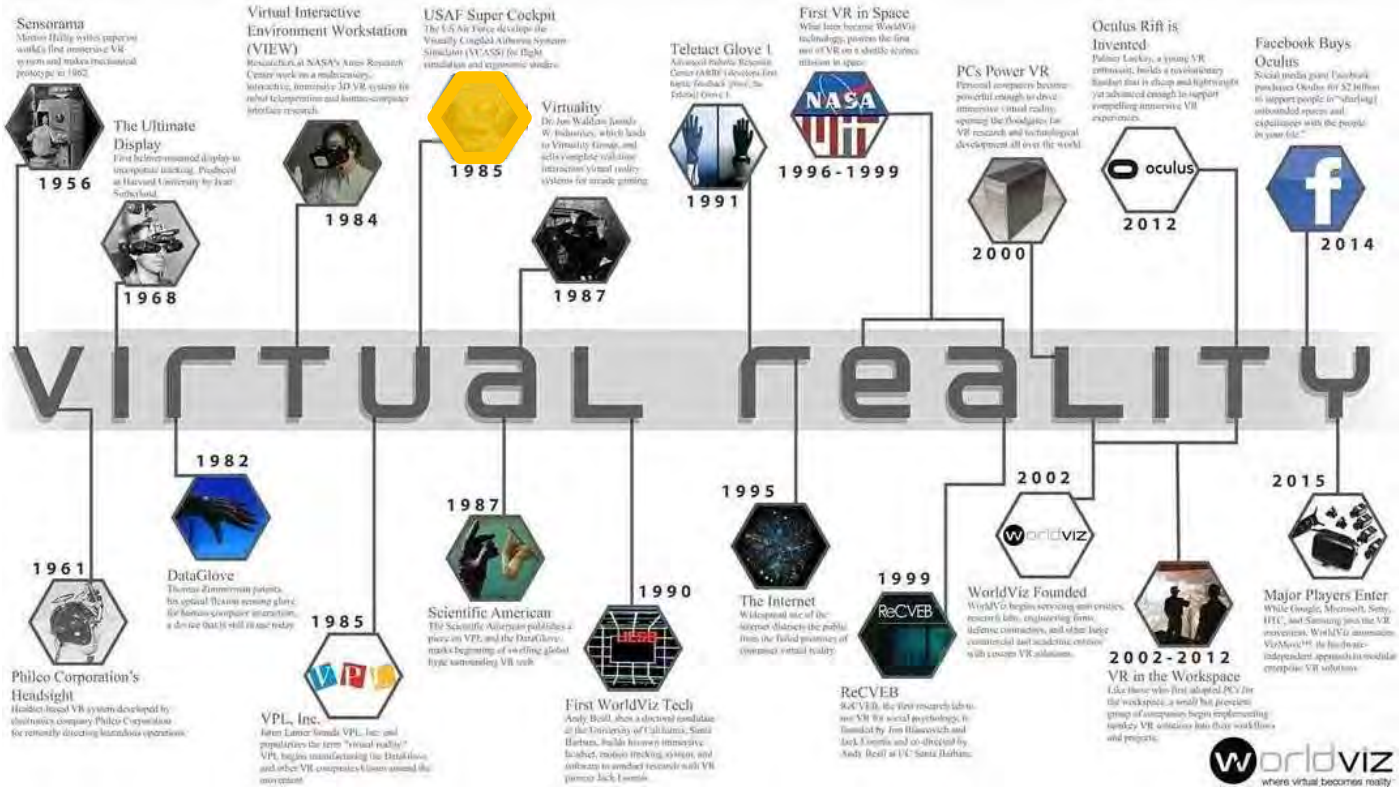


VPL, Inc.

One of the first companies that developed and sold virtual reality products. It was founded by VR pioneer Jaron Lanier in 1985. VPL started in the corner of Lanier's cottage in the San Francisco Bay Area. "VPL" stood for "Visual Programming Languages", and Lanier said that the goal of the company was to create a visual programming language to bring programming to a mass audience.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Super Cockpit (1986-1989)

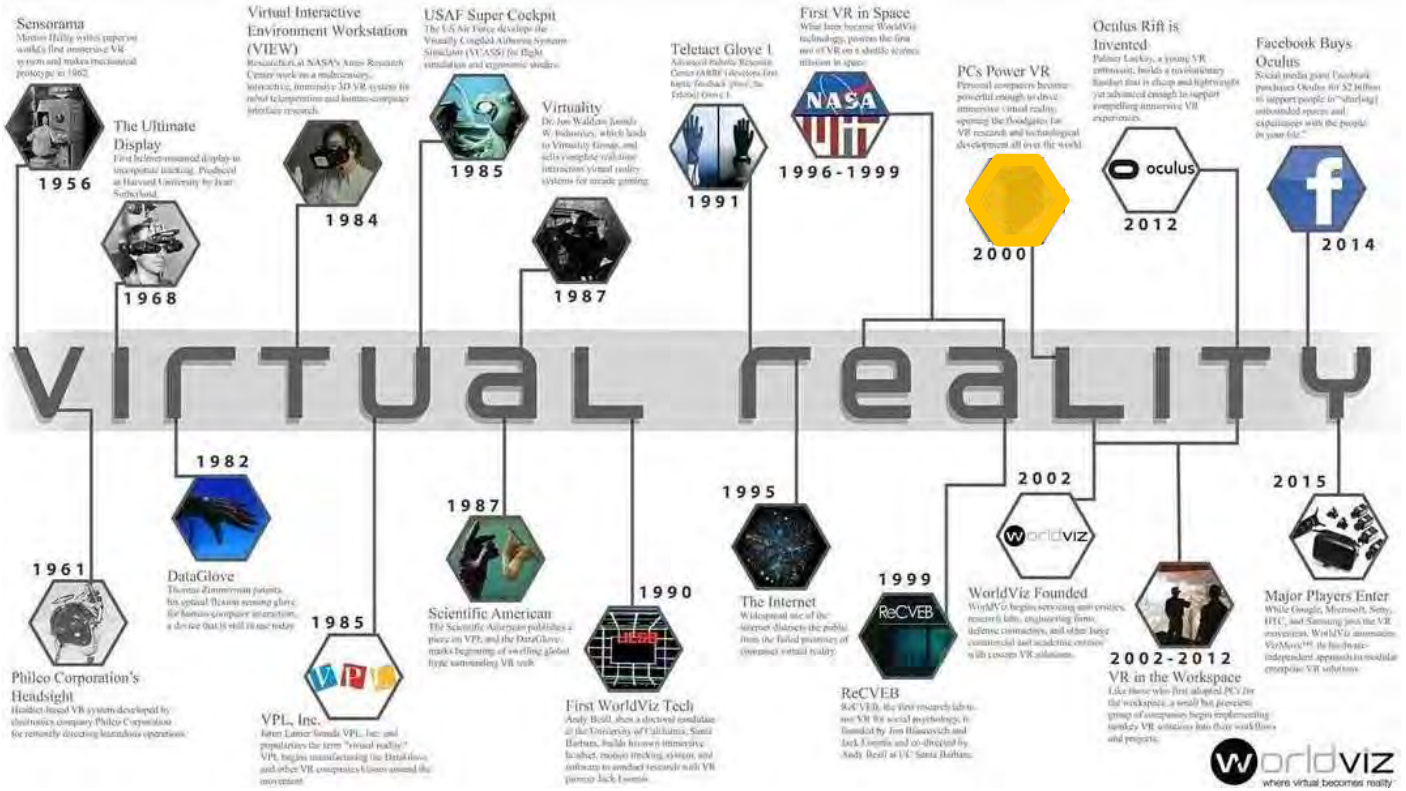


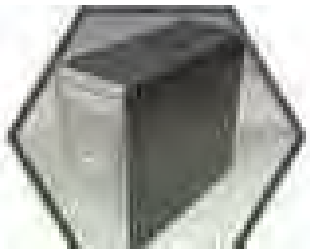
USAF Super Cockpit Program 1986-1989

Dr. Thomas Furness is a pioneer in the development of interfaces between humans and complex machines. Most of his work has centered on the concept of virtual interface technologies which prove a circumambience of three dimensional spatial information to the human using the visual, auditory and tactile sensory modalities.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

PC Power VR (1998-2000)



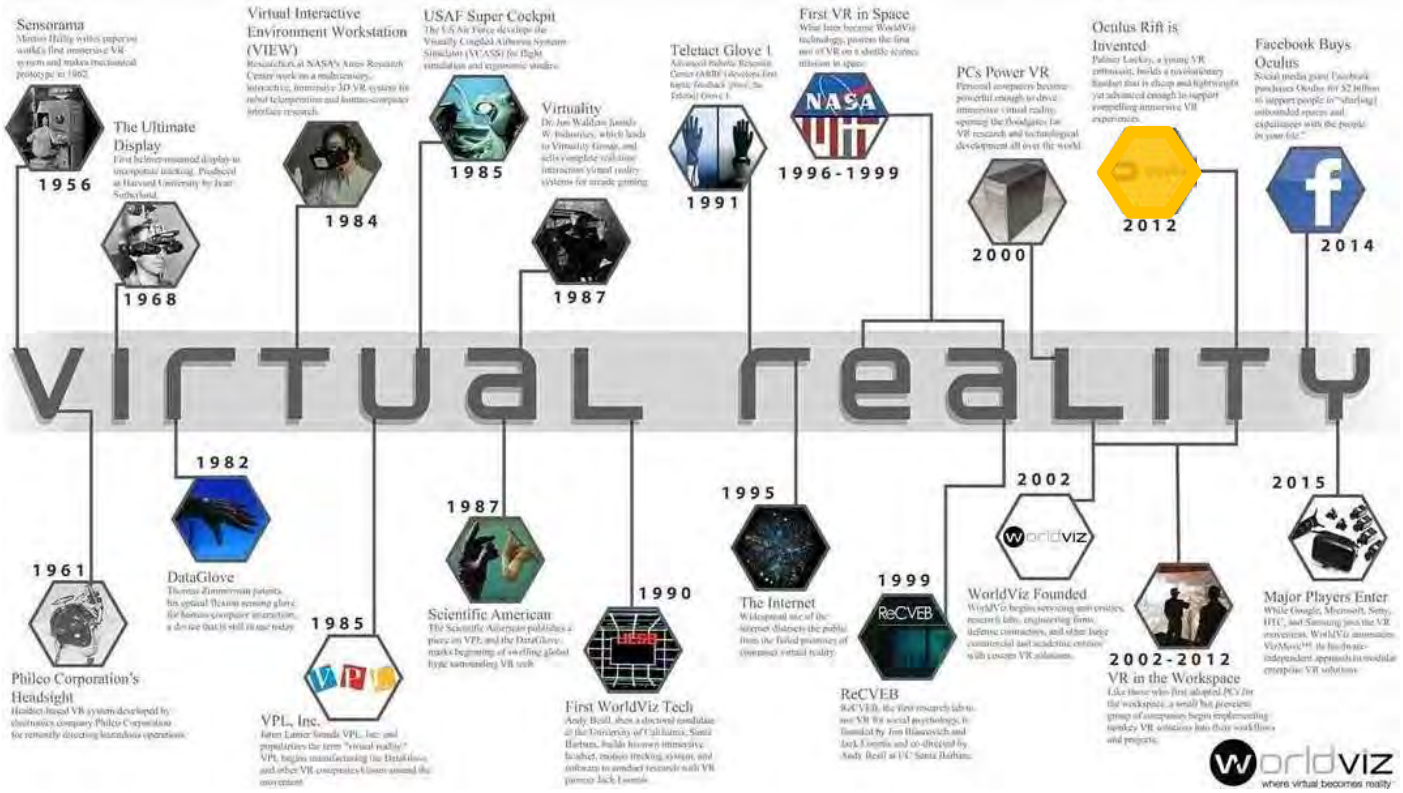


PC Power VR 1998-2000

The first personal computers capable of running virtual reality came onto the market in the late 90s. But the head- mounted displays were cumbersome and of lower resolution.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Oculus Rift (2012)

