ESILV
ENGINEERING SCHOOL
DE VINCI PARIS

IHM & Extended Reality (xR)

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… - …
2022/2023

SUMMARY

02. Extended Realities

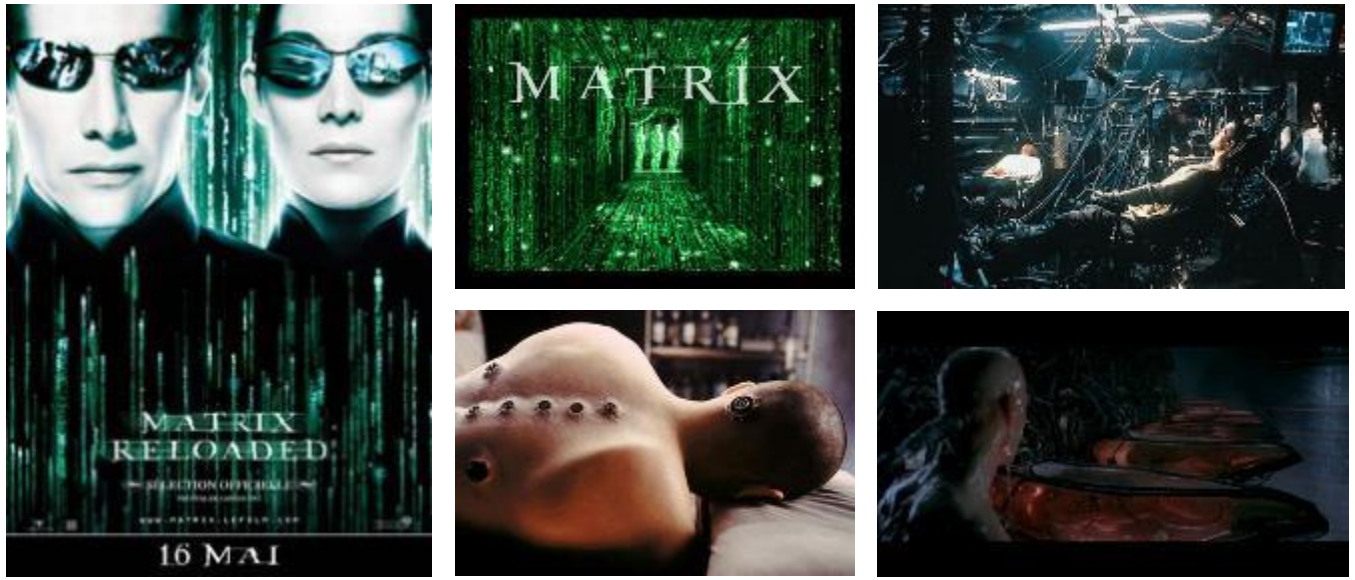
01. Introduction
02. Augmented reality
03. Virtual Reality
04. Mixed Reality

Introduction

From science fiction to reality

- Film **The Matrix** 1999, 2003
  - An imaginary future in which the reality perceived by most humans is in fact a **virtual simulation** called the "Matrix", created by intelligent machines to subjugate and use the human population.

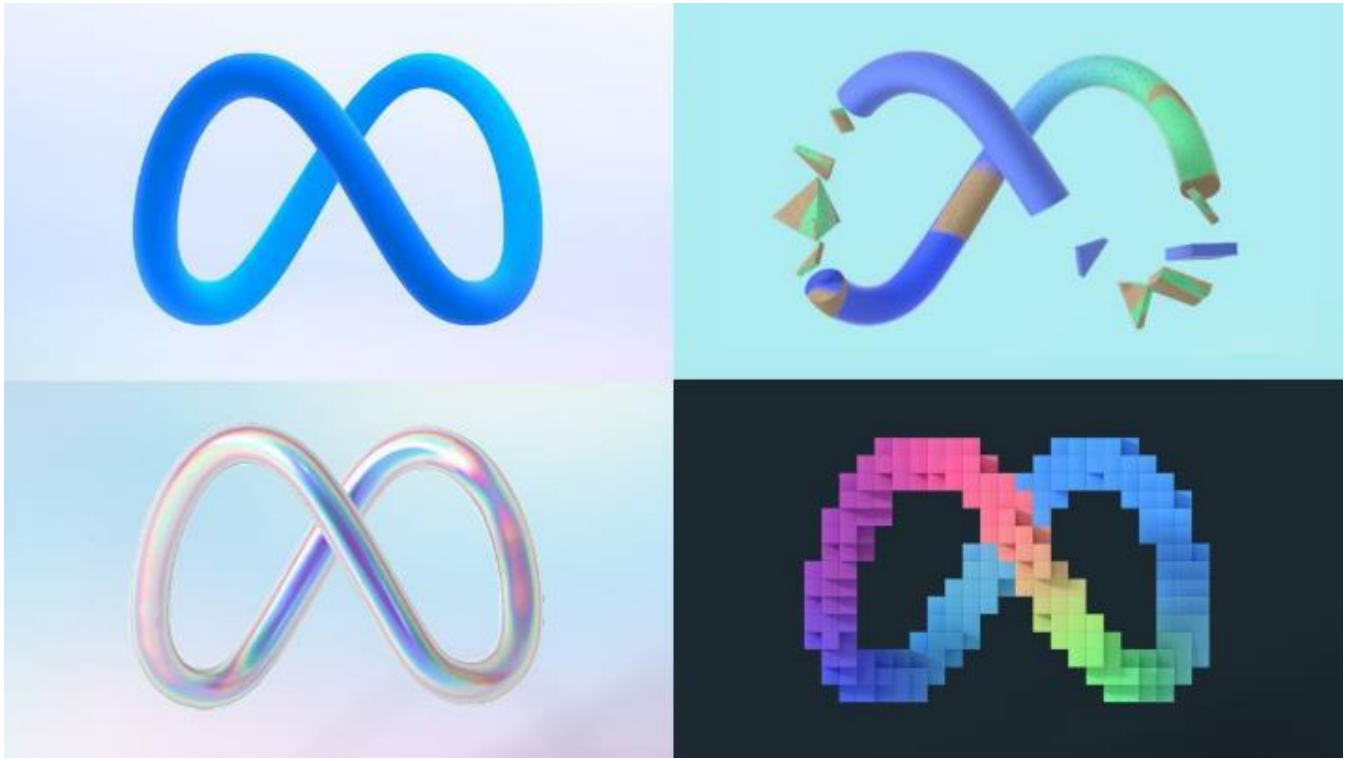
  - "The Matrix" (1999) -- 'Construct' Scenes : https://www.youtube.com/watch?v=AGZiLMGdCE0
  - The Matrix - Battery: https://www.youtube.com/watch?v=IojqOMWTgv8



From science fiction to reality

- Facebook goes meta
  - **Metverse** : https://www.youtube.com/watch?v=gElfIo6uw4g
  - **Horizon World :** https://www.youtube.com/watch?v=02kCEurWkqU&t=3s

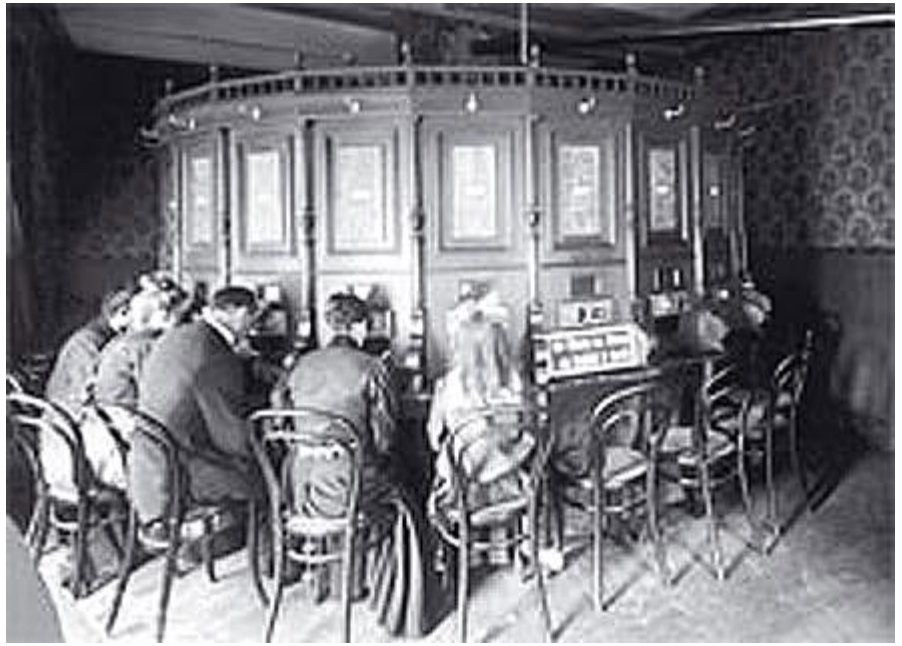
The metaverse is a hypothetical iteration of the Internet as a single, universal and immersive virtual world that is facilitated by the use of virtual reality (VR) and augmented reality (AR) headsets. In common parlance, a metaverse is a network of 3D virtual worlds focused on social connection.



Before VR

First **stereoscope** created by the English physicist Charles Wheatstone, who submitted a paper to the Royal Academy in 1838.

The **stereoscope** had two mirrors at 90° which reflected the gaze laterally towards two specially prepared stereoscopic drawings. Then the principle was applied to photography.



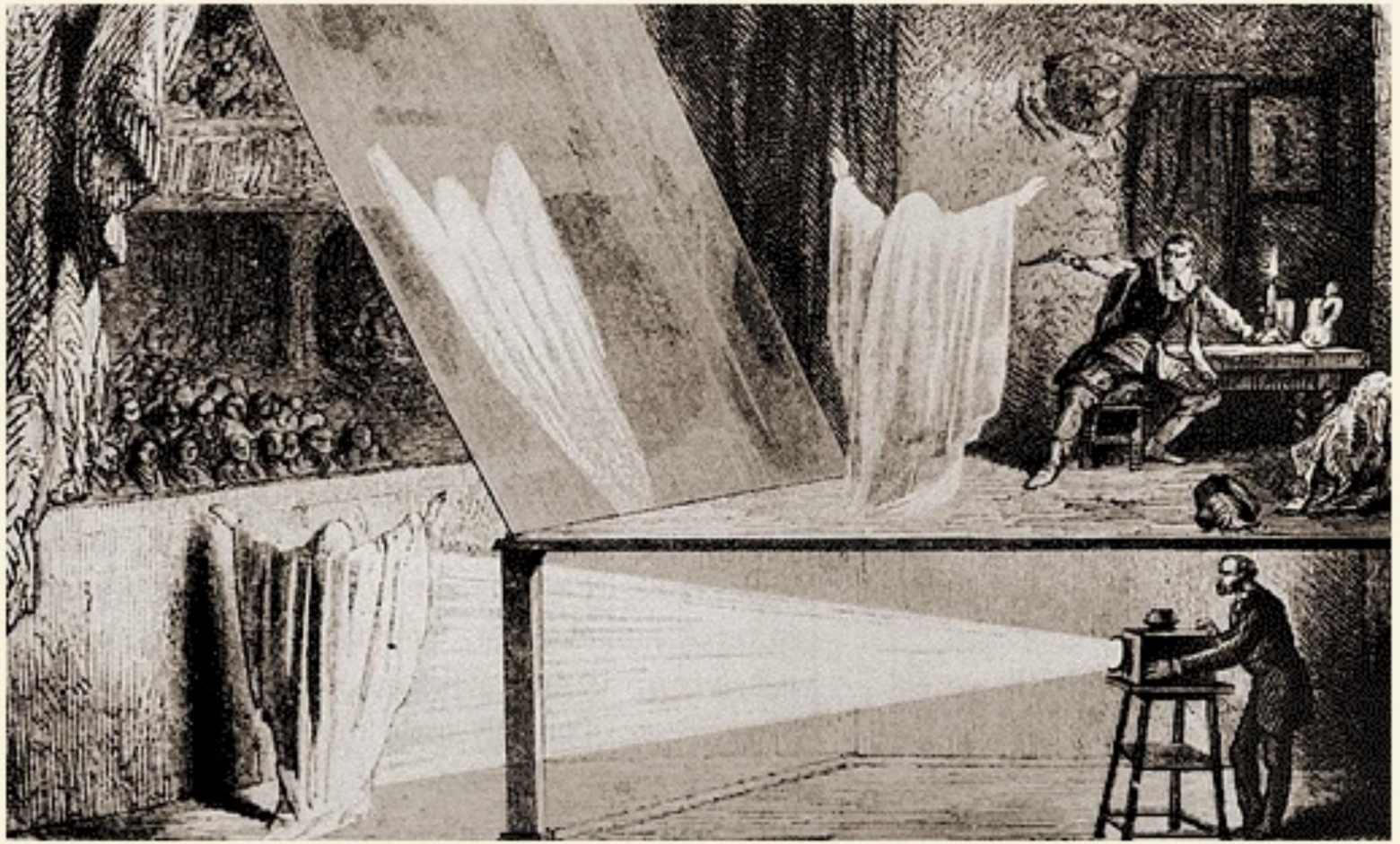
Stereoscope projection at the "Kaiserpanorama" in the Vienna Prater, around 1900

Before AR

Pepper's ghost is an illusion technique used in the theatre, cinema, amusement parks, museums, television, and concerts.