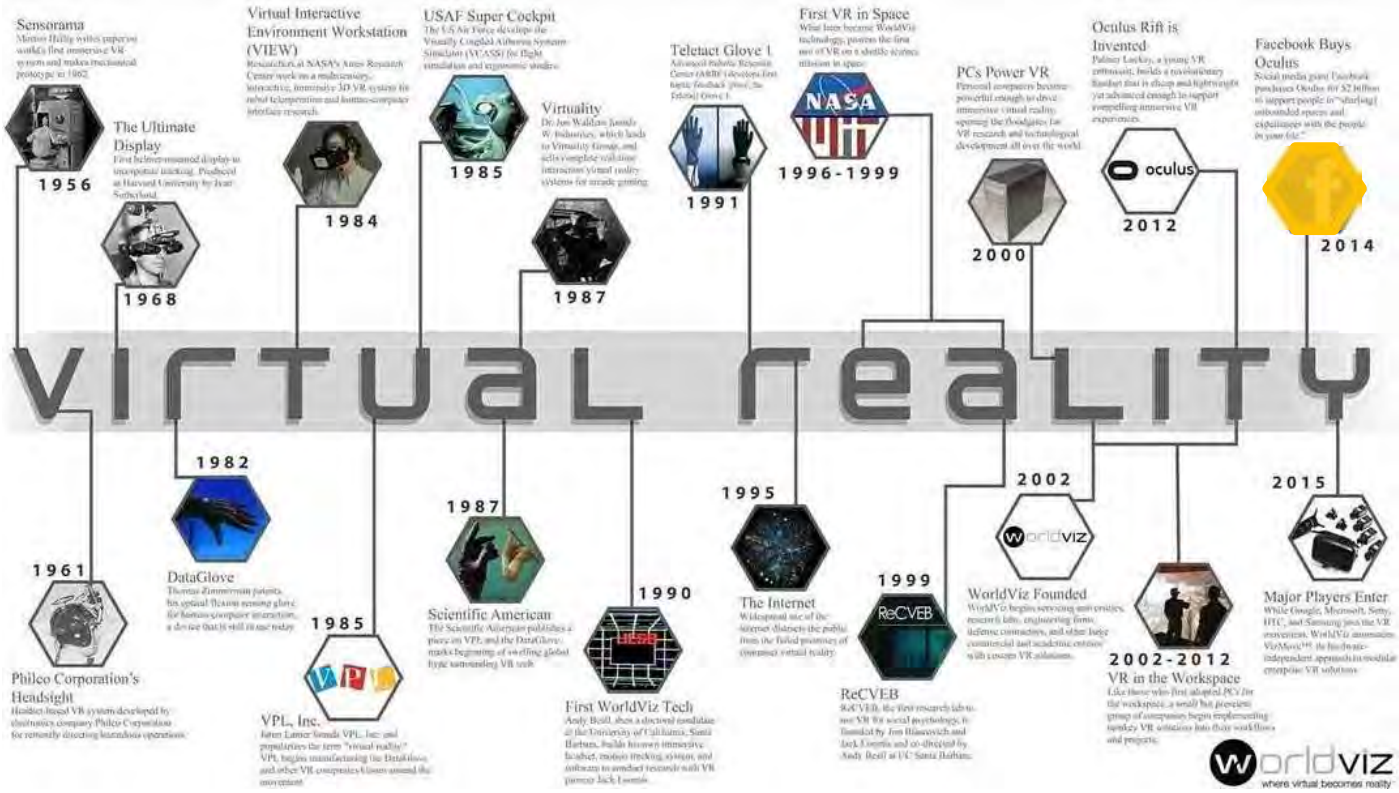


Oculus Rift
August 2012

In just 30 days, the Oculus Rift Kickstarter campaign raised $2,437,429, a mere 947% over their intended goal. It was a testament that the average tech consumer was ready for a VR device.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Facebook Buys Oculus (2014)

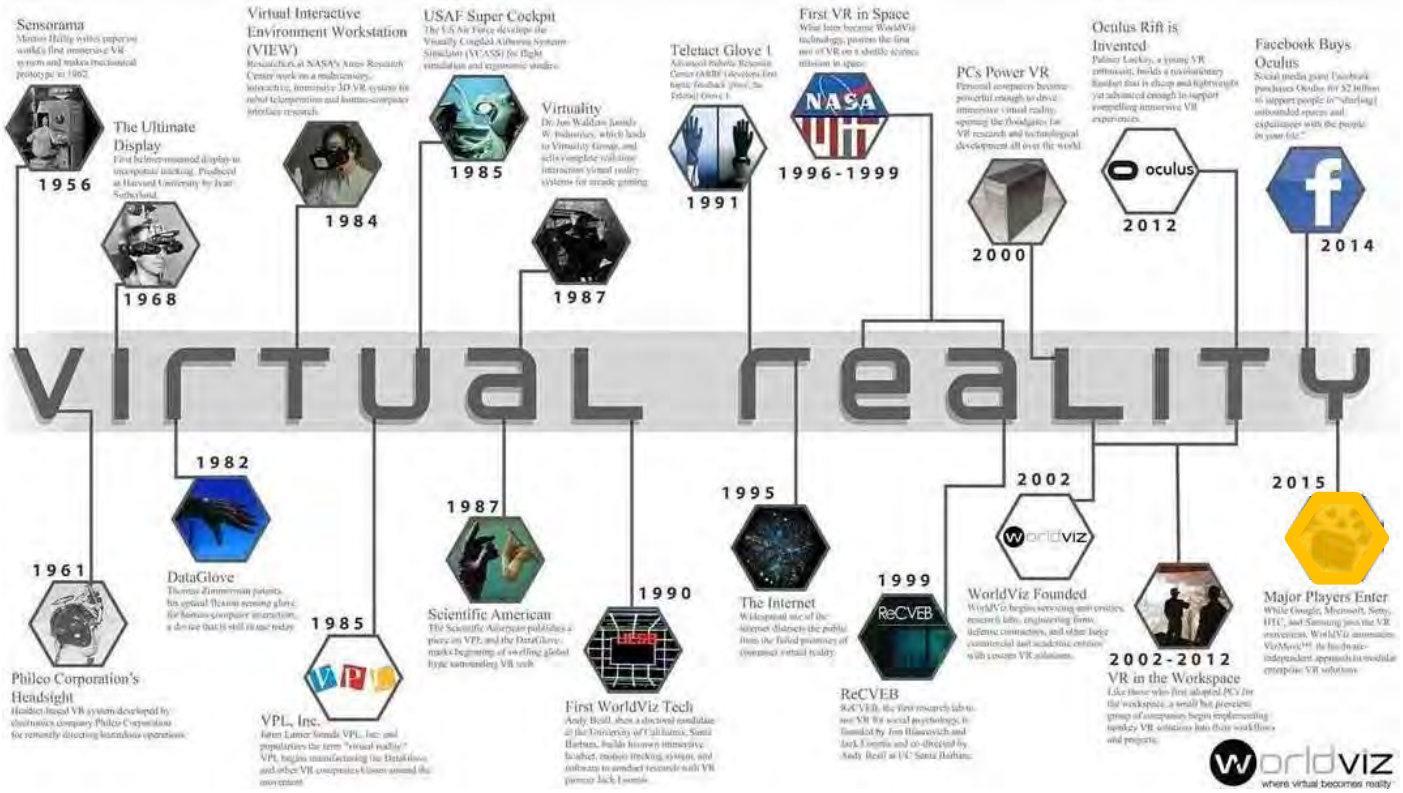


Facebook Buys Oculus
April 2014

The $2 billion acquisition deal of the virtual reality pioneer becomes official. The exact price of the acquisition came out to $2,001,985,000. The VR startup will operate somewhat independently and maintain its main offices in the Irvine and Los Angeles areas.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

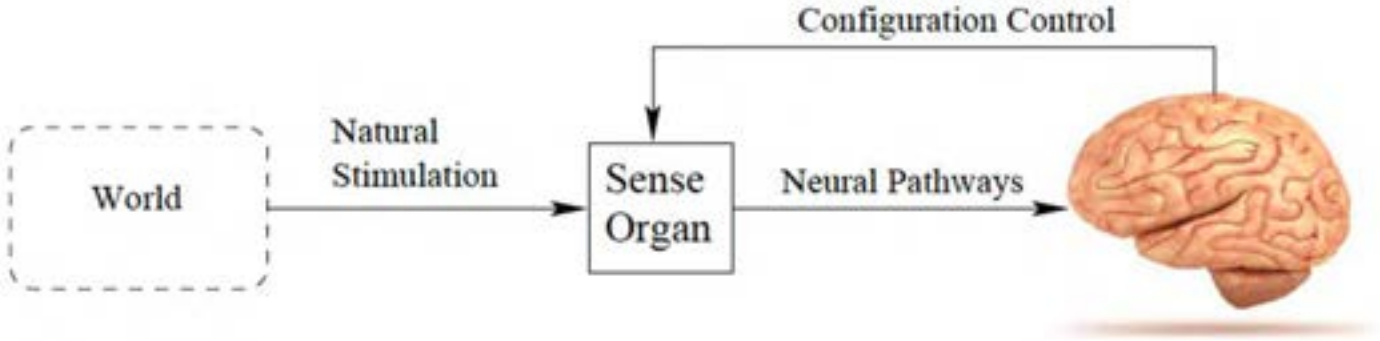
Major Players enter (2015)



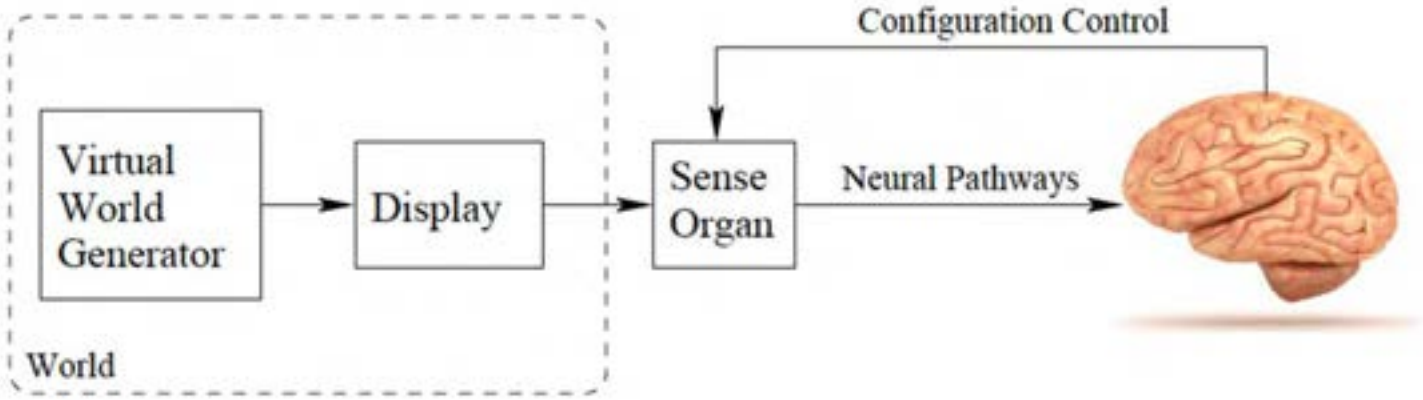
Major Players enter the VR Market

Aside from Facebook, 10 other companies were added to the VR Watchlist: Amazon, Google, Virtuix, AMD, Qualcomm, Samsung, Nvidia, Microsoft, Sony, and Valve.

How Virtual Reality works?



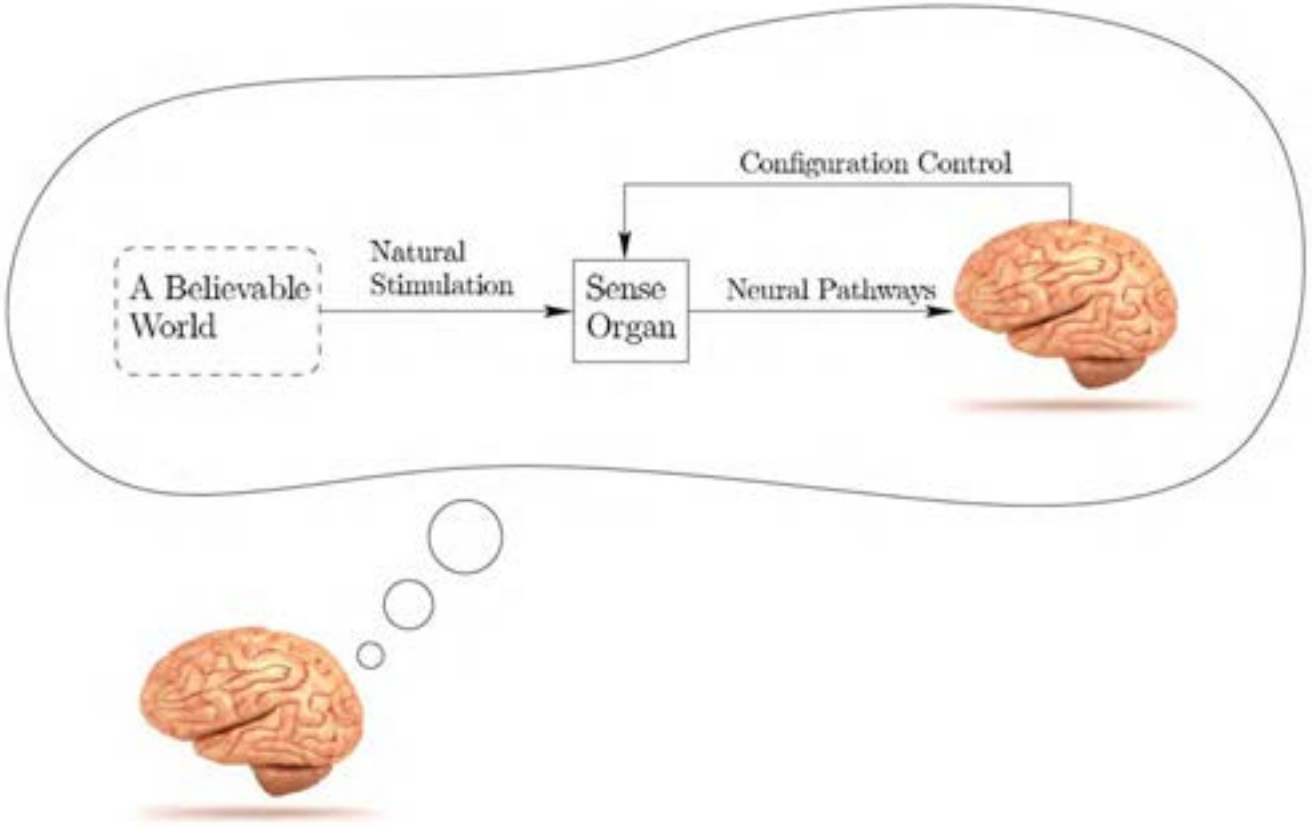
Under normal conditions, the brain (and body parts) control the configuration of sense organs (eyes, ears, fingertips) as they receive natural stimulation from the surrounding, physical world.



A VR system “hijacks” each sense by replacing the natural stimulation with artificial stimulation that is provided by hardware called a display. Using a computer, a virtual world generator maintains a coherent, virtual world.

How Virtual Reality works?

Virtual reality tricks your brain into believing you are in a 3D world.



If done well, the brain is “fooled” into believing that the virtual world is in fact the surrounding physical world and natural stimulation is resulting from it.

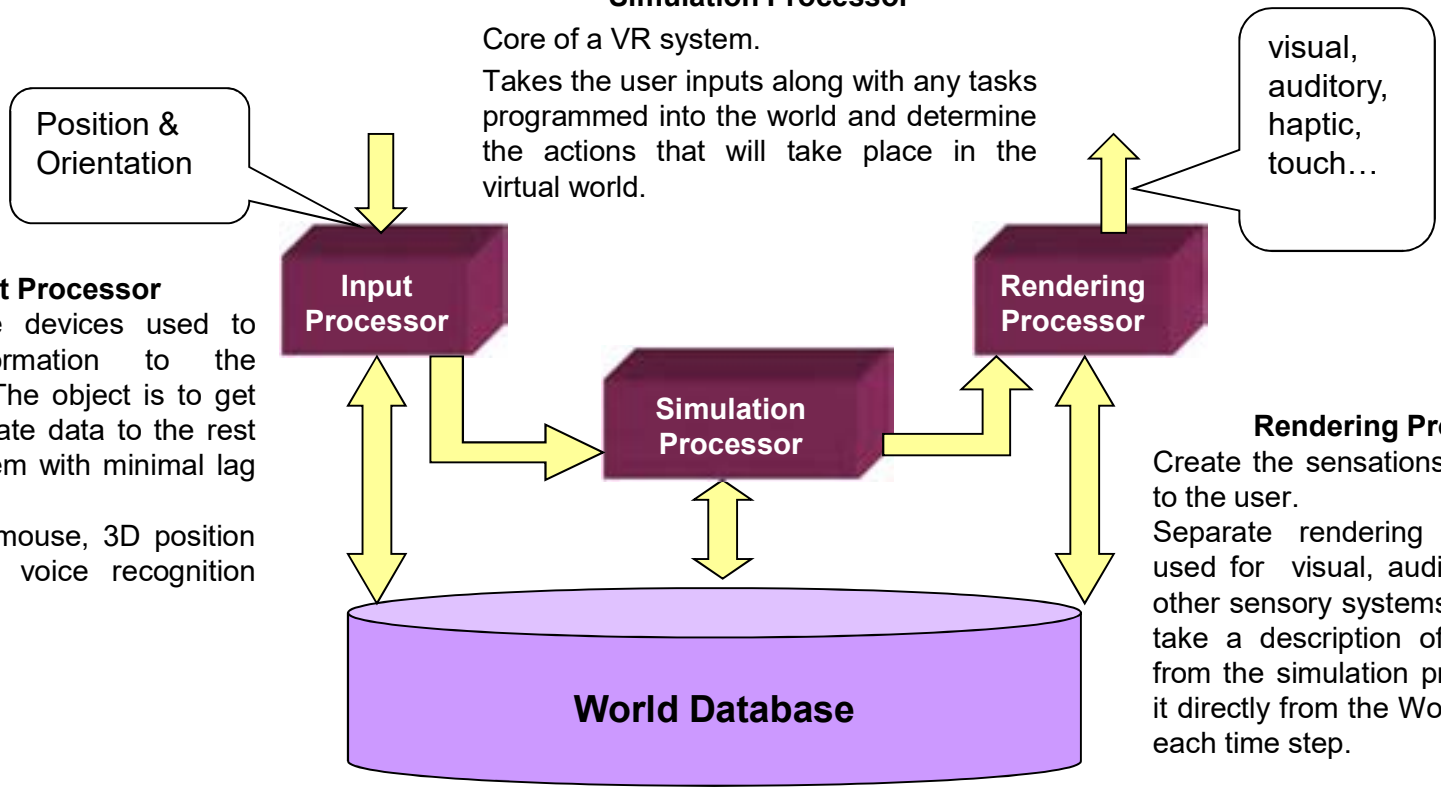
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Architecture of VR System

Simulation Processor

Core of a VR system.

Takes the user inputs along with any tasks programmed into the world and determine the actions that will take place in the virtual world.



Input Processor

Control the devices used to input information to the computer. The object is to get the coordinate data to the rest of the system with minimal lag time.

Keyboard, mouse, 3D position trackers, a voice recognition system, etc.

Rendering Processor

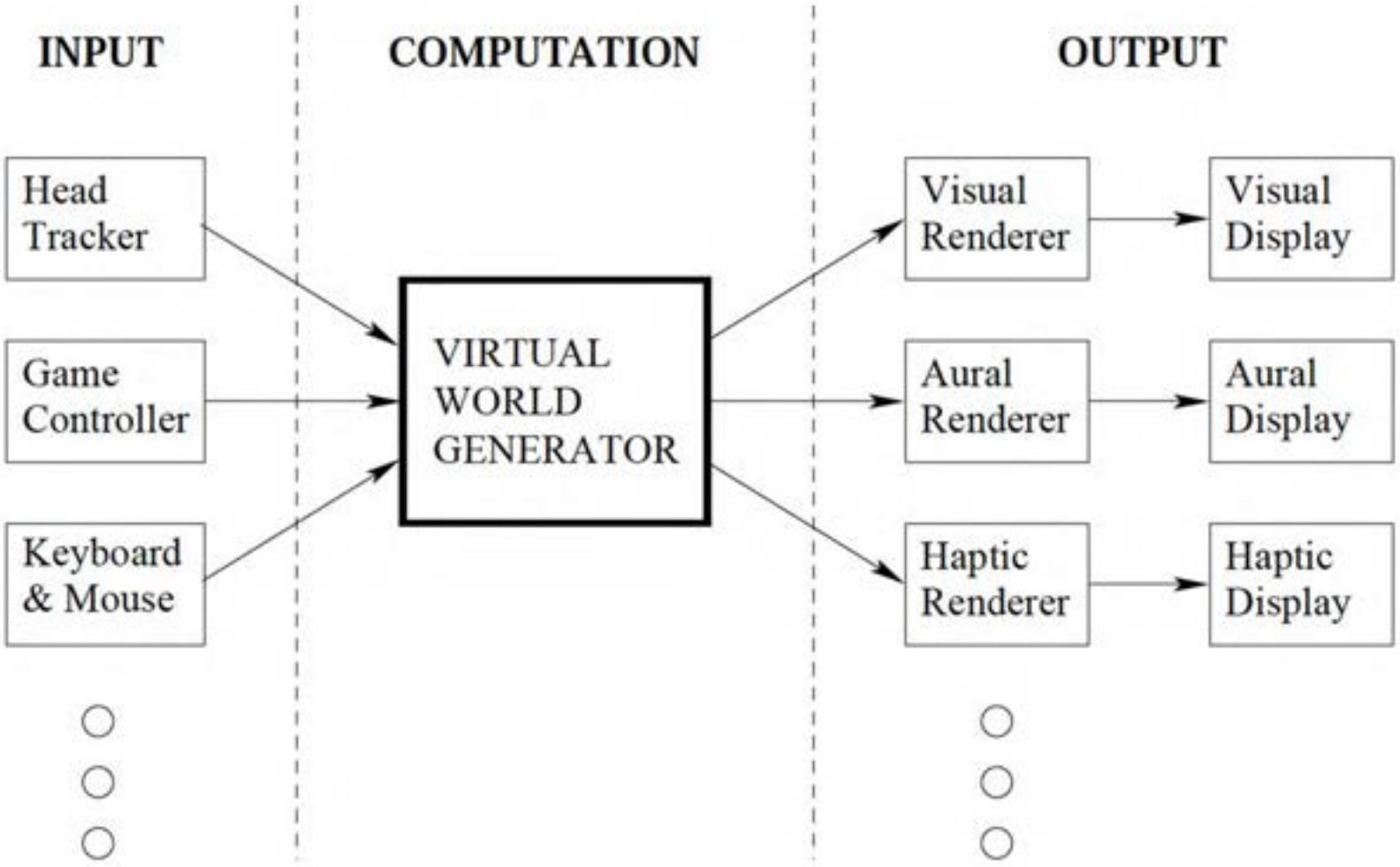
Create the sensations that are output to the user.

Separate rendering processes are used for visual, auditory, haptic and other sensory systems. Each renderer take a description of the world stat from the simulation process or derive it directly from the World Database for each time step.

World Database (World Description Files)

Store the objects that inhabit the world, scripts that describe actions of those objects.

Components of VR System



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Current Virtual Reality devices in Market

The **Oculus Rift** is a virtual reality headset developed and manufactured by Oculus VR, a division of Facebook Inc., released on March 28, 2016.

Google Cardboard is a virtual reality (VR) platform developed by **Google** for use with a head mount for a smartphone. Named for its fold-out **cardboard** viewer, the platform is intended as a low-cost system to encourage interest and development in VR applications.

The **Samsung Gear VR** is a mobile virtual reality headset developed by Samsung Electronics, in collaboration with Oculus, and manufactured by Samsung. When in use, a compatible Samsung Galaxy device (Galaxy Note 5, Galaxy S6/S6 Edge/S6 Edge+, or Galaxy S7/S7 Edge) acts as the headset's display and processor, while the Gear VR unit itself acts as the controller.

HTC Vive can be ordered now for $799. Includes headset, two wireless controllers, and two base stations for 360 degrees room-scale motion-tracking.