It is named after the English scientist John Henry Pepper (1821–1900) who began popularising the effect with a theatre demonstration in 1862

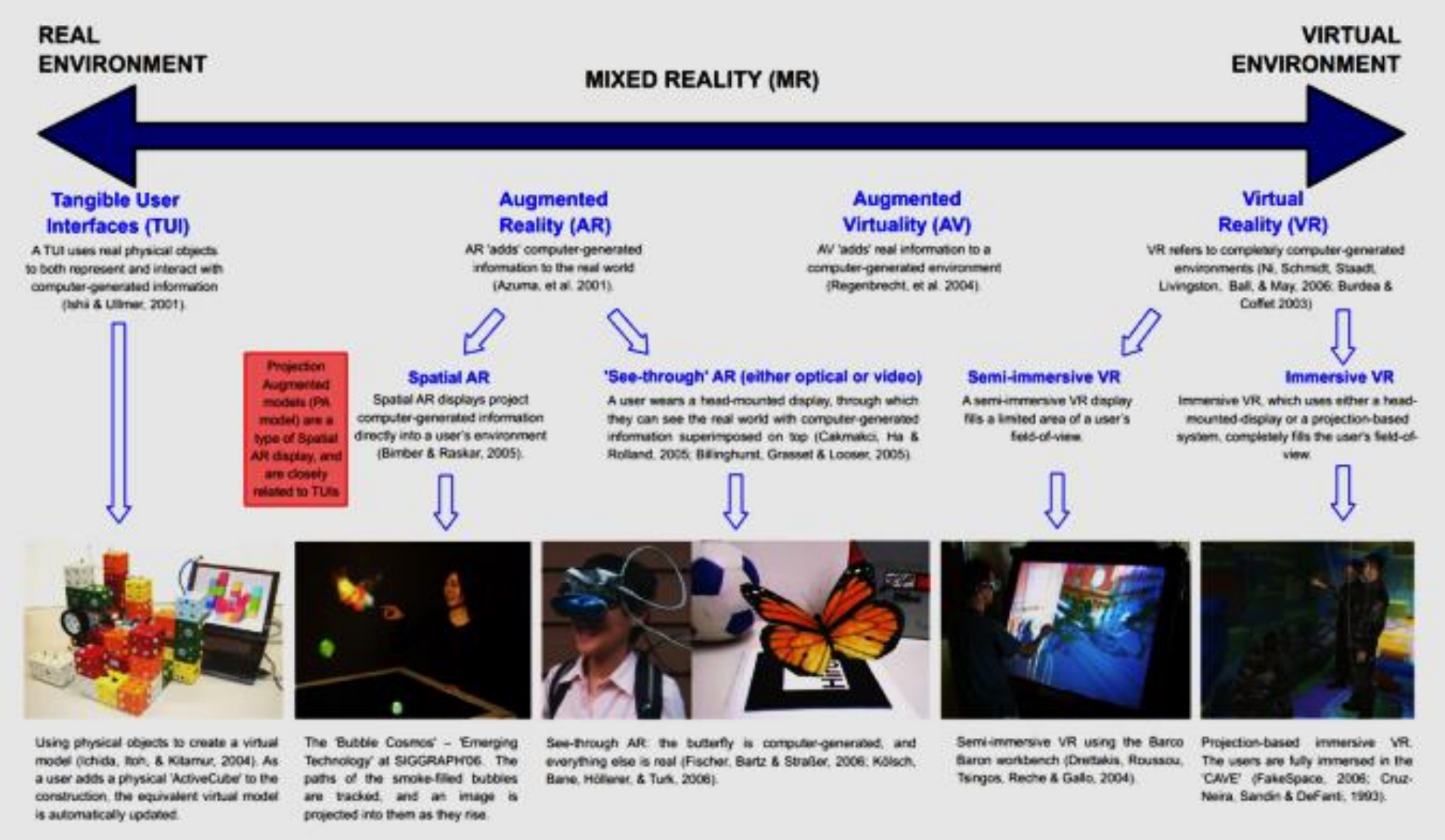
Pepper's Ghost 1862



Reality-virtuality continuum (Paul Milgman, 1994)

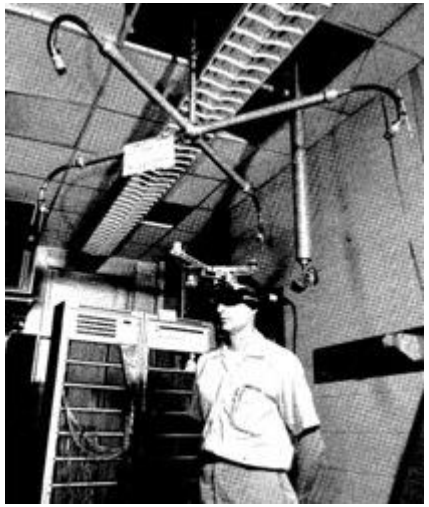
- Continuous scale that goes from the **all real** (reality) to the **all virtual** (virtuality),.

- It encompasses all possible compositions of real and virtual objects



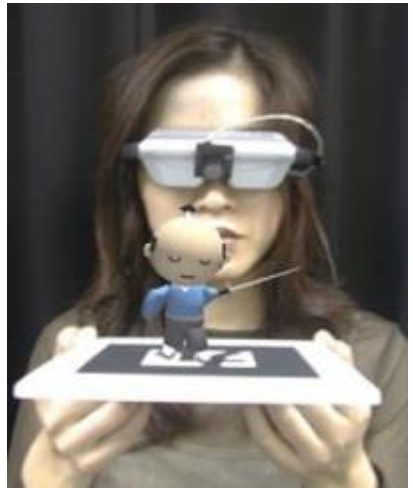
Extended reality history

- **1968** : The Sword of Damocles - **First virtual reality machine** - MIT , (Ivan Sutherland)
- **1992**: Proposal of the **word augmented reality**, (Tom Caudell and David Mizell)
- **1992**: Virtual Fixtures - **first AR system**, at the U.S. Air Force Research Laboratory (Louis Rosenberg)
- **1994**: **Virtual Reality Continuum** Proposal, (Paul Milgram and Fumio Kishino)
- **1996** : Introduction of **2D markers** for virtual objects visualization, (Jun Rekimoto)



Ivan Sutherland

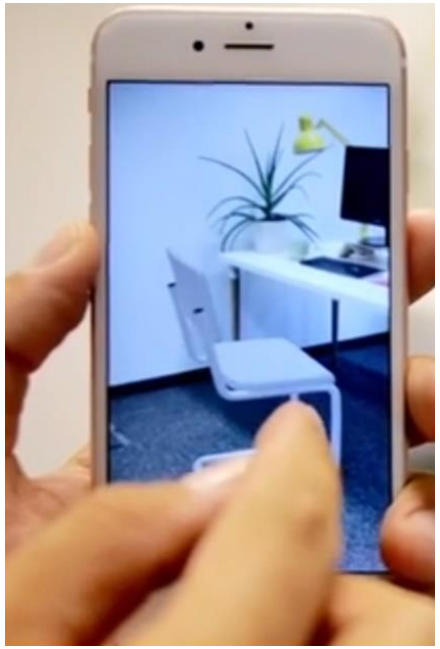
Luis Rosenberf
(First AR application)



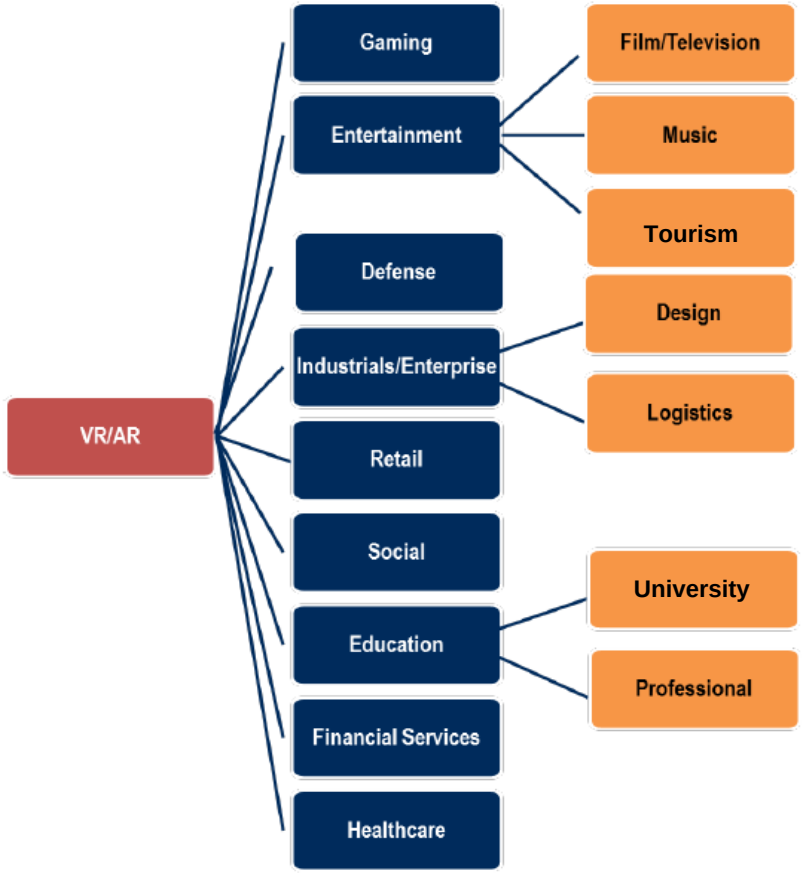
Jun Rekimoto

Extended reality history

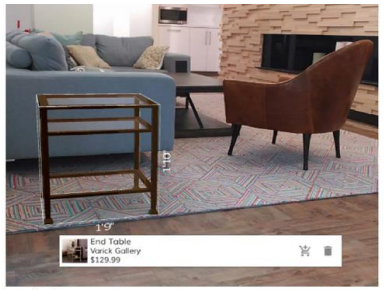
- **2010: virtual dressing rooms** had been developed for e-commerce.
- **2012:** royal Dutch mint strikes the first **coin with augmented reality**.
- **2015:** first **live greeting cards** made using augmented reality through iGreet mobile App.
- **2018: USDZ AR file support** for iPhone so people can experience augmented reality.
- **2018:** Canadian e-commerce company Shopify, integration ARkit2 to **allow merchants to upload 3D** models of their products so that costumers could see them in their real world environments.