Virtual Reality in Healthcare

Healthcare is one of the biggest users of virtual reality for things like:

- ✓ Surgery simulation
- ✓ Phobia treatment
- ✓ Robotic surgery
- ✓ Skills training

HumanSim System

- ✓ Fully interactive environment
- ✓ Training scenarios

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Virtual Reality in Military

- ✓ Used by the Army, Navy, and Air Force for different training purposes like
  - ✓ Flight simulation
  - ✓ Battlefield simulation
  - ✓ Medic training
  - ✓ Vehicle simulation
  - ✓ Virtual boot camp
- ✓ Vehicle and flight simulation typically uses a Cave system

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Virtual Reality in Entertainment

- ✓ The entertainment industry is another industry with the most advocates of virtual reality
- ✓ Some examples of virtual reality in Entertainment
  - ✓ Virtual museums
  - ✓ Theatre
  - ✓ Virtual theme parks
  - ✓ Gaming
- ✓ Recent advances in VR Gaming
  - ✓ Occulus Rift
  - ✓ Omni and Cyberith

Types of Virtual Reality

Immersive VR

- ✓ Completely immerse the user's personal viewpoint inside the Virtual 3D- World.
- ✓ The user has No Visual Contact with the physical world.
- ✓ Often equipped with a Head Mounted Display (HMD).

Types of Virtual Reality

Window on World (WOW)

- ✓ Also known as Desktop VR.
- ✓ Use of a monitor to display the visual world.
- ✓ Does not require special hardware.
- ✓ Low cost , low performance, less Immersion.

Types of Virtual Reality

Telepresence

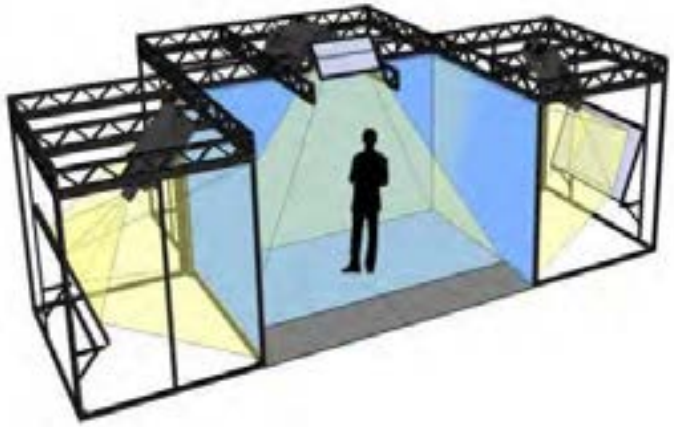
- ✓ Real-time Telepresence
  - ✓ Interaction are reflected to some real world objects.
- ✓ Delayed Telepresence
  - ✓ Interactions are recorded, and later operations are applied to the real-world object.

Head Mounted Display(HMD)

- ✓ A Helmet or a face mask providing the visual and auditory displays.
- ✓ Use LCD to display stereo images.
- ✓ May include built-in Head-tracker and Stereo headphones.

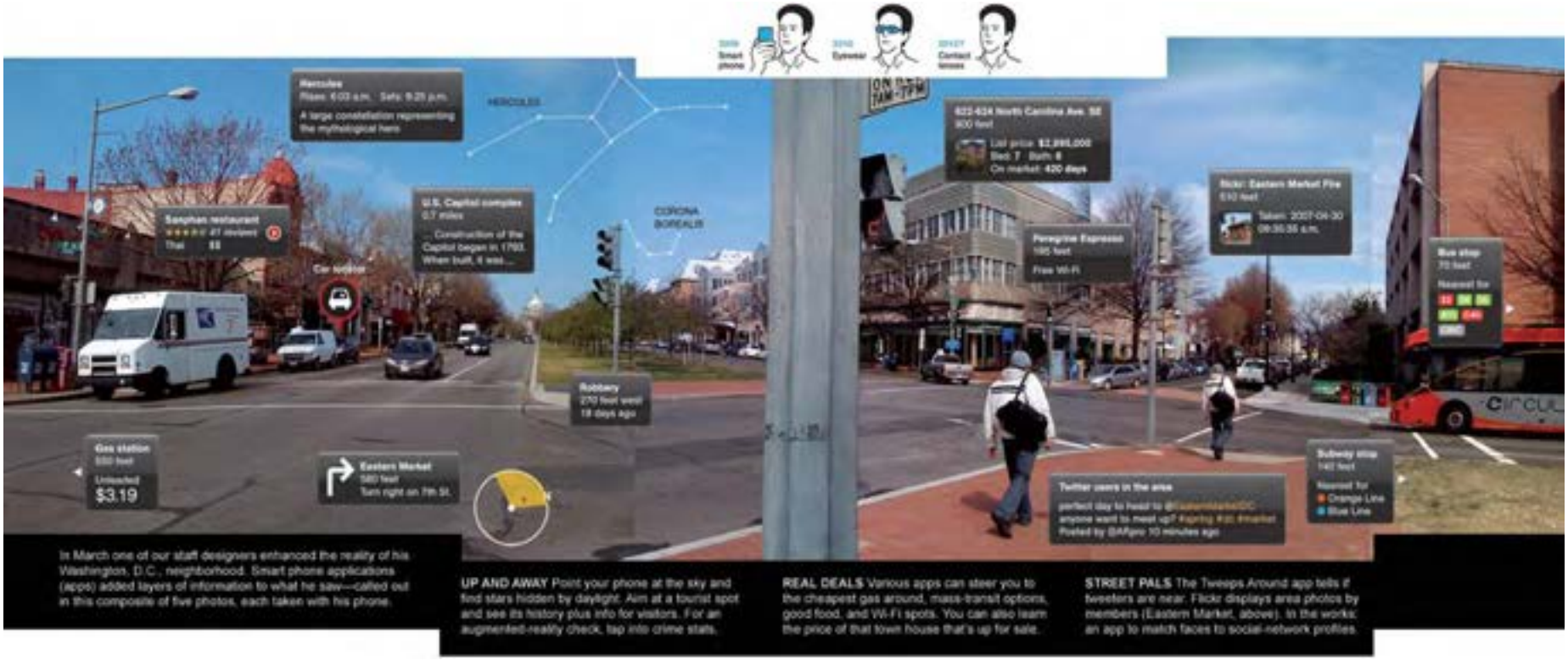
Cave Automatic Virtual Environment (CAVE)

- ✓ Provides the illusion of immersion by projecting stereo images on the walls and floor of a room-sized cube.
- ✓ A head tracking system continuously adjust the stereo projection to the current position of the leading viewer.

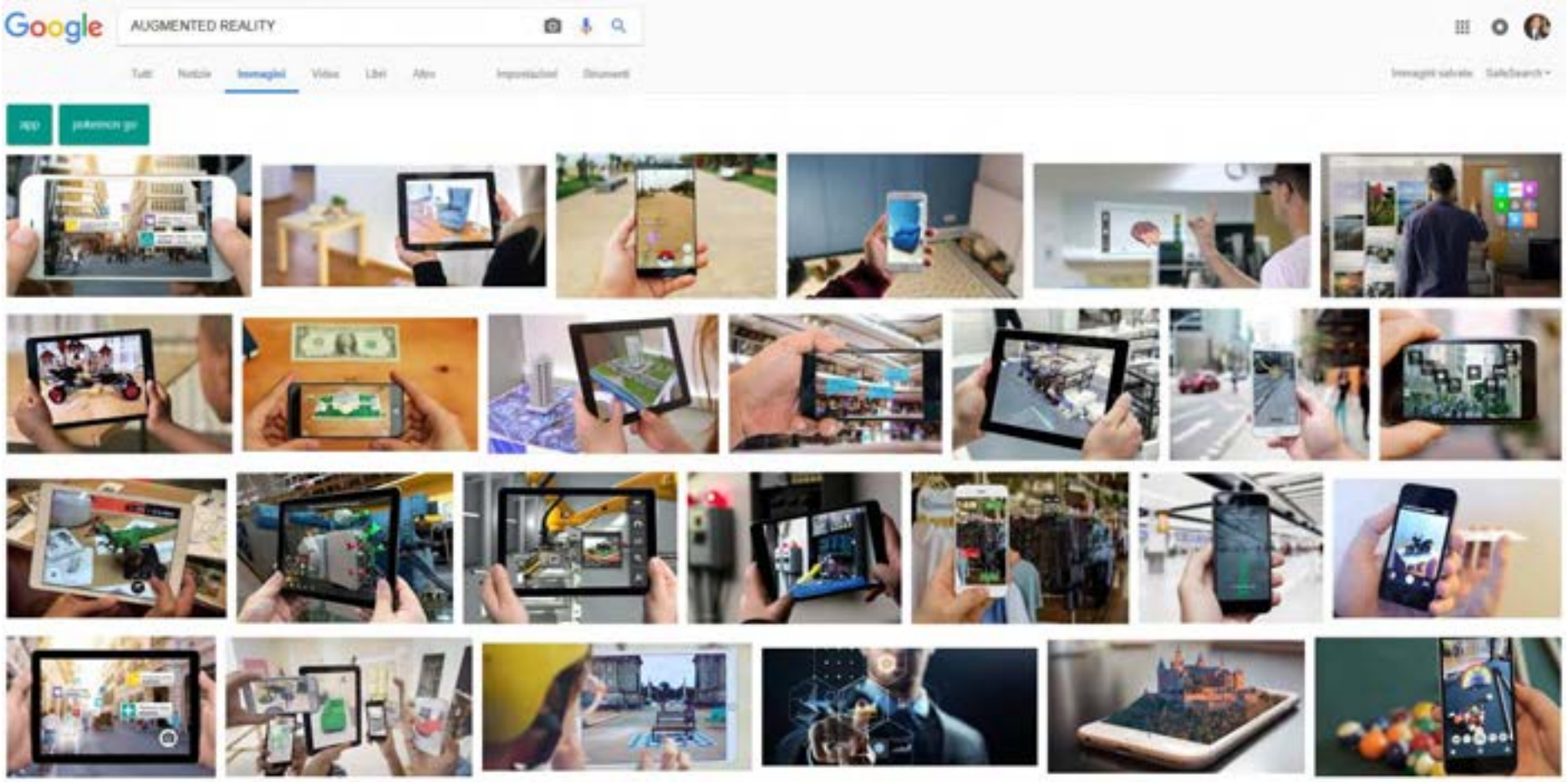


DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Augmented Reality : Portal to Future



AUGMENTED REALITY



Confused with Augmented Reality And Virtual Reality

Differences

Augmented Reality

- Virtual Pop-out of the image
- It enhances the real world
- Some times viewing glasses are not required
- A camera (Capturing Device) plays an important role in VR. It acts as a mediator between user and real world

Virtual Reality

- Real Time Experience
- It leaves you blind to real world
- A VR headset is required
- Most important part of VR is motion sensing and sensing personal emotions, etc.

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

AR History Timeline

1968

Ivan Sutherland created the first head mounted display system

1974

Myron Kruger built an artificial reality lab.

1990

Tom Caudell coins the term augmented reality

1994

Julie Martin creates first AR theater production " Dancing in Cyberspace"

1998

Sports Vison broadcast the first virtual 1st & 10 line on a football field

1999

Naval researchers use a Battlefield AR training

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

AR History Timeline (cont'd)

2000

Hirokazu Kato created the ARToolkit. This is an open source library . Sources use video tracking, computer graphics and a camera.

2009

ARToolkit brings AR to web browsers

2013

AR us used for auto repair by car manufacture Volkswagen. MARTA provided a step by step guide repair assistance.

2014

Goggle Glass is available to consumers. The beginning of wearable AR

2014

Magic Leap invests $50M in AR

2015

Investment reaches $700 million for AR and VR

2016

Microsoft Hololens developer kit and Meta 2 Developer Kit available

What is Augmented Reality?

1997 - Azuma's definition:

"Augmented Reality is a technology which:

1. *Combines real and virtual world aspects* — **Display System**
2. *Is interactive in real time* — **Interaction System**
3. *Registers the virtual imagery with the real world in three dimensions* — **Tracking System**

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Technology behind Augmented Reality

Display

See-through HMDs

Projection-Based Displays

Handheld Displays

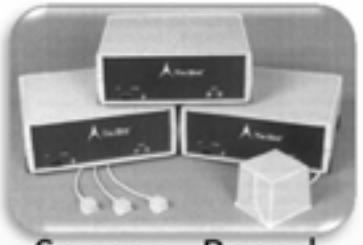
Interaction

Tangible AR

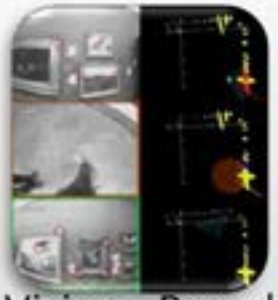
Collaborative AR

Hybrid AR Interface

Tracking



Sensor - Based



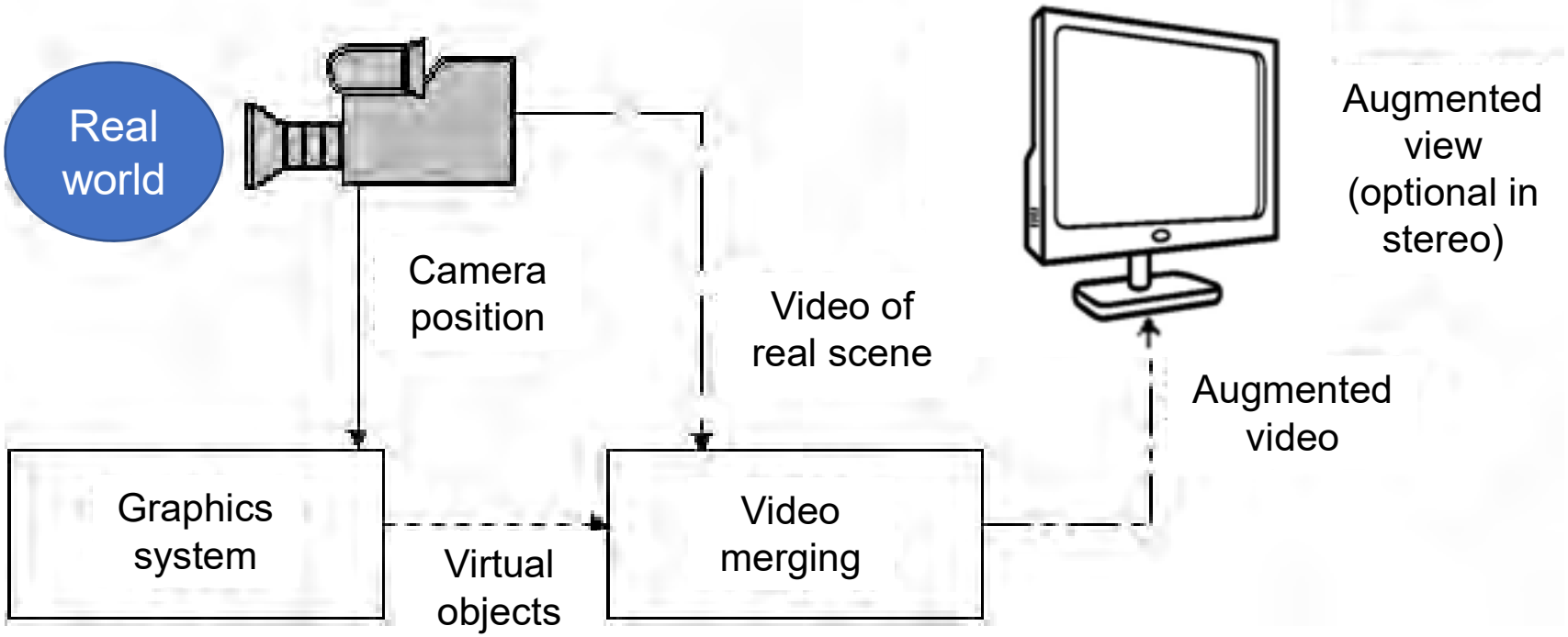
Vision - Based

Hybrid

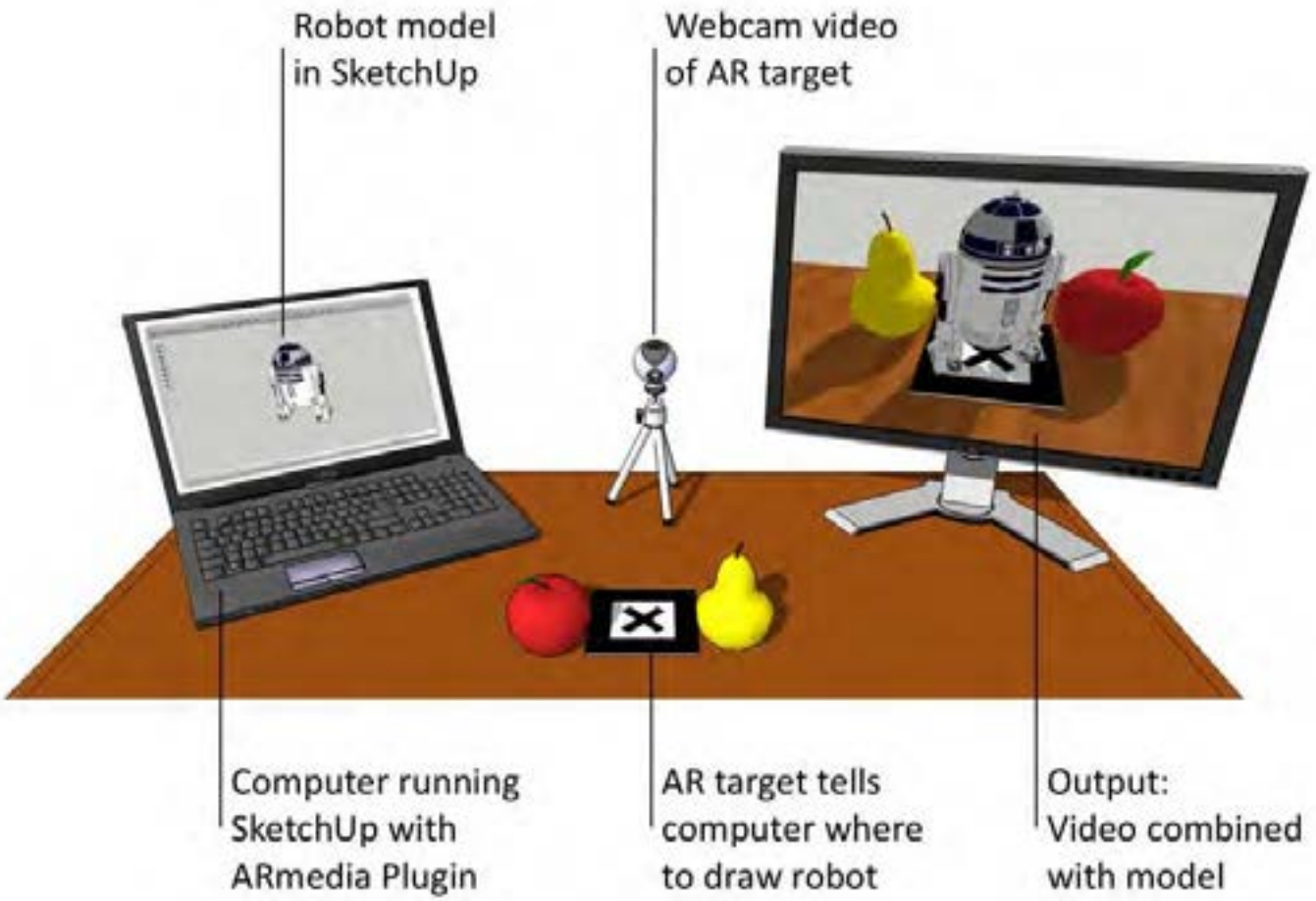
Display Technologies

- Monitor Based
  - Laptops
  - Cell phones
  - Projectors (more Ubiquitous Computing)
- Head Mounted Displays:
  - Video see-through
  - Optical see-through

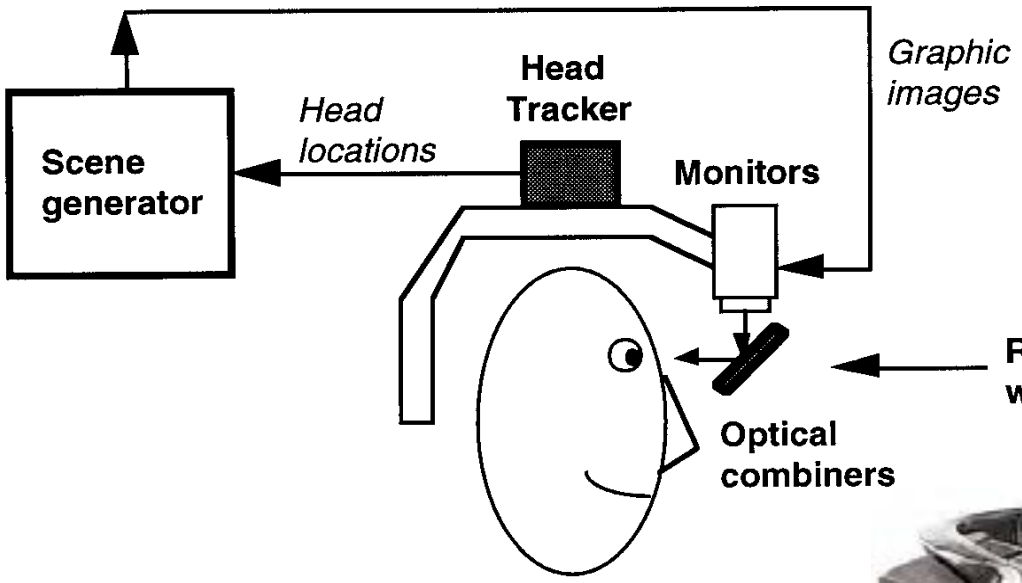
Monitor Based Augmented Reality



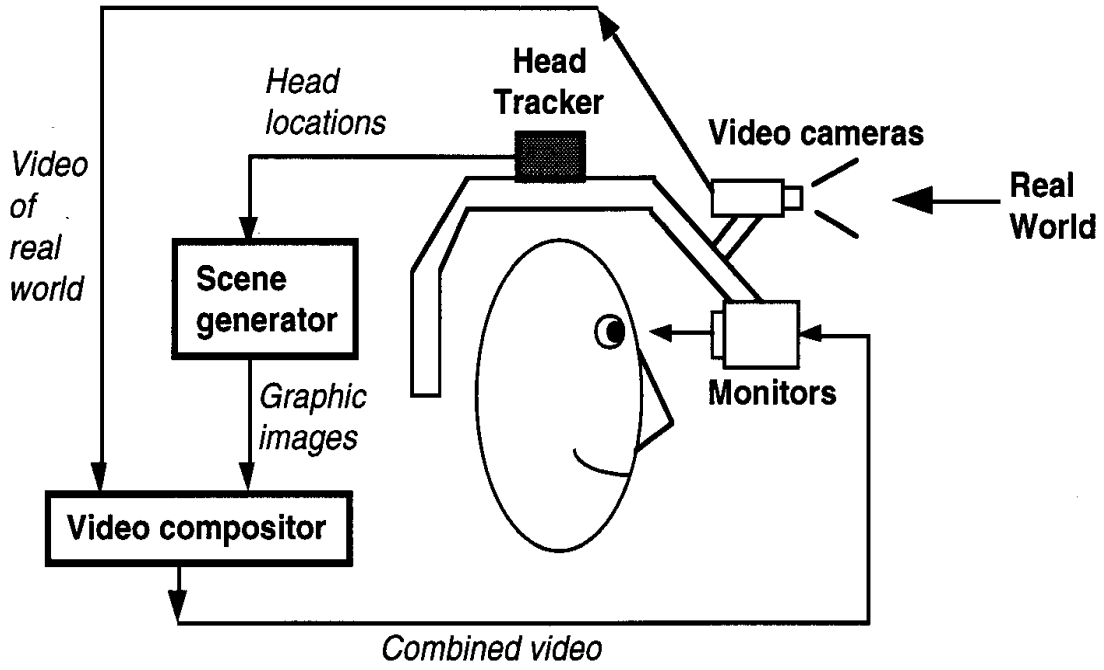
How it works


Robot model in SketchUp
Webcam video of AR target
Computer running SketchUp with ARmedia Plugin
AR target tells computer where to draw robot
Output: Video combined with model

Optical see-through HMD



Video see-through HMD



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Advantages of the different typologies

Video see-through	Optical see-through	Monitor display
Flexibility in composition strategies	Simplicity	Consumer-level equipment
Real and virtual view delays can be matched	Resolution	Most practical and simplest available
Wide field of view	No eye offset	A lot of current research aimed here
		Other current active area is a flip-down optical display.