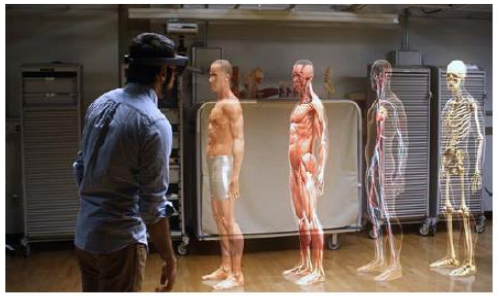
XR use cases



Source: Honeywell



Source: Google



Source: Microsoft

Source: Rockwell Collins

XR use cases

simulation & training

visualization & entertainment

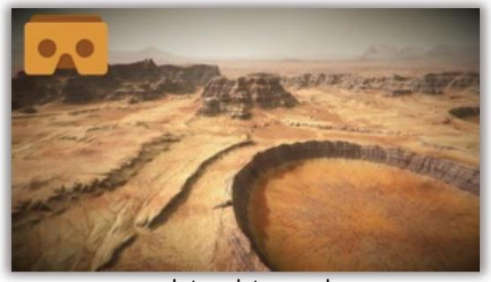
remote control of vehicles, e.g. drones

gaming

robotic surgery

architecture walkthroughs

education



virtual travel

a trip down the rabbit hole

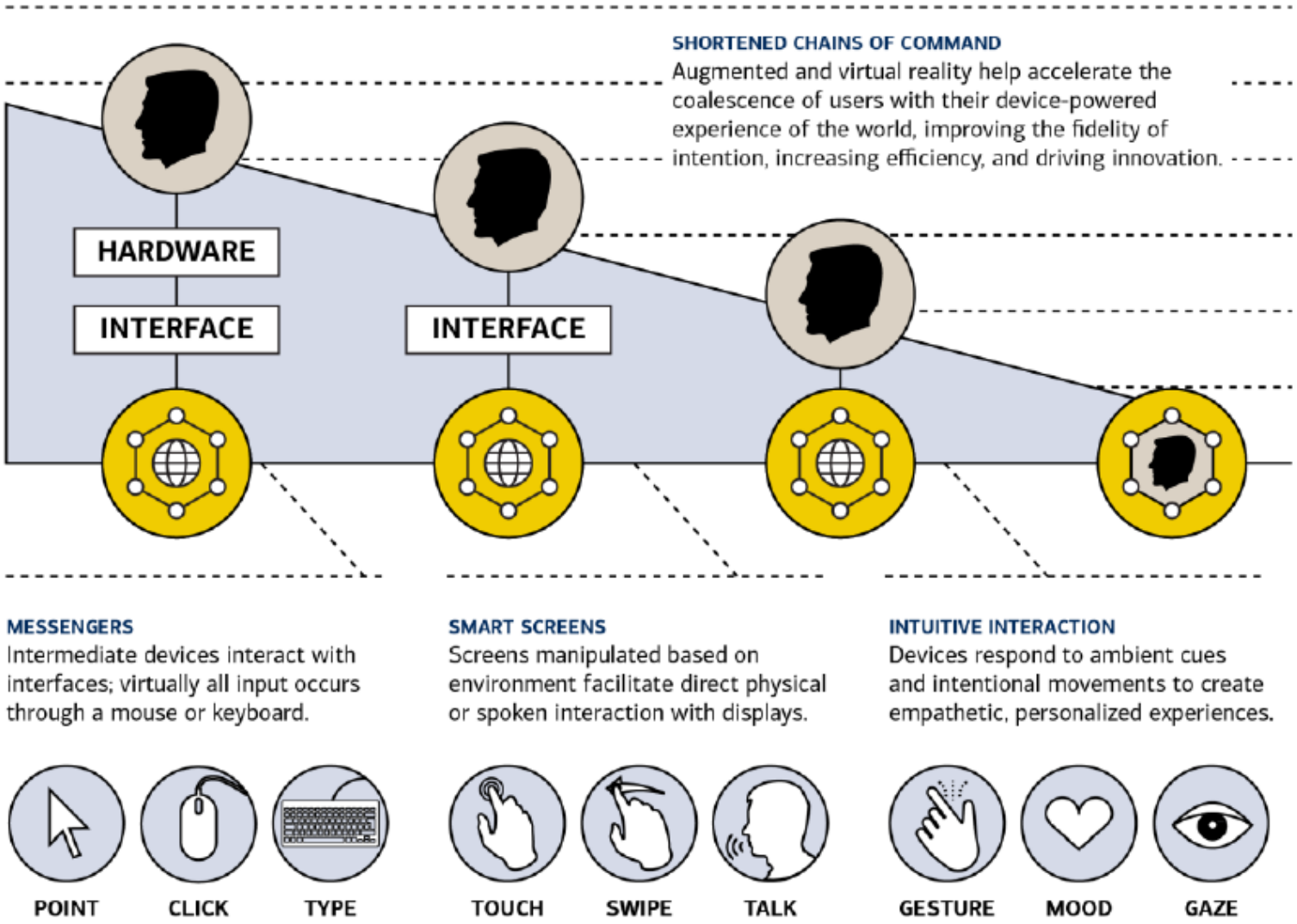
XR use cases

VR at Stanford's Medical School

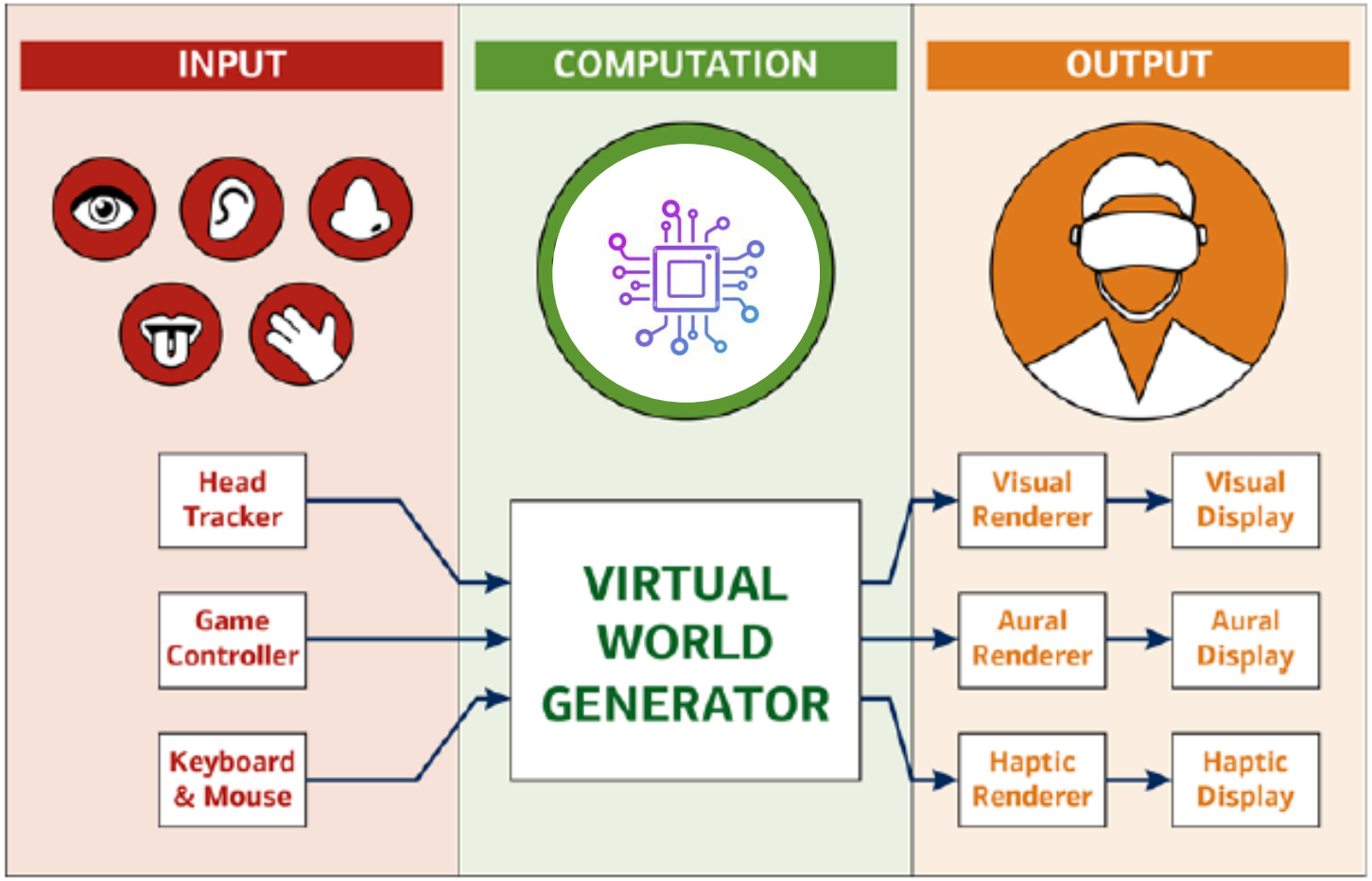
photo from Stanford Medicine News

- Lucile Packard Children's Hospital: used to alleviate pain, anxiety for pediatric patients
- VR Technology Clinic: applications in psychotherapy, mental health, for people with phantom pain, …
- help train residents, assist surgeons planning operations, …

Revolution in Human-Computer Interaction



xR workflow



Source: BofA Merrill Lynch Global research

The Brain

Revolution in Human-Computer Interaction

- 4th computer revolution after the PC, the laptop, the smartphones

Personal Computer
e.g. Commodore PET 1983

Laptop
e.g. Apple MacBook

Smartphone
e.g. Google Pixel

AR/VR
e.g. Microsoft Hololens

xR : an emerging technologie

National Academy of Engineering

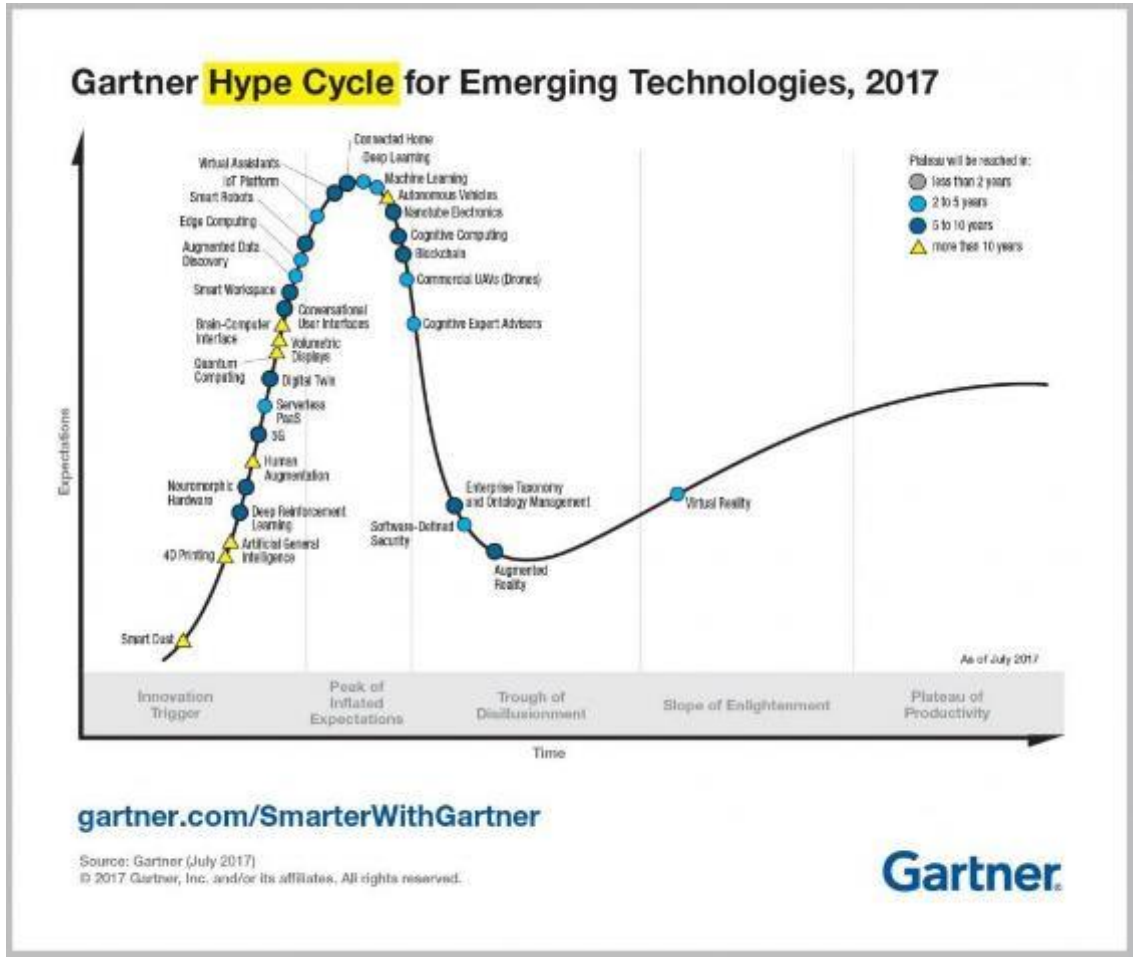
"Enhance Virtual Reality" is 1 of 14 NAE grand challenges for engineering in the 21st century

image from NAE

xR : an emerging technologie

- Curve describing the evolution of interest in a new technology.

- Three major families of emerging technologies in the next 10 years:
  - **Artificial intelligence**
  - **Extended realities**
  - **Digital platforms (IoT, 5G, quantum...)**

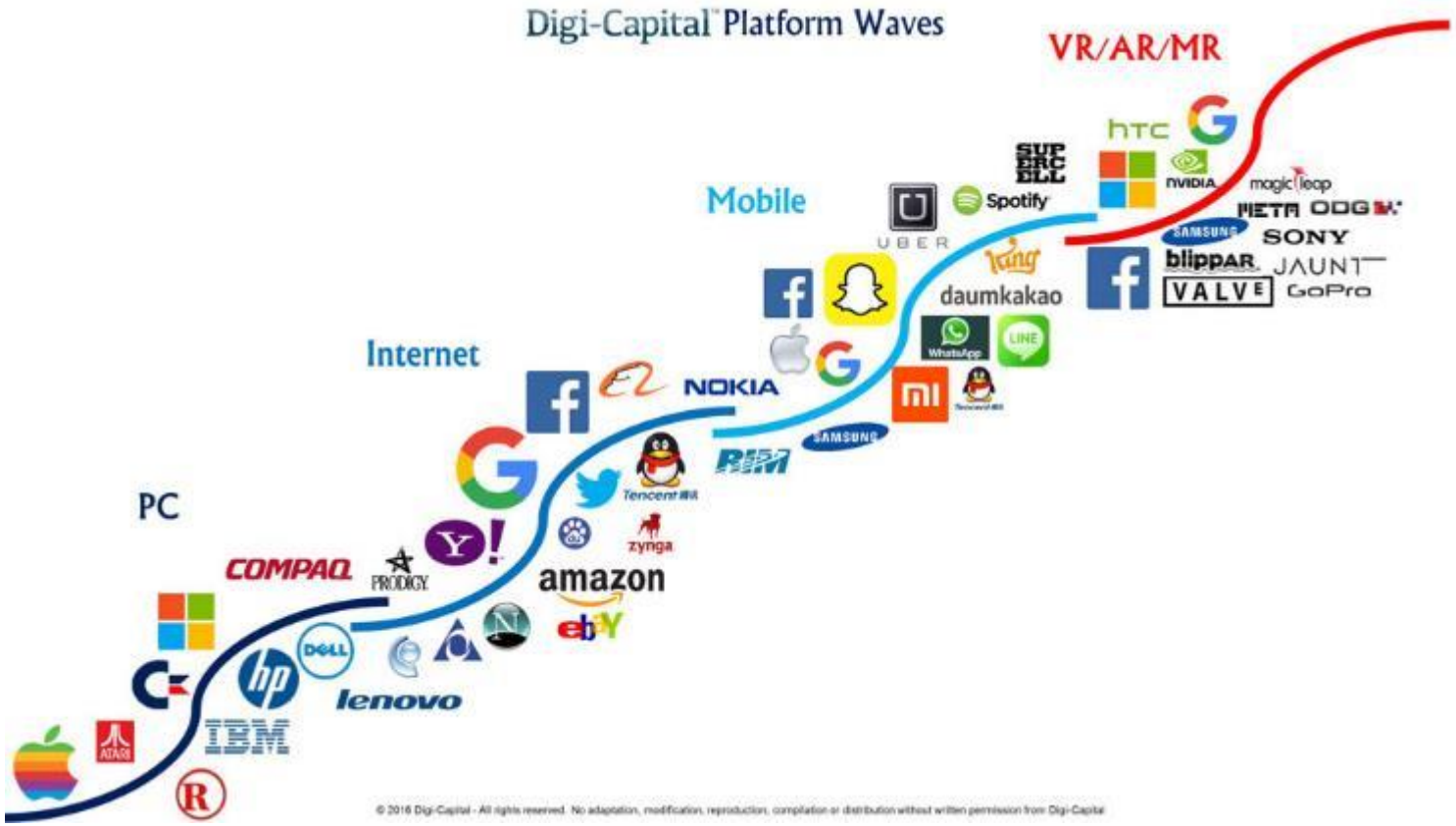


xR ecosystem

Source : Cabinet Digi-Capital

xR ecosystem

- Operators' waves



Exciting Engineering Aspects of VR/AR

- Integrates various technologies such as sensors, Big Data, cloud, AI, and wearable technology.

- cloud computing
- shared experiences

- CPU, GPU
- IPU, DPU?

- sensors & imaging
- computer vision
- scene understanding

- compression, streaming

images by microsoft, facebook

- VR cameras

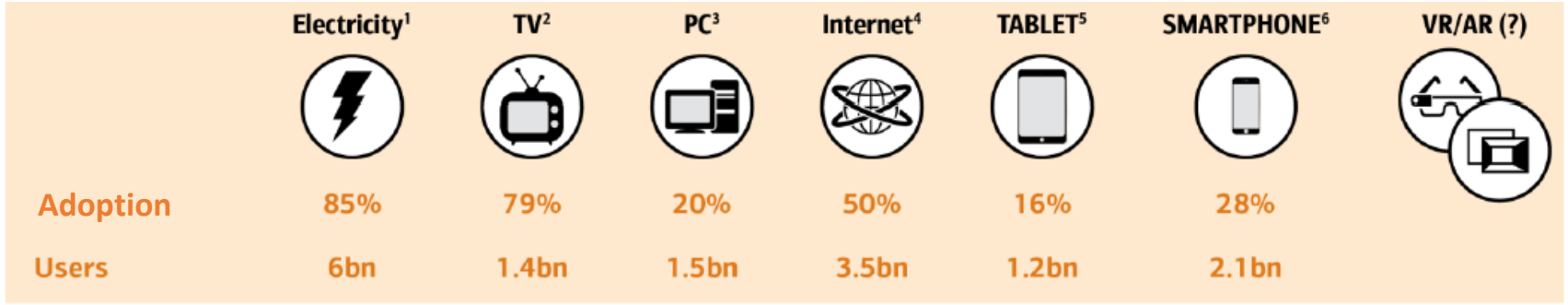
- photonics / waveguides
- human perception
- displays: visual, auditory, vestibular, haptic, …

- HCI
- applications

Adoption of AR/VR

- A computer cycle takes place every 10 to 15 years,
- Each new major cycle completely reshapes the IT landscape.

In 2016



Source: [1] 2012 / World Bank, UN; [2] 2012 / TVTechnology; [3] 2015 / Gartner, UN; [4] 2016 / ITU; [5] 2016 / eMarketer; [6] 2016 / eMarketer

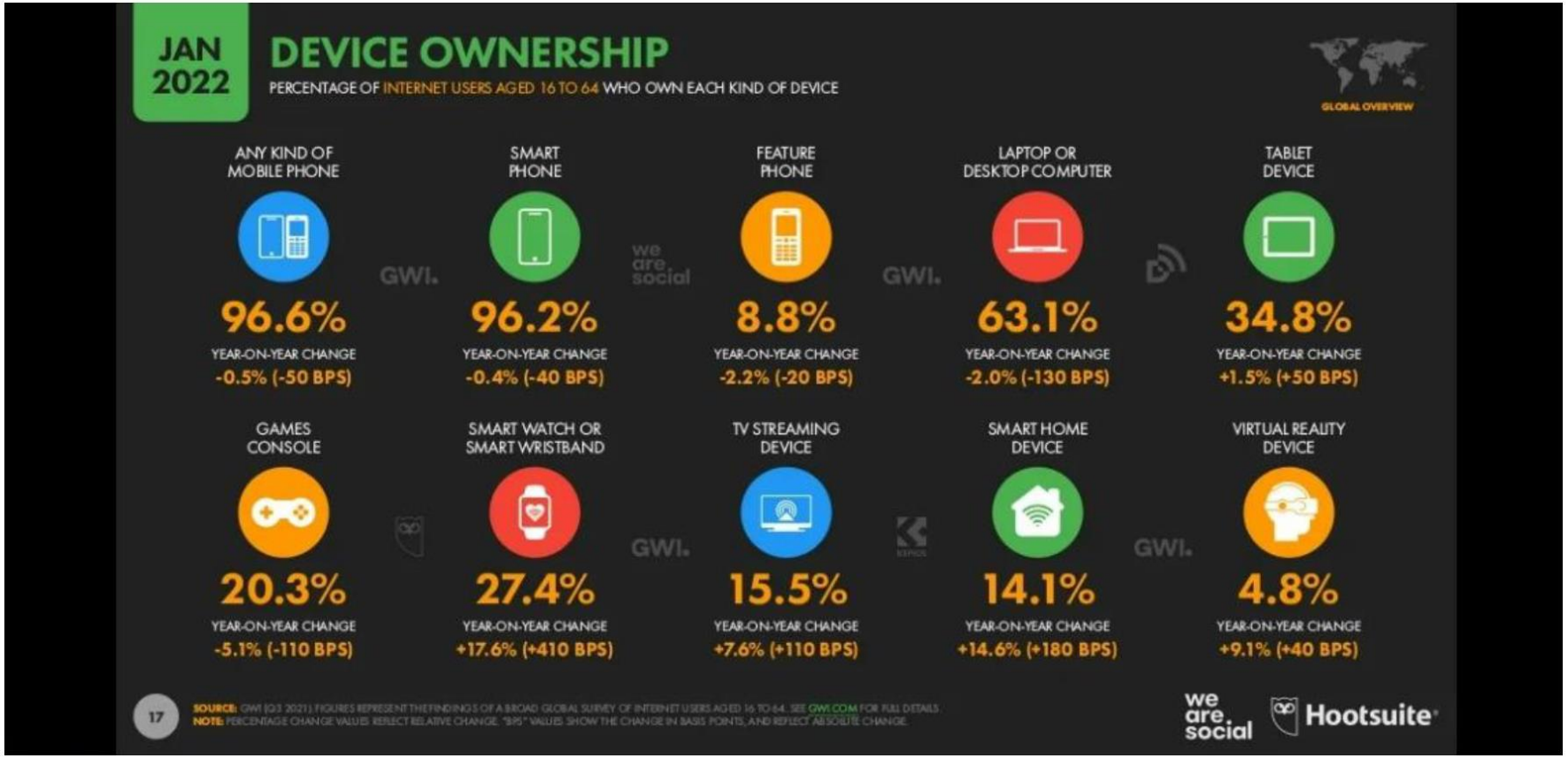
Source: BofA Merrill Lynch Global Research

(Based on industry experts Mitchell Waldrop and Chris Dixon of Andreessen Horowitz)

Adoption of AR/VR

- 96% of the world's population uses a cell phone.
- ~5% of the world's population uses VR/AR devices.

Today (2022)



Extended Reality Types : VR / AR / MR

Virtual Reality

Digital environments
that shut out the real world.

Augmented Reality

Digital content on top
of your real world.

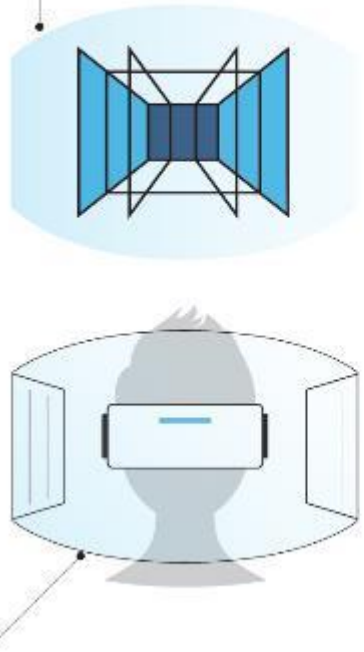
Mixed Reality

Digital content interacts
with your real world.