AR DEVICES

ORA-2 by Optinvent

Meta 2 Augmented Reality

Magic Leap One

Microsoft HoloLens

Video Composition for AR

Chroma-keying

- ✓ Used for special effects
- ✓ Background of computer graphics images is set to a specific color (green or blue)
- ✓ Combining step replaces all colored areas with corresponding parts from video

Evolution of display technologies

Past

- **Bulky Head mounted displays**

1st HMD by Ivan Sutherland (1968)

Evolution of display technologies

Present

- ✓ **Handheld devices**
- ✓ **Lightweight head mounted displays**

Leap Motion's AR HMD

Xiaomi smartphone

Microsoft Hololens

Evolution of display technologies

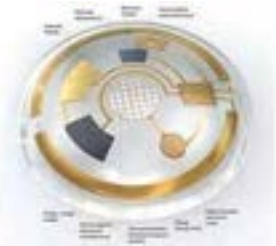
Future

- ✓ **Wide FOV see through**
- ✓ **Retinal displays**
- ✓ **Contact lens**

Lumus DK40

Magic Leap One

Intel's Vaunt smartglasses



Contact lens concept

Evolution of interaction systems

Past

- ✓ Limited interaction
- ✓ Viewpoint manipulation

Evolution of interaction systems

Present

- ✓ Screen based
- ✓ Simple gestures

Future

- ✓ Natural gesture
- ✓ Multimodal input (gestures and speech)

Evolution of interaction systems

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

Evolution of tracking technologies

Past

- ✓ Location based
- ✓ Marker based

Evolution of tracking technologies

Present

- ✓ Image based
- ✓ Hybrid tracking

Evolution of tracking technologies

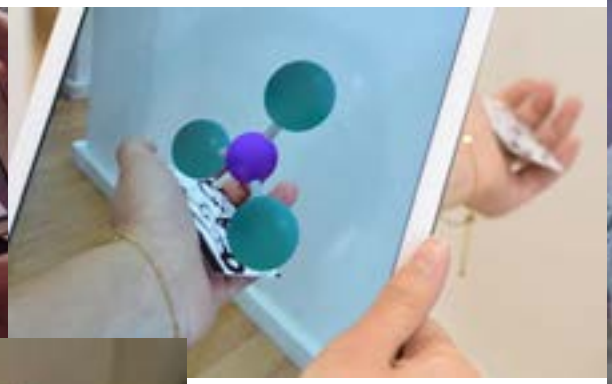
Future

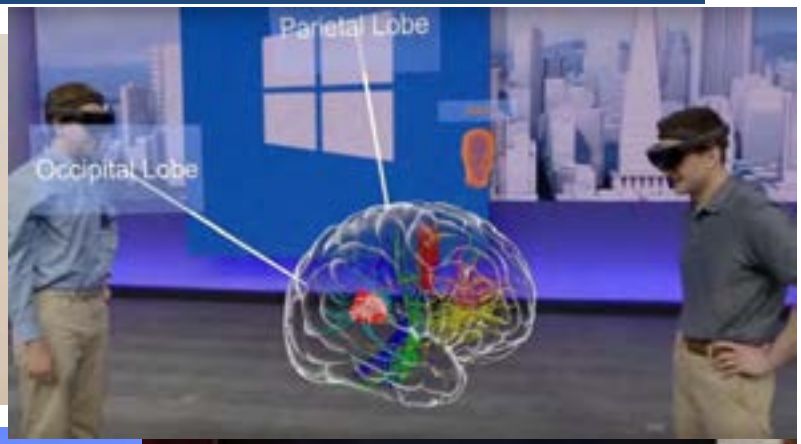
- ✓ Ubiquitous
- ✓ Model based
- ✓ Environmental

Examples For Augmented Reality

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

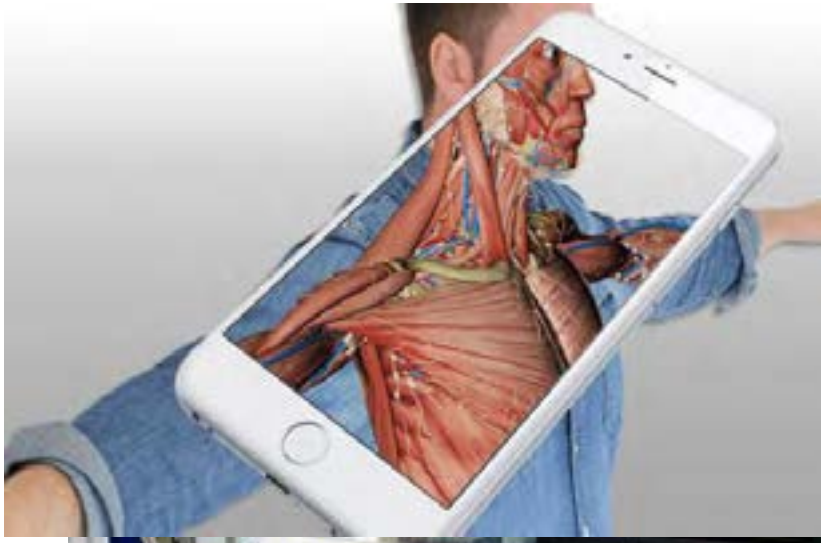
Augmented Reality in Education





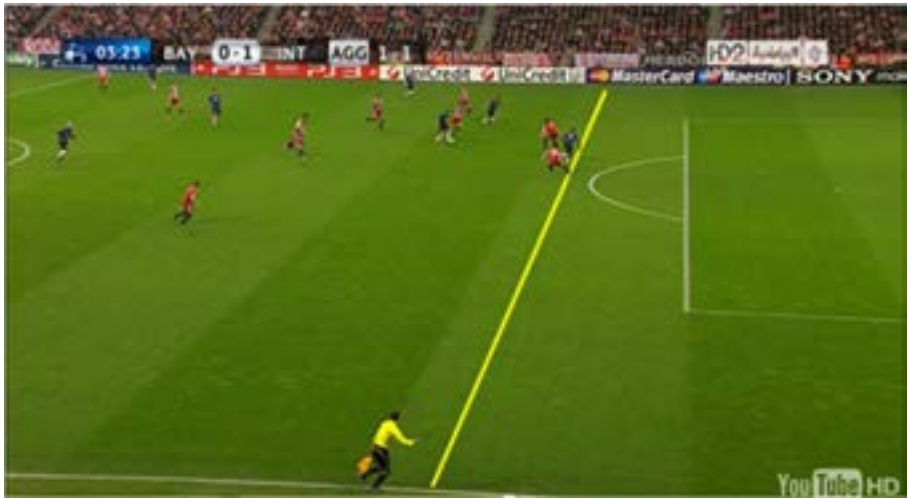
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

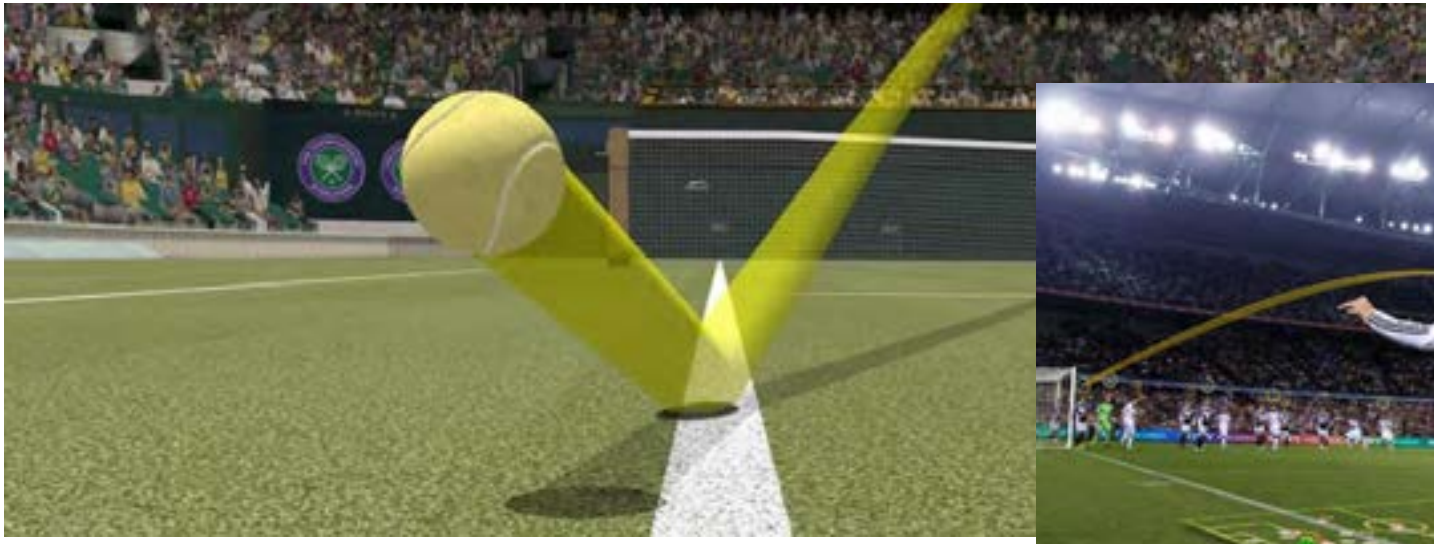
Augmented Reality in Medicine



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

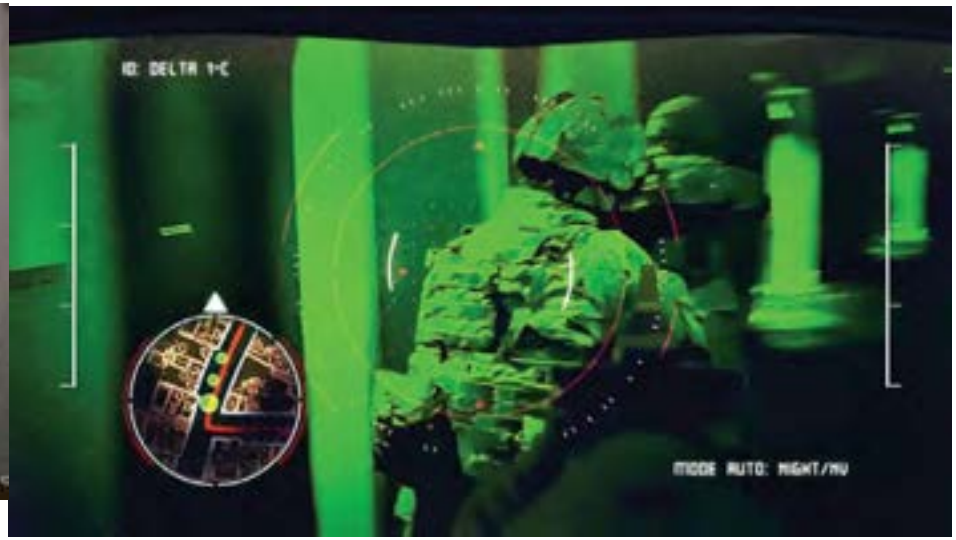
Augmented Reality in Sports





DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Augmented Reality in Military



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Augmented Reality APPS

Manufacturing
Maintenance
Security

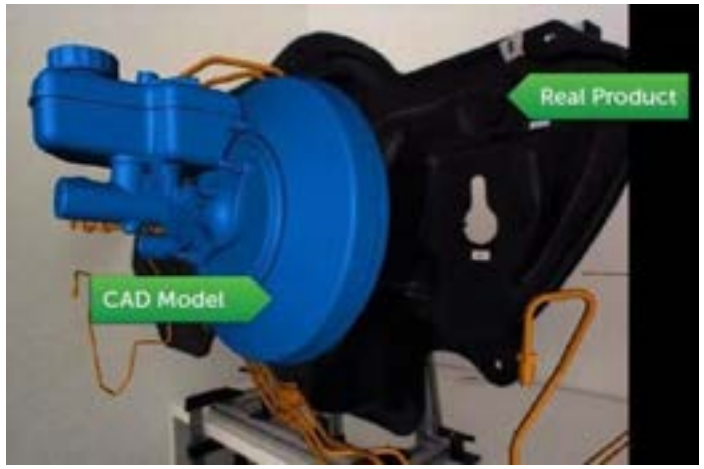
AR APPLICATIONS FOR I4.0

Design Checking

Fast detection of design flaws allowing evaluate alternatives and visualizing simulation results.