Extended Reality Types : VR / AR / MR

VIRTUAL REALITY (VR)

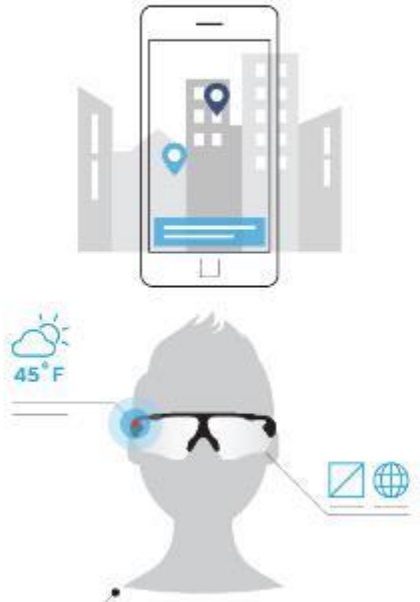
Completely digital environment



Fully enclosed, synthetic experience with no sense of the real world.

AUGMENTED REALITY (AR)

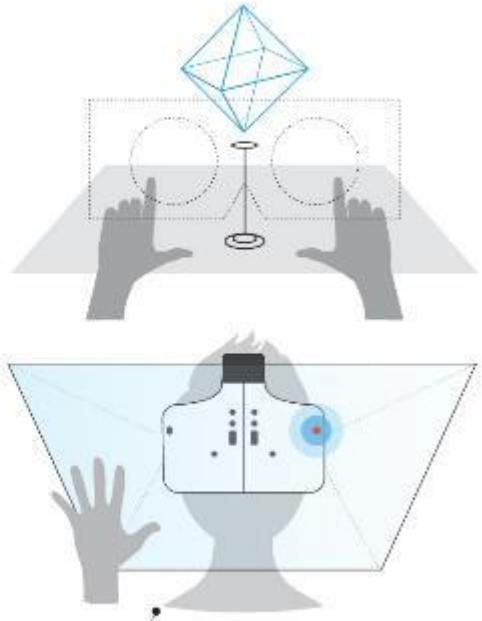
Real world with digital information overlay



Real world remains central to the experience, enhanced by virtual details.

MERGED REALITY (MR)

Real and the virtual are intertwined



Interaction with and manipulation of both the physical and virtual environment.

Also Diminished Reality (DR)

not covered in this course

- Deleting an element on a "real" image in real time
  - Real image

  - Image after deletion

Diminished Reality (DR)

- It is a type of computer-aided reality technology that allows, to remove, conceal, or eliminate real-life objects from your environment in real-time. Those objects are made artificially invisible and replaced with backgrounds or other digital 3D objects.

- It is referred to as the opposite of augmented reality (AR), diminished reality takes from the world instead of adding to it.

- DR and AR can be complementary

- Example : https://www.youtube.com/watch?v=y5nDW5QNWcI

Augmented Reality

Augmented reality

- Augmented reality
  - Interactive experience that combines the real world and computer-generated content (virtual objects)
  - Real environment, virtual objects
  - the virtual is projected onto the real, in real time
    - on screen
    - on the real ...or almost

Types of Augmented Realities

- Augmented reality
  - Marker-based
    - Recognition-based
  - Marker-less
    - Location-based
    - Projection-based
    - Overlay-based

Recognition-based Augmented Reality

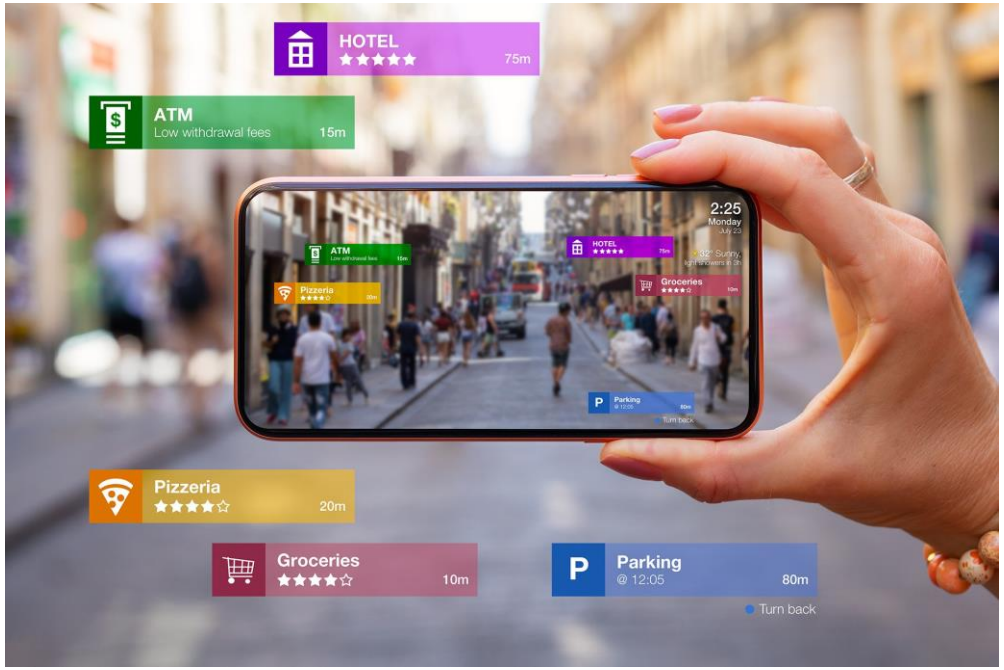
- AR type that uses markers that must be recognized to display elements such as a 3D version of an object or image or additional information about an object.
- Recognition-based augmented reality is one of the most widely used at the moment, since it only requires smartphones or tablets to make it work.

Overlay-based Augmented Reality

- Replaces, entirely or partially, the real vision of an object to show you an "augmented" version.
- A variation of recognition-based augmented reality, but instead of using a specific marker, it uses real objects that are detected in real time.

Location-based Augmented Reality

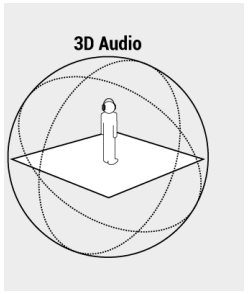
- At the opposite of recognition-based augmented reality. Location-based augmented reality shows you things based on where you are physically at that moment, without having to use a marker, just your surroundings.
- To operate, it uses the components of an average smartphone: accelerometer, digital compass and of course, GPS. These are the elements responsible for knowing your position.



Projection-based Augmented Reality

- It projects an image onto physical elements and spaces in the real world.
- One of the most appealing, as it is possible to make these projections interactive, like a keyboard projected onto a desk.
- Can also be used to see how an object fits into its future location and choose its possible position and orientation.
- Holograms is another example of projection-based AR.

Types of augmentation



- **Visual**
  - See virtual objects
- **Sound**
  - Listen to virtual 3D Sound
- **Haptics**
  - Touch new feeling
- **Movement**
  - Undergo movements
- **Smell, taste**
  - Artificially smell and taste

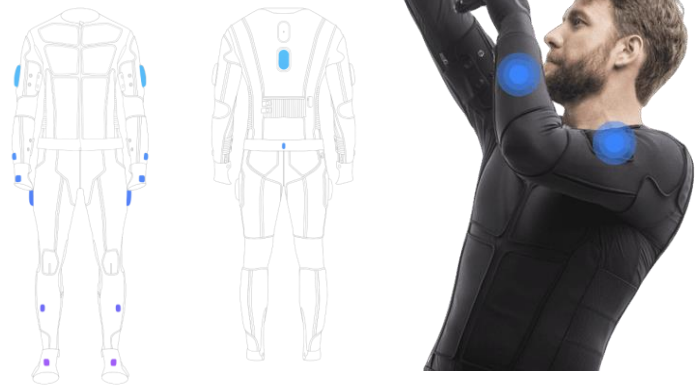
Haptic AR

Haptic Feedback

TESLASUIT's full body haptic feedback system uses electro muscle stimulation (EMS) and transcutaneous electrical nerve stimulation (TENS) to simulate a range of real-life feelings and sensations.

Motion Capture

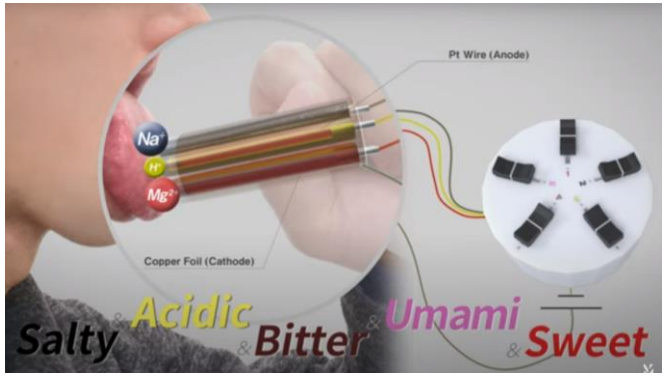
TESLASUIT's motion capture system uses 14 Inertial Measurement Unit (IMU) sensors to identify specific points around the TESLASUIT to track, record and monitor the movements and positioning of users. Each IMU sensor is made up of an accelerometer, gyroscope, and magnetometer.



https://teslasuit.io/

Taste AR

Production of a novel taste display which uses ion electrophoresis in five gels containing electrolytes that supply controlled amounts of each of the five basic tastes to apply a given taste to the user's tongue



Homei Miyashita (Meiji University), https://dl.acm.org/doi/abs/10.1145/3334480.3382984

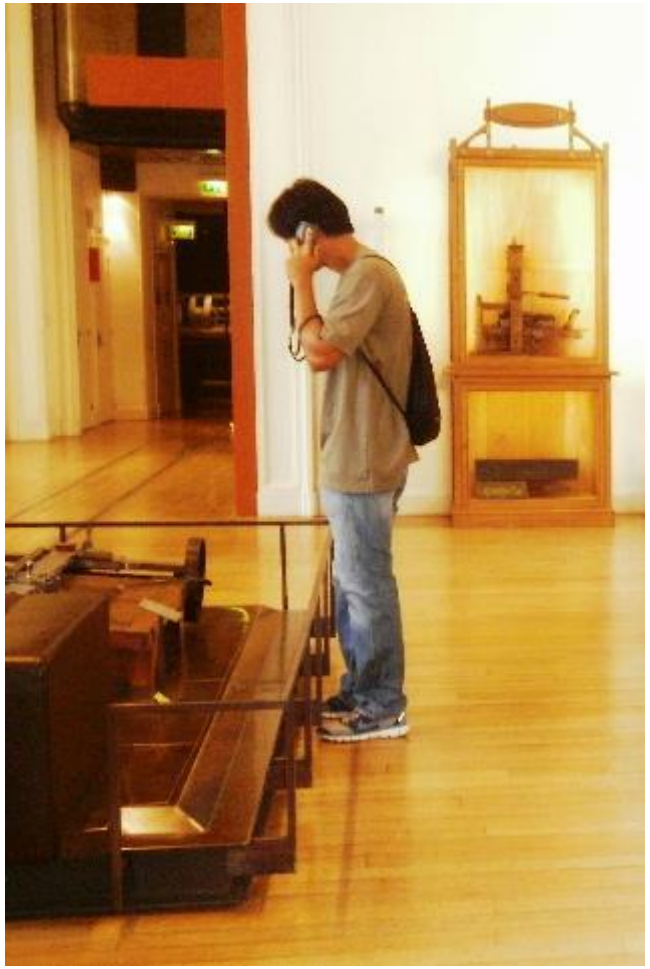
Sound AR

Spatialized audio guide (SARIM)

Automatic detection of the position and visitor orientation

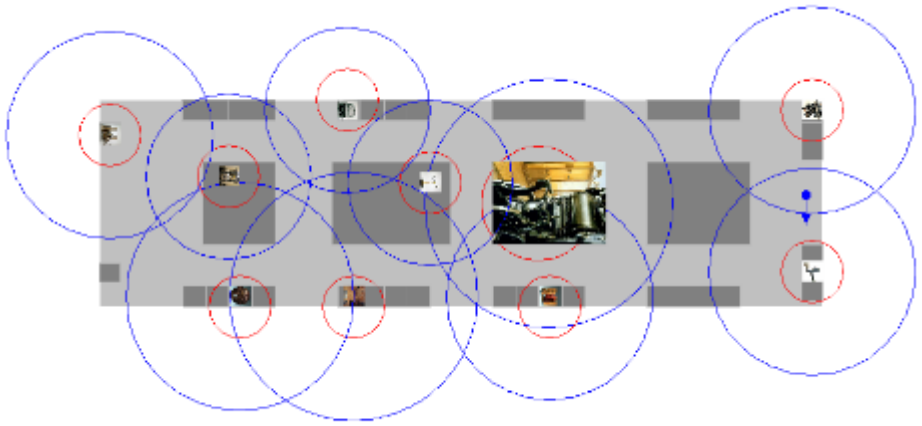
Classic audio guide (audiopass)

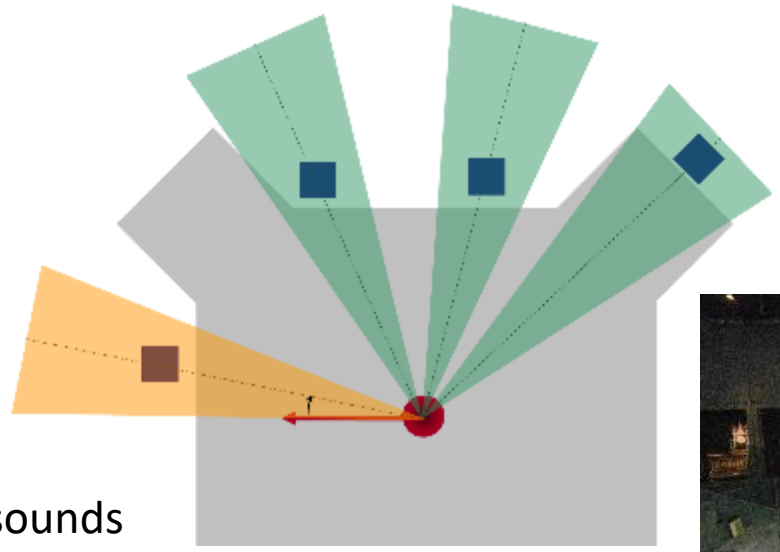
Manual selection of the object by the visitor and the desired content



Kaghat & Azough, Musée des arts et métiers, Paris, https://www.sciencedirect.com/science/article/abs/pii/S0045790620304614

Sound AR





- Immerse the visitor in an environment of ambient machine sounds
- Automatically gide the visitor through the museum

Experiments repeated in a real environment

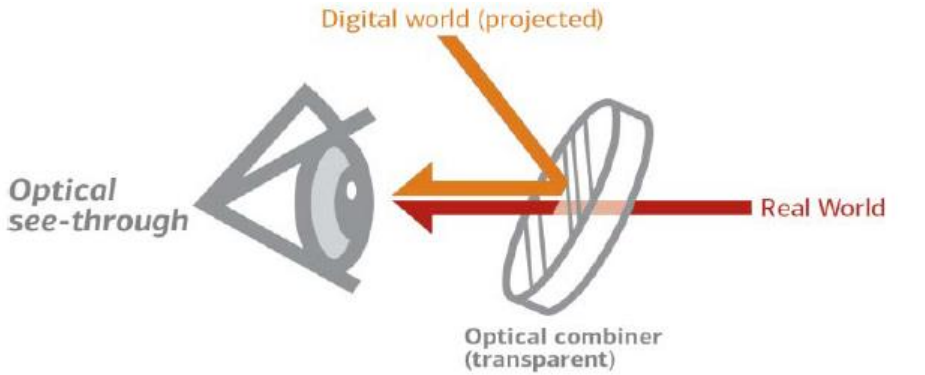




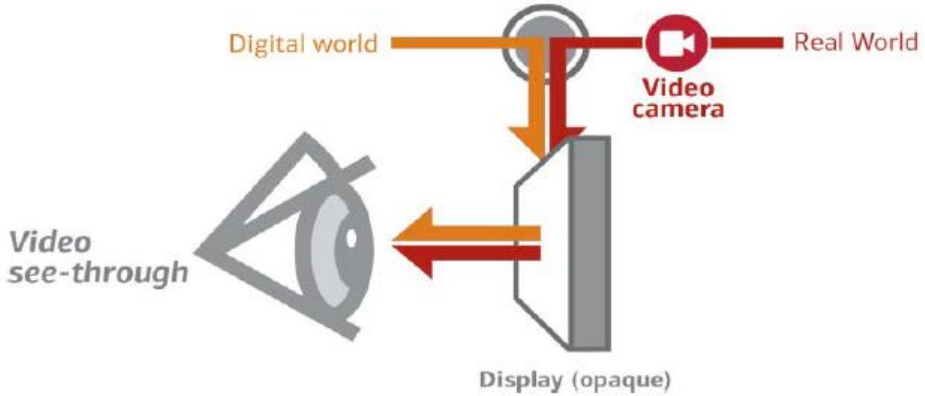



See though configurations for visual augmentation

- Optical see-through
  - Virtual objects are projected on a transparent support

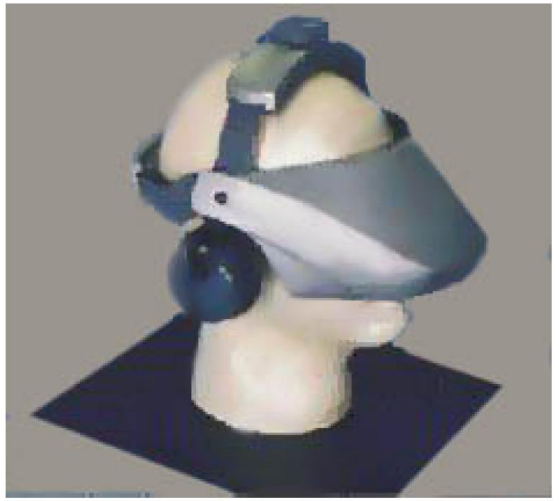


- Video see-through
  - Virtual objects are added to the view filmed by the camera in real time, then displayed on the screen

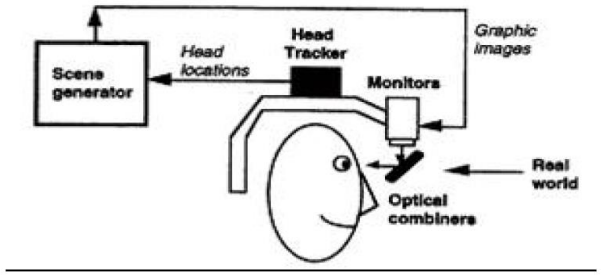


See though configurations for visual augmentation

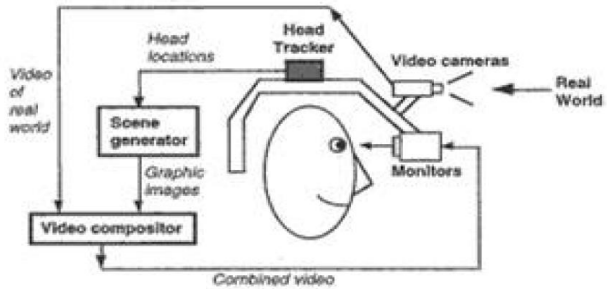
Optical See-Through HMD.



Video See-Through HMD.



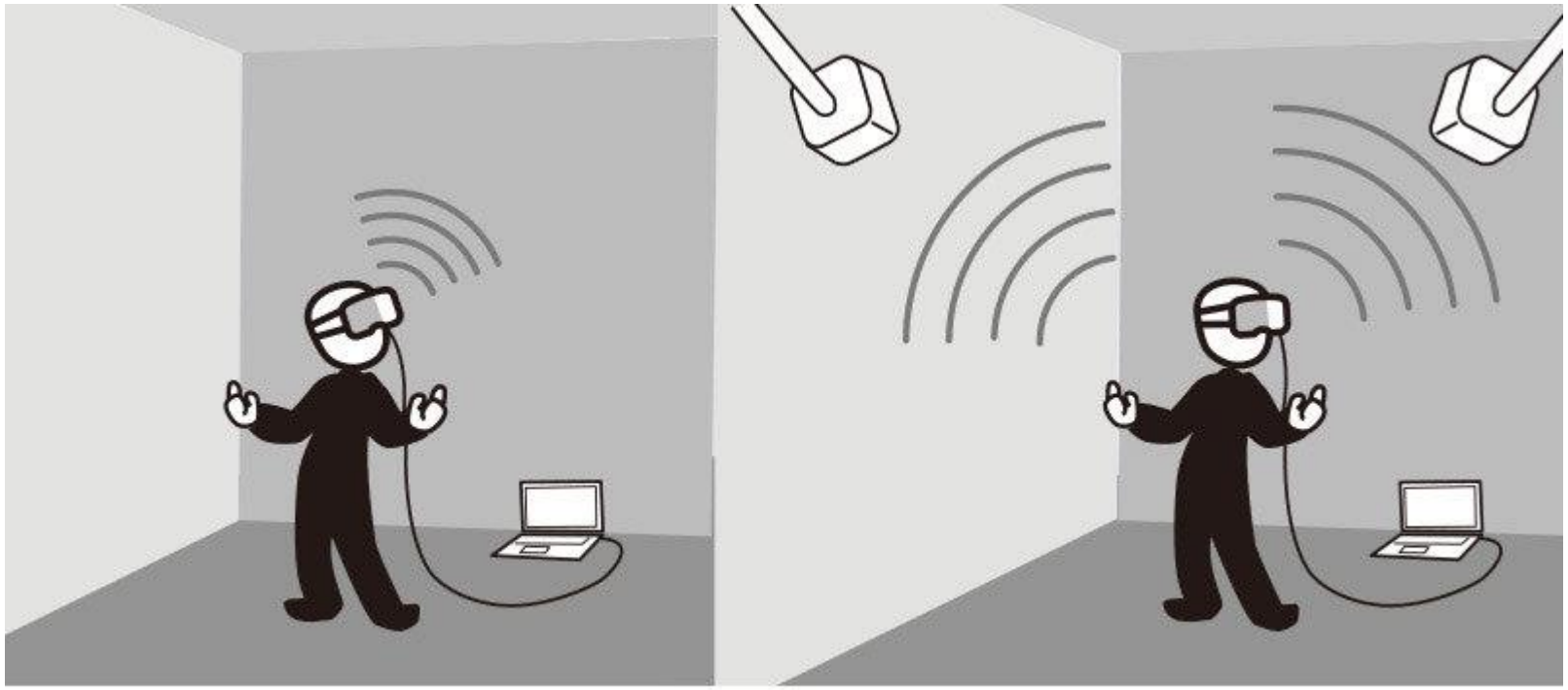
Optical See-Through Scheme.



Video See-Through Scheme.