Deviation analysis

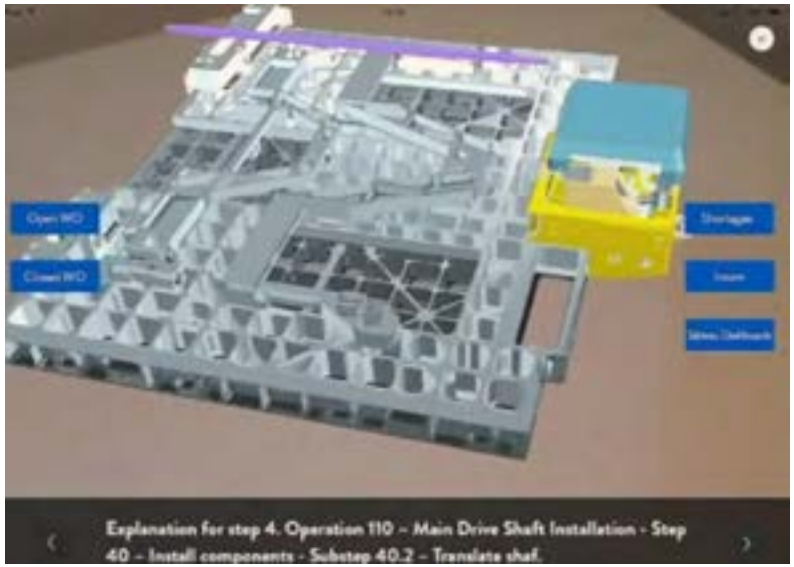
Combining virtual 3D objects on top of real products reduces or replace the need for physical prototypes.



AR APPLICATIONS FOR I4.0

Step by step assembly

- Interactive and intuitive step-by-step guidance
- Superimposition of 3D models to highlight construction parts
- Superimposition of 3D animations to show how to perform tasks directly on an area of interest
- Attachment of digital labels a and comments to real components



AR APPLICATIONS FOR I4.0

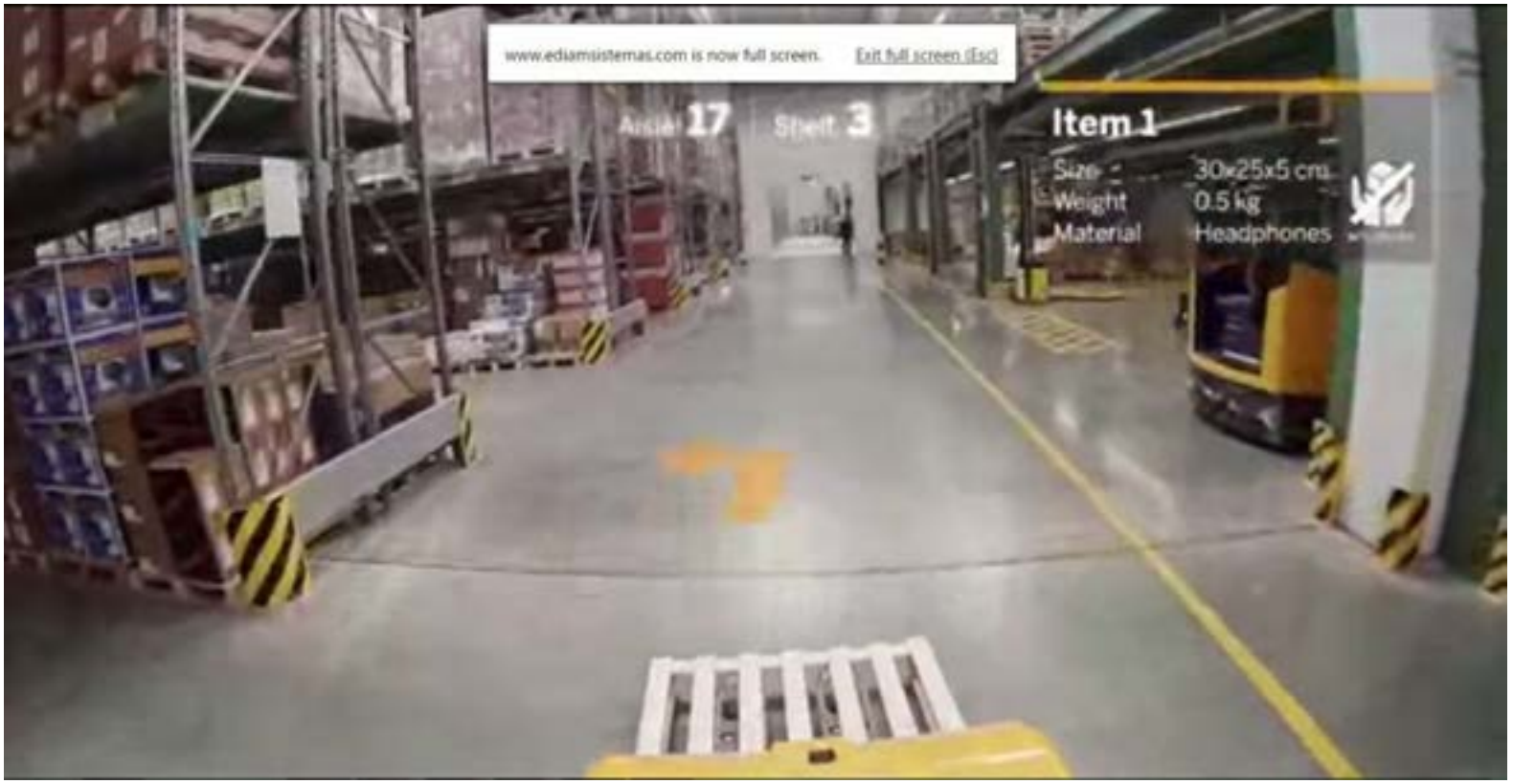
Step by step service and manteinance

Step-by-step instructions in a head-mounted display (HUD) directly in the user's field of view, facilitate and accelerate the maintenance, repair, or installation of complex units.

AR APPLICATIONS FOR I4.0

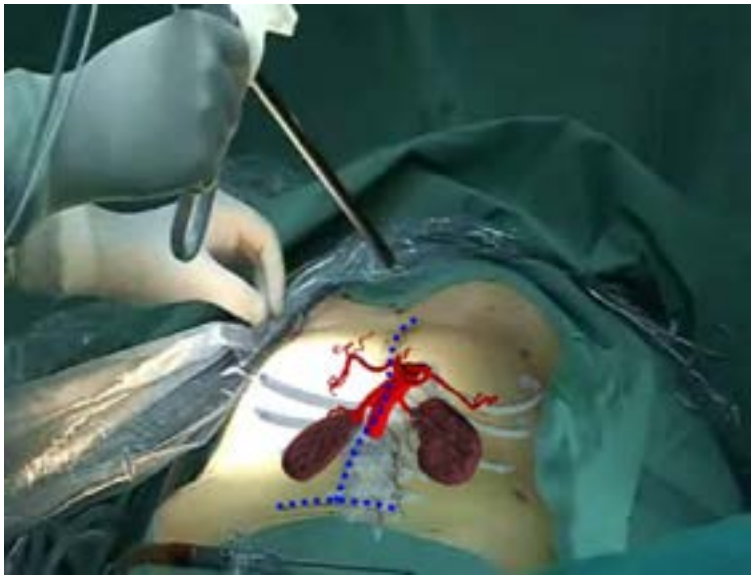
- **Advanced documentation**
  - 3D information directly from documents and manuals.
  - Hands free operation with AR + Smart Glasses

Logistics - Picking



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

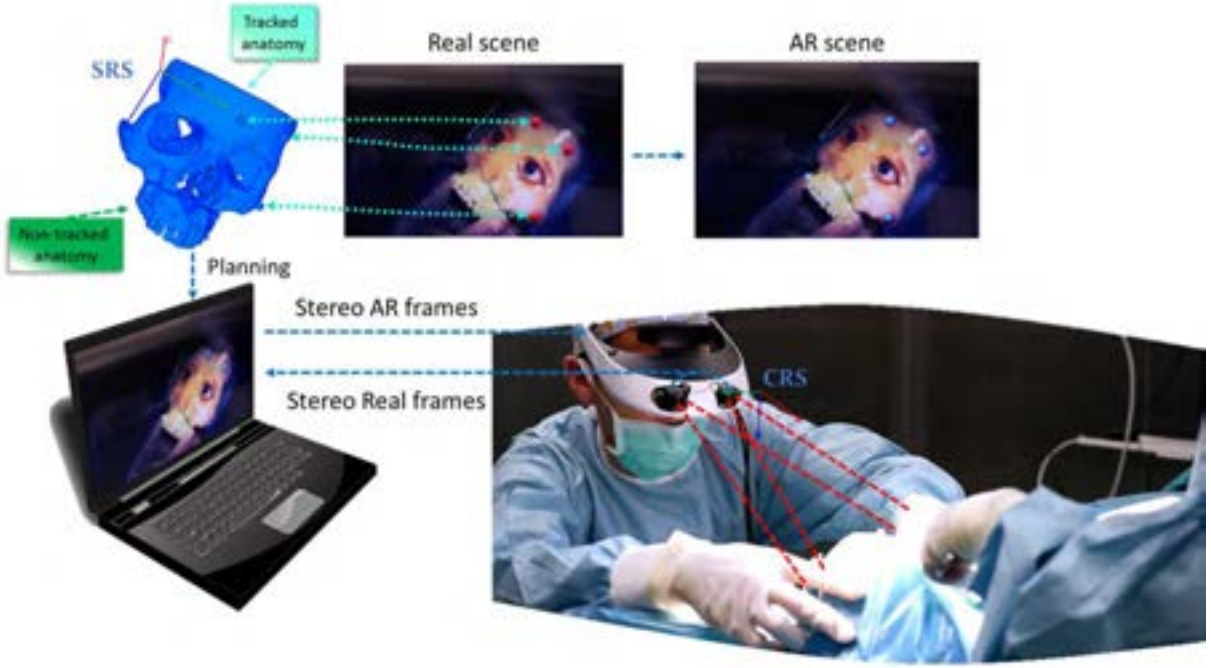
UNIPI and Augmented Reality challenge



UNIVERSITÀ DI PISA

ENDOCAS
CENTER FOR COMPUTER ASSISTED SURGERY

Augmented reality for maxillofacial surgery



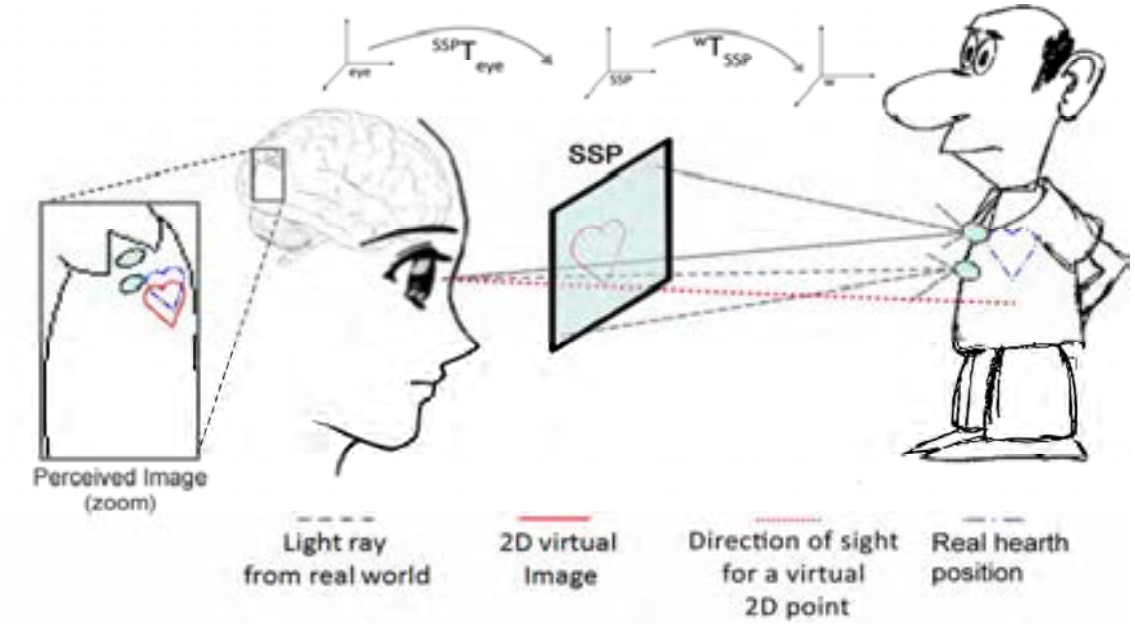
"Augmented reality for maxillofacial surgery: validation of a wearable system for maxillary repositioning," *Journal of Cranio-Maxillofacial surgery,* 2014.