Configurations for user tracking

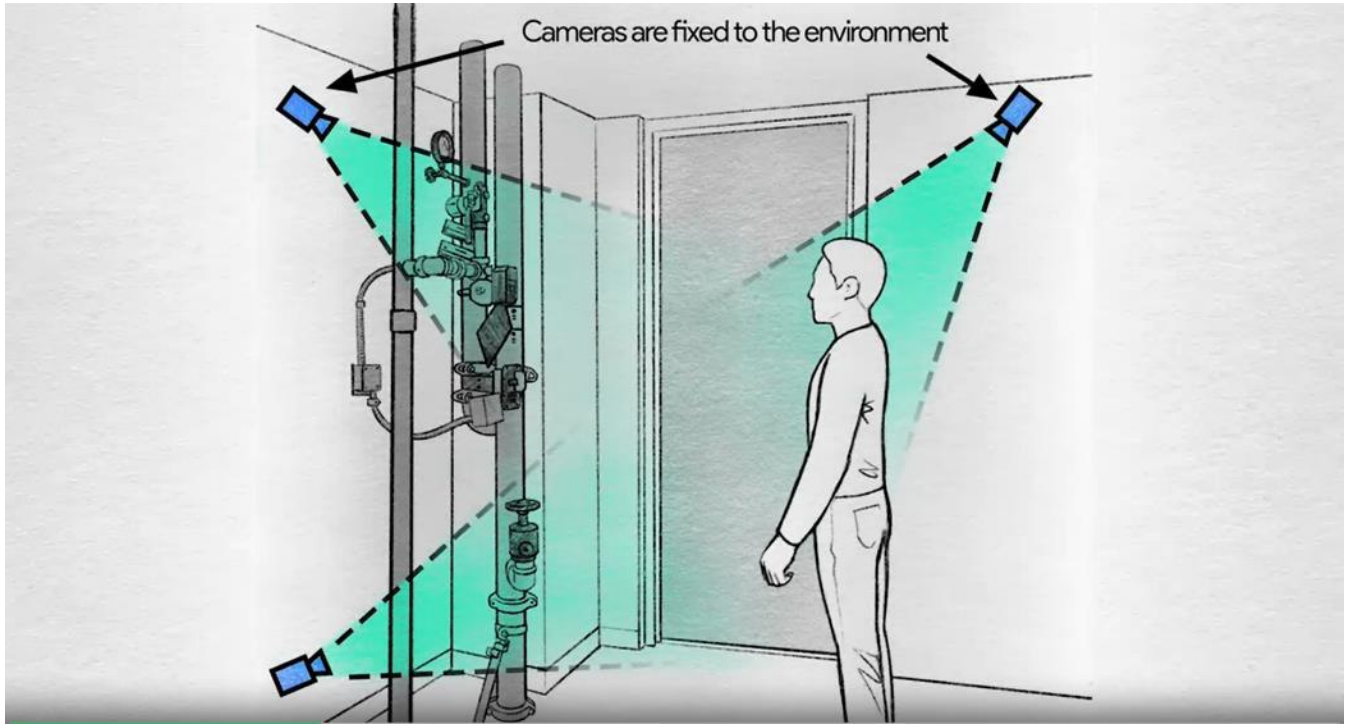
- Inside out tracking
- Outside in tracking



Outside-in tracking

- Cameras fixed in the augmented space
- Example:
  - Oculus rift
  - HTC Vive

- (+) Gain in functionality,
- (-) loss in portability

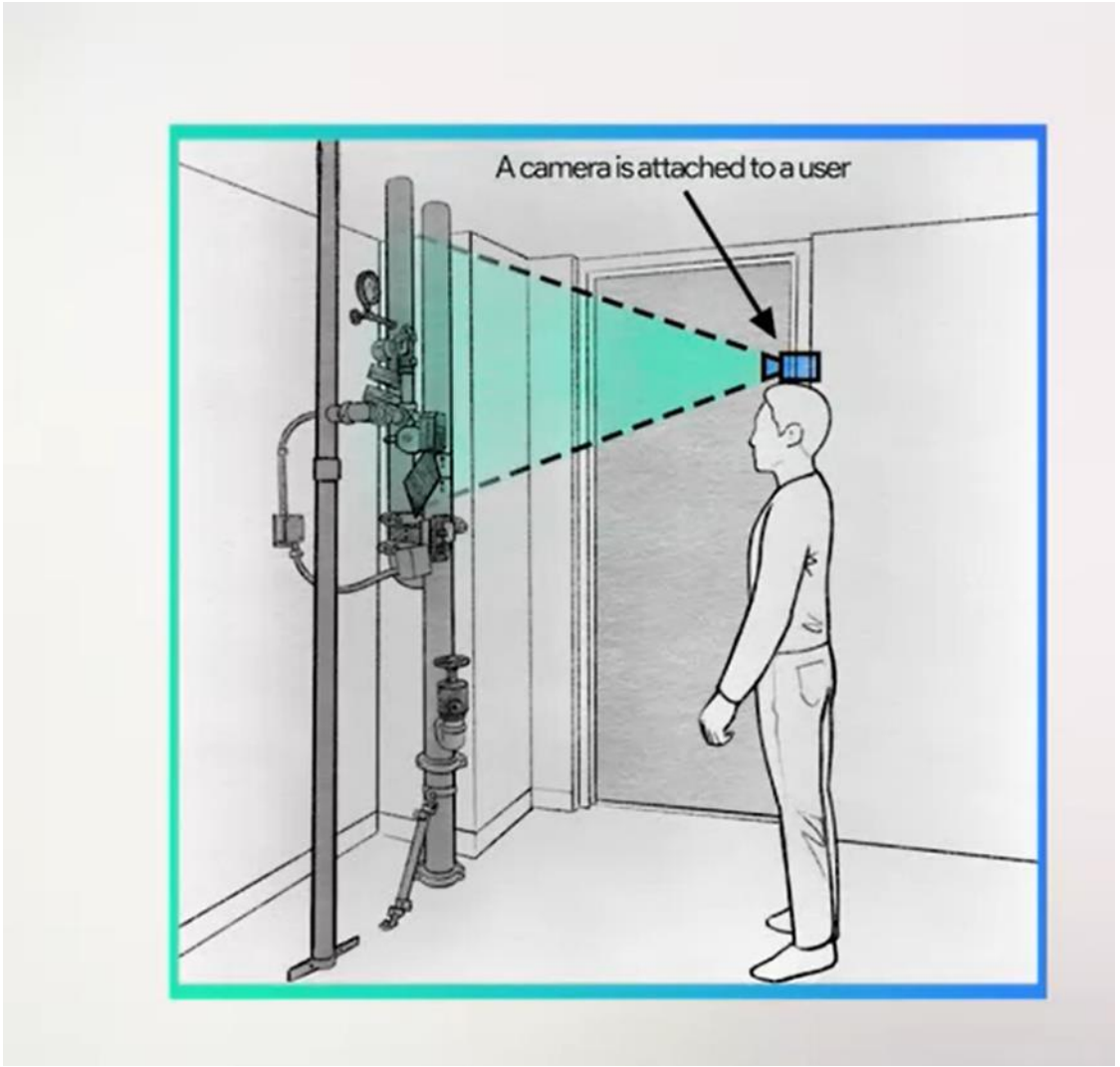


Inside-out tracking

- Camera attached to the user's helmet

- Example:
  - Hololens:
    - 5 cameras to analyze the environment
    - 1 camera to measure the depth
    - 1 HD camera video,
    - 1 light sensor
    - 4 microphones
  - Oculus Quest

- (+) : Gain in portability
- (-) :
  - Footprint
  - Energy consumption
  - Heater



Motion tracking for AR

- Accelerometer :
  - measures acceleration : the change in velocity divided by time.
  - Acceleration forces can be static, like gravity, or dynamic, like motion or vibration.

- Gyroscope:
  - Measures orientation and angular velocity.
  - Gyroscopes measures the rotation of the phone, and the AR experience updates in consequence.

- Magnetometer:
  - Gives smartphones simple orientation linked to the Earth's magnetic field (N, S, E, W)
  - This feature is essential for location-based AR applications.

- GPS :
  - Global satellite navigation system that provides geolocation and time information to a GPS receiver, such as in your smartphone.
  - This feature is essential for location-based AR applications.

Visualizing the real world with AR

- Phone Camera:
  - With mobile AR, your phone's camera provides a live feed of the surrounding real world on which AR content is overlaid. In addition to the camera itself, complementary technologies such as machine learning, image processing and computer vision helps to produce high-quality images and spatial maps for mobile AR.

- Display:
  - The screen of your smartphone is important to get sharp images and display 3D rendered assets. For example, a phone with screen specs of 5.5-inch AMOLED QHD (2560 x 1440) display at 534 ppi, which means the phone can display 534 pixels per inch, resulting in rich and vivid images.

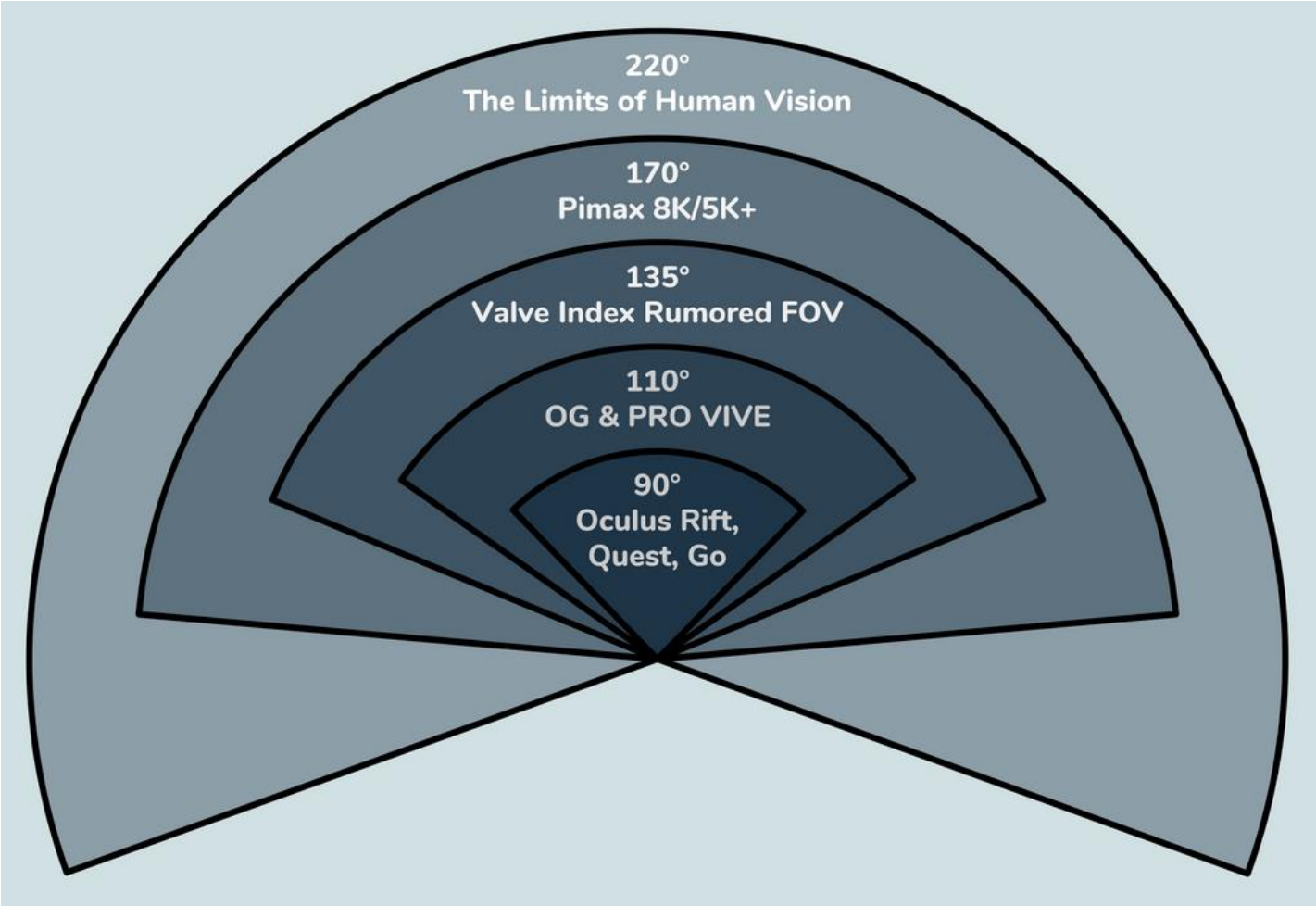
Augmented Reality Glasses

- Selection Criteria:
  - Battery life
  - Processor power
  - Connectivity options (Bluetooth, WiFi, etc.)
  - Camera(s) to detect the environment and/or capture images in HD
  - Screen resolution
  - Microphone, Speaker
  - Internal sensors (GPS, gyroscopes, magnetometers and accelerometers)
- Examples:

Source : www.aniwaa.fr

Field of view (field of view)