Registration error with the Hololens

5mm at 50 cm

Confirmed in Condino et Al 2018 Journal of Healthcare Engineering

Optical See-Through AR display



Natural view

User dependent calibration troubles

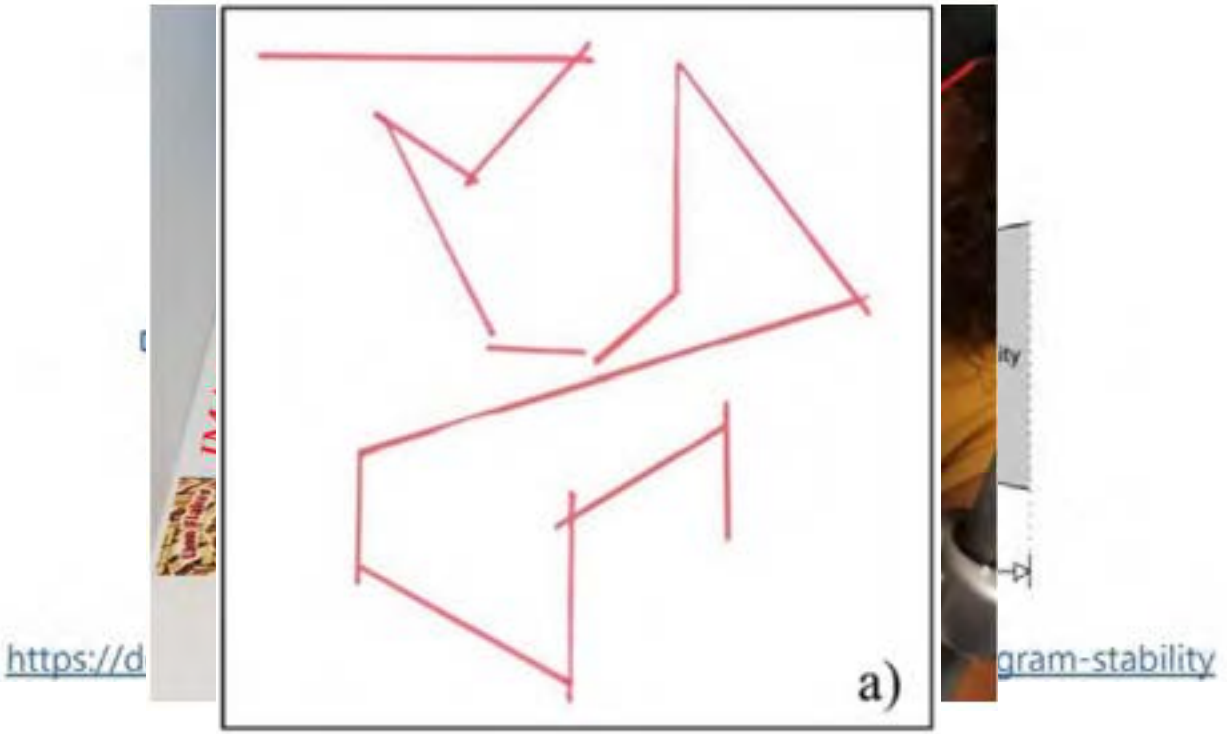
Focus discrepancy troubles

Vergence-accommodation conflict

Perceptual Limits of Optical See-Through Visors for Augmented Reality Guidance of Manual Tasks

S Condino, M Carbone, R Piazza, M Ferrari, V Ferrari

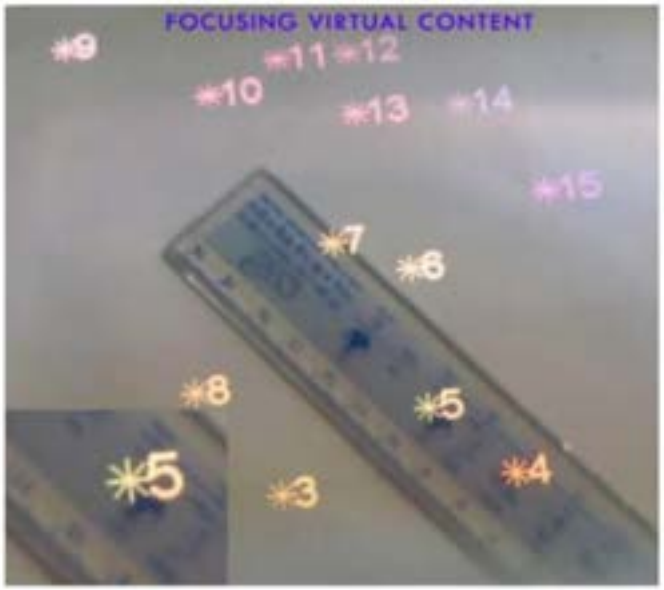
IEEE Transactions on Biomedical Engineering 2019

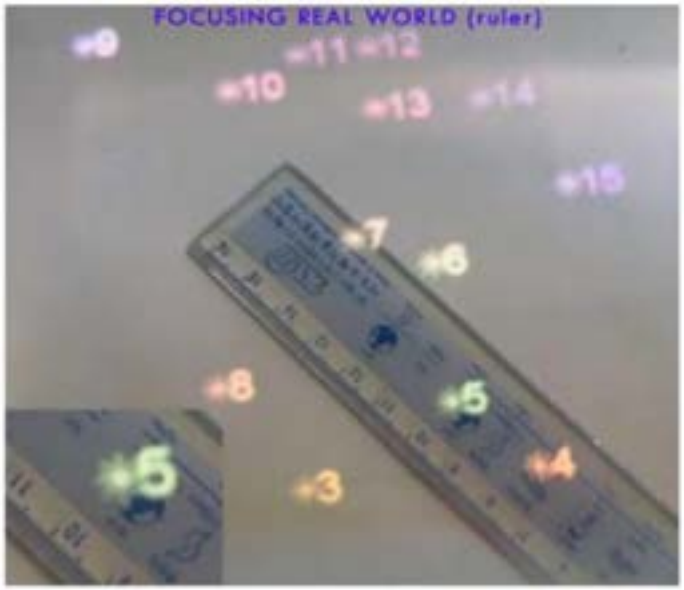


Perceptual Limits of Optical See-Through Visors for Augmented Reality Guidance of Manual Tasks

S Condino, M Carbone, R Piazza, M Ferrari, V Ferrari

IEEE Transactions on Biomedical Engineering 2019





VIDEO AND OPTICAL SEE-THROUGH
AUGMENTED REALITY SURGICAL SYSTEMS
VOSTARS
PHOTONICS21

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

IN SUPREMÆ DIGNITATIS 1343

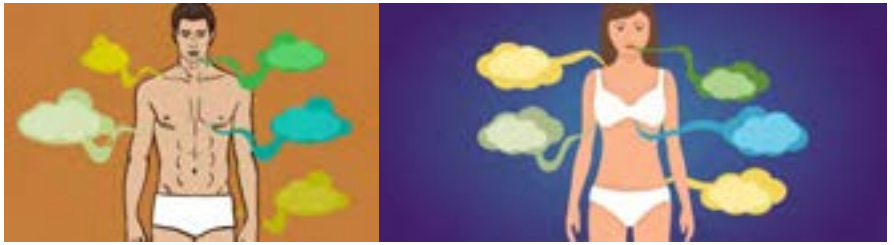
HORIZON 2020

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Main objectives

POTION aims to study the **human capacity to transmit emotions and influence social behaviour through body odour**: chemosignals.

When we feel emotions such as happiness and fear, the human body produces chemosignals which are released through sweat and which could be emotionally contagious the moment they are perceived by others.



DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

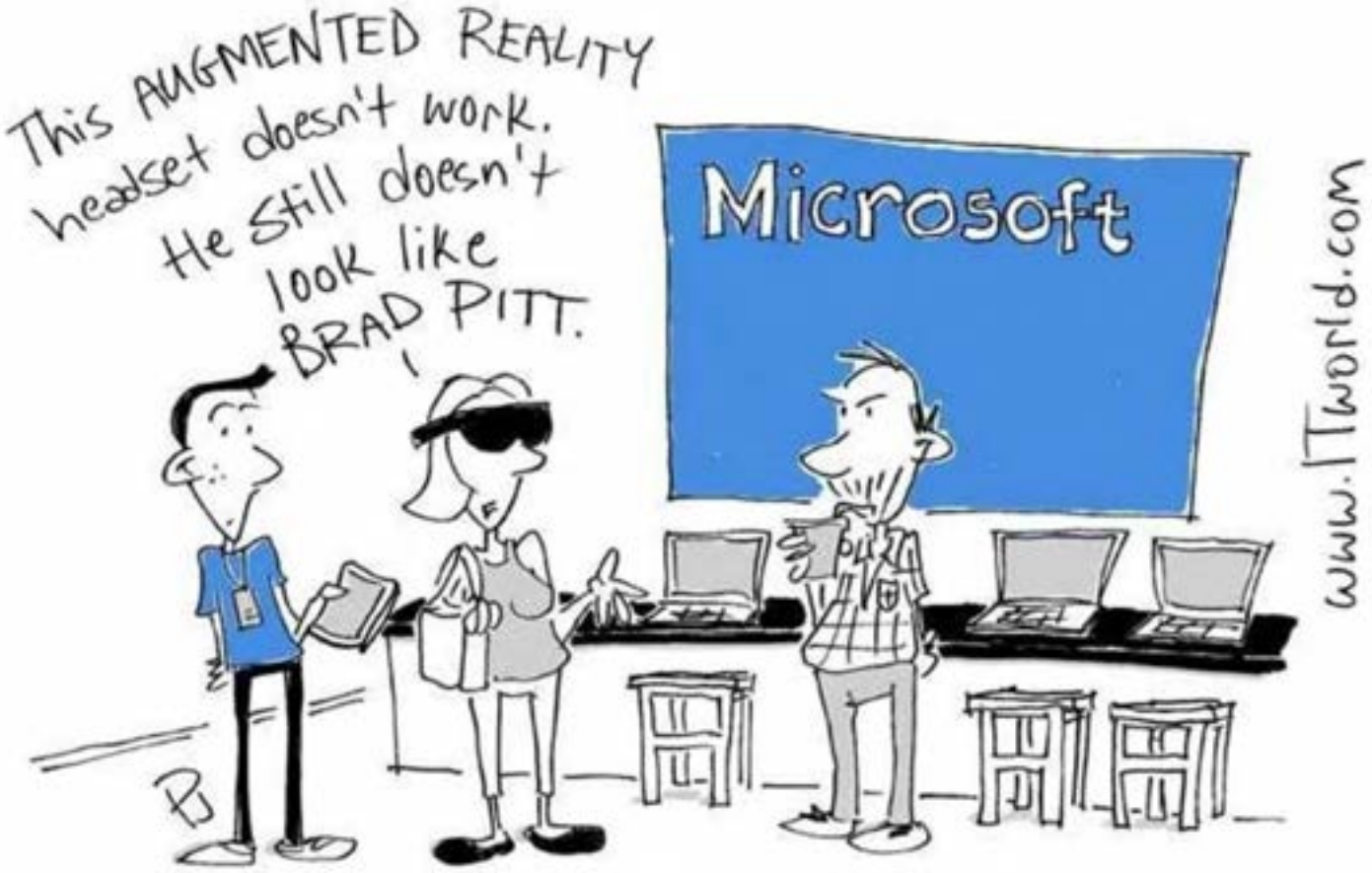
Identify human chemosignals in body odours

POTION will take up the challenge of identifying **human chemosignals associated to happiness and fear.**

To this aim, sweat will be collected in **sorbent pads** or **tubes** placed under the armpit of subjects undergoing a controlled emotional stimulation (vision of fear- or happiness-inducing **movies** in **virtual reality**).

Strict recruitment criteria and a specific protocol concerning diet, smoke and personal hygiene will reduce odour variability and possible contaminations.

Conclusion

Virtual, Augmented reality and Mixed reality have a very strong potentials and maybe they are currently only at an initial stage but for sure they will have a very big role in our lives in the future when these technologies are matured enough.

ANY QUESTIONS?