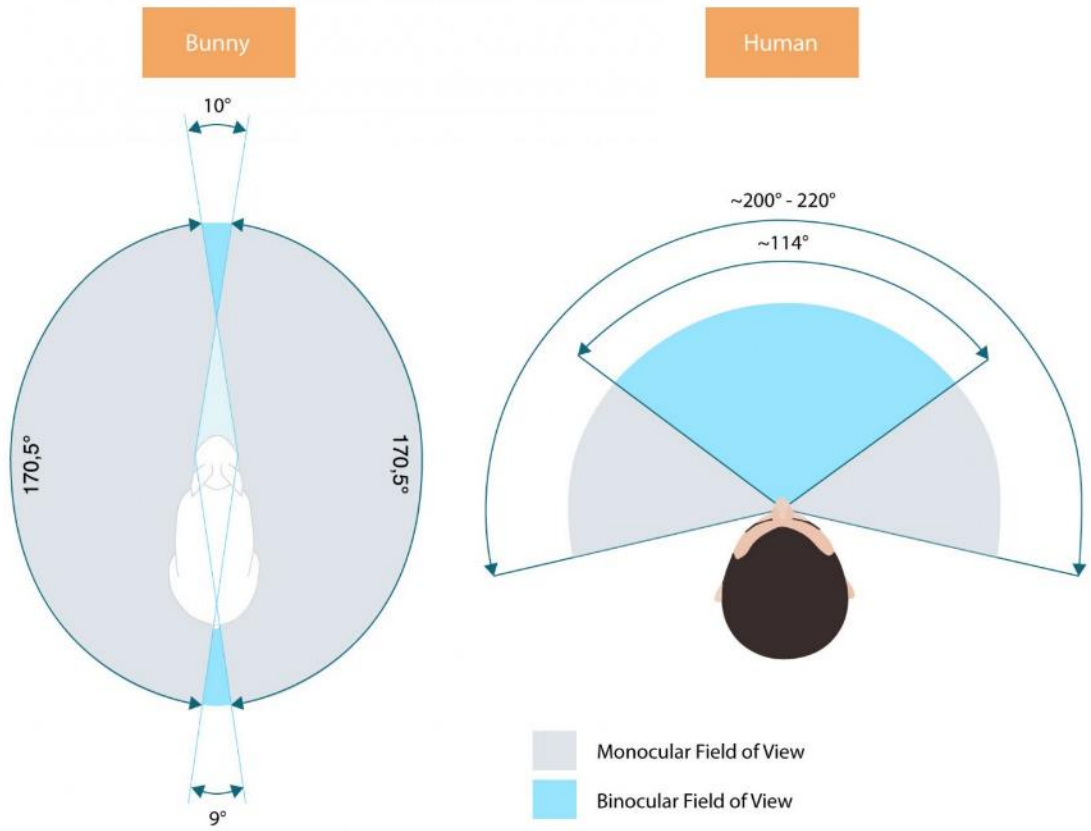
- The "field of view" refers to the portion of vision covered by the display system of a VR headset. A wide field of view immerses the user in a virtual environment, while a narrow field of view can feel like using binoculars.



Field of view (field of view)

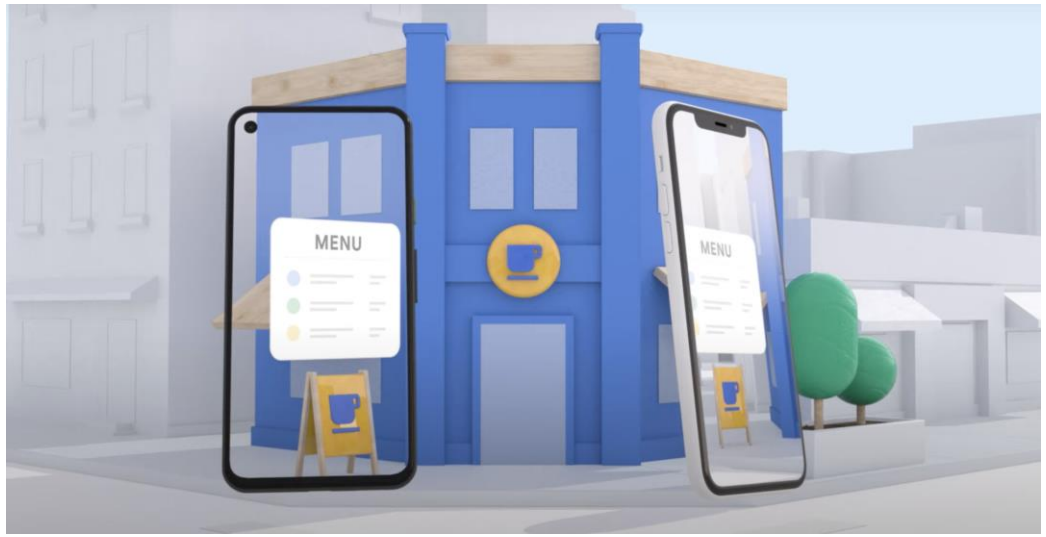
- There are two types of fields of vision that work together to form human vision.
  - The monocular visual field describes the field of vision of only one of our eyes. For a healthy eye, the horizontal monocular field of view is between 170° and 175° and consists of the angle from the pupil to the nose,
  - The binocular visual field is the combination of the two monocular visual fields of most humans. When combined, they provide humans with an area of vision of 200°-220°.

- While a wider field of view is important for immersion and presence, it is in this binocular stereoscopic field of view that most of the action takes place in everyday life, as well as in virtual reality headsets.



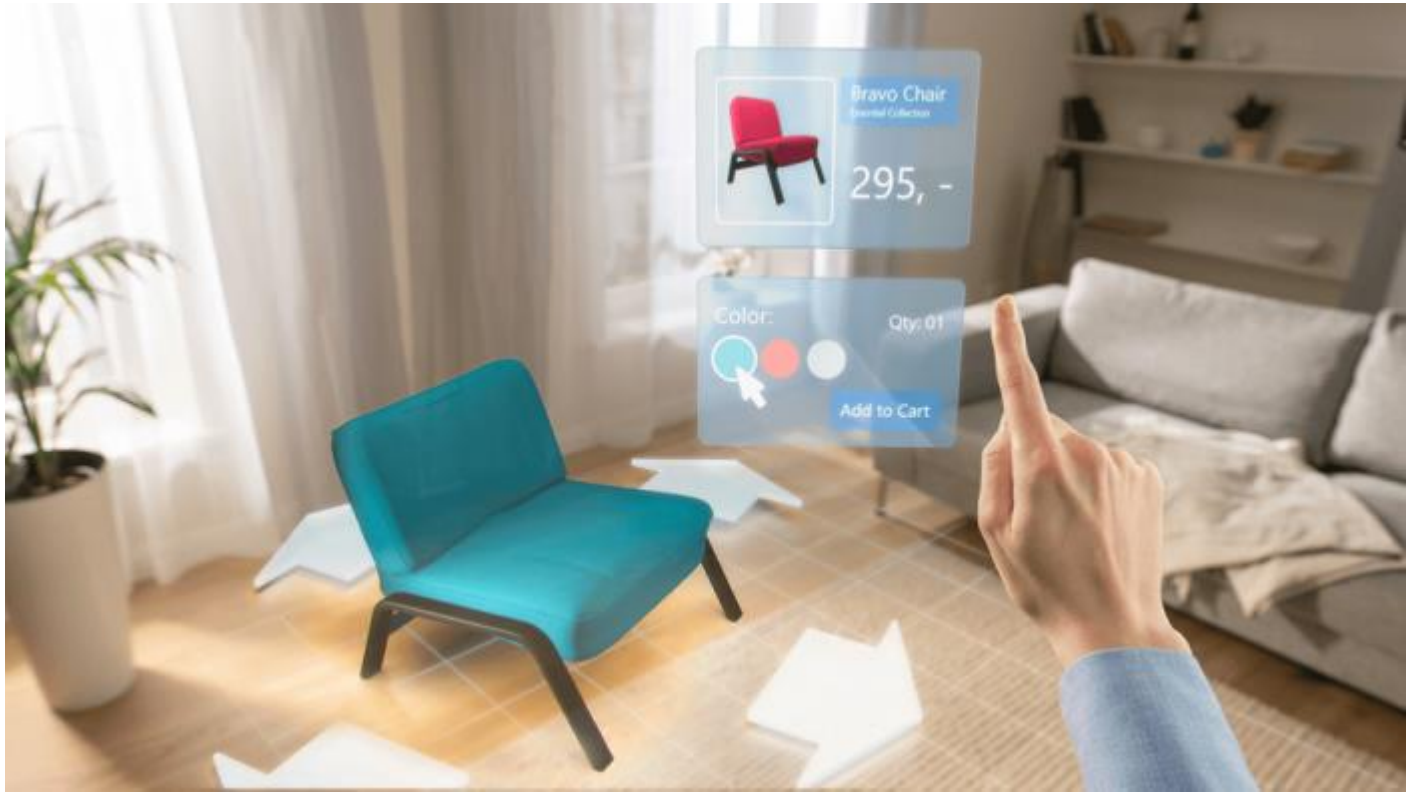
Shared AR: Cloud Anchors

- With Cloud Anchors in place, users can save and share AR experiences arround the world, whether it's for education, gaming, shopping or creative expression.
- Cloud anchors enables :
  - Persist AR experiences in the real world : place AR object in physical environment and another to see the same object at the same place at a later time. (virtual signs that help users find their way, virtual notes on their kitchen..).
  - Real-time collaborative experiences : enable real-time collaboration between users. (play a virtual game of ping-pong on the coffee table, paint a virtual mural together with their community.
- https://www.youtube.comch?v=b4mgaIuCozk



Plane ground recognition

- Use a set of features to recognize the soil
  - Invariant points
  - The soil must be quite variable in texture
- Use anchors to attach virtual content to a trackable point in the real world.



AR development libraries (SDK, ToolKit)

	Entreprise	Plateformes	Logiciel	Documen-tations	Open source	Prix/Licence	Support de lunettes intelligentes	SLAM : Localisation et mappage simultanés	Reconnaissance en nuage	Soucis
Arcore (2018)	Google	Android 7+ iOS 11+	Android Studio 3.1 Unity 2017.4 Xcode 9.3 Unreal Engine.	Moyenne	Oui√	Gratuit	Oui√	Oui√	Non ×	insuffisance de documentation
Arkit	Apple	iOS	Xcode 10 Swift 4	Forte √	Non ×	Gratuit	Oui√	Oui√	Non ×	ne fonctionne que sur les appareils Apple.
Vuforia	QualCommi nc	Android 4+ iOS 9+ Windows 10	Android Studio Unity 17.2 Xcode 10.1 Visual Studio 15.9	Forte √	Non ×	Dev : libre Classique 499$ / app Nuage 99$ / mois	Oui√	Non ×	Oui√	Solution payante et propriétaire Pas d'AR sans marqueurs
Wikitude	Wikitude GmbH	Android 4+ Windows 10 iOS 9	Unity 5.5.6 Xamrin 8.3.0 Android Studio Cordova 5.1.3	Forte √	Non ×	Verssion D'essai Verssion Pro 500$ - 2500$	Oui√	Oui√	Oui√	licence d'essai limitée.
Maxst	Maxst	Android 4+ iOS 9+ Windows 10	Unity 5.6.2 Android Studio Visual Studio 17	Forte √	Non ×	Verssion Gratuit Pro : 999$	Dans la verssion Entreprise Seulement	Oui√	Dans la verssion Pro et entreprise	licence d'essai limitée.
Kudan	KUDAN LIMITED	Android iOS	Unity 5.0 Xcode	Faible ×	Non ×	Verssion Gratuit Pro 1300$ / ans	Oui√	Oui√	Oui√	Documentation très limitée. Manque de forums
ARToolkit (1999)	DAQRI	Android iOS Windows	Unity Android Studio Xcode	Faible ×	Oui√	Gratuit	Non ×	Non ×	Oui√	Documentation très limitée. Manque de forums

AR development libraries

- Recommended development environment :
  - vuforia / ARCore / ARKIT
  - Unity

- Quick sample : https://www.youtube.com/watch?v=khavGQ7Dy3c