UNIVERSITY of NICOSIA

Session 9

Trends in Visualization Technology

META-511: Non-Fungible Tokens (NFTs) and the Metaverse

We are here

1. What is an NFT?
2. Copyright and provenance in NFTs
3. PFPs
4. Art NFTs
5. Generative art
6. Key Considerations in the NFT Space
7. Gaming NFTs
8. What is a metaverse?
9. Trends in Visualization Technology ← **Week 9**
10. Financing models for NFTs and the metaverse
11. Off-chain objects and the broader environment
12. A vision for the future

We will discuss trends in visualization technology

- Part 1
  - Introduce Visualization and its uses
  - Highlight enabling technologies
  - Learn the basics of 3D computer graphics and CGI
  - Present Photorealistic Rendering and requirements
  - Discuss Codec Avatars
  - Describe latest developments in 3D Scanning, NeRFs

- Part 2
  - Understand the difference between Virtual, Augmented and Mixed Reality
  - Present examples and use cases for each technology
  - Explore the hardware equipment and sensors used for each visualization technology
  - Historical overview and evolution of the sector
  - Understand the challenges and opportunities in the sector
  - Explore development needs

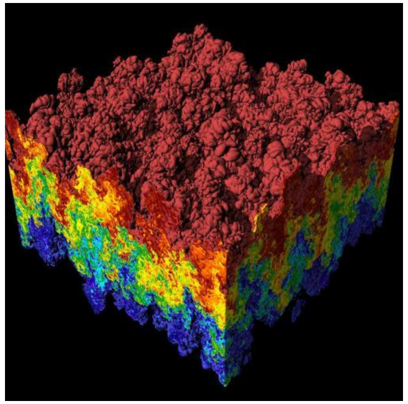
This is an educational course only

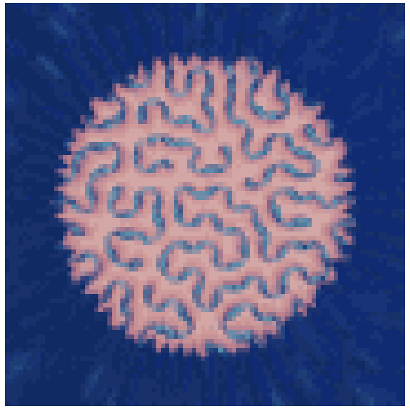
- We will discuss various projects, individuals or NFTs in this course
- These projects, tokens or the individuals associated with them, are only referenced for educational purposes
- Nothing in this course should be taken as a recommendation to buy or sell an NFT or token or any other financial instrument or security
- More generally, cryptoassets are extraordinarily volatile investments. Please take care if you are buying cryptoassets
- The information provided during this session does not, and is not intended to, constitute legal advice.
- Instead, all information, content, and materials made available is intended for general educational purposes only.

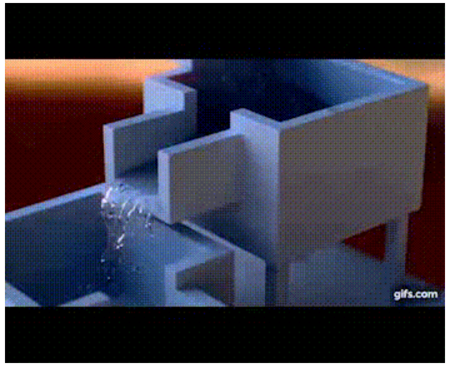
Session 9: Trends in Visualization Technology

1. 3D Rendering, Visualization, Computer Graphics

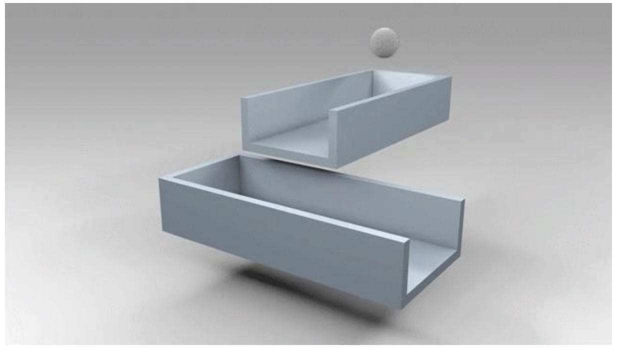
Visualization Uses





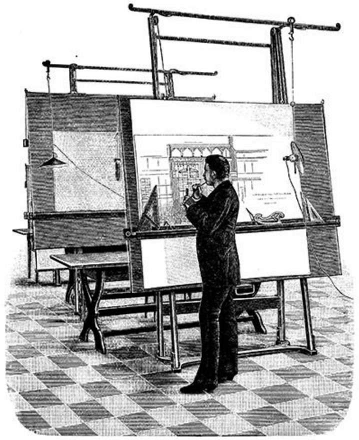


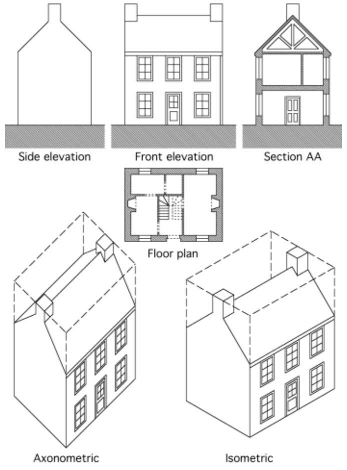
By Mtpanchal - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=74343778



Definitions and Origins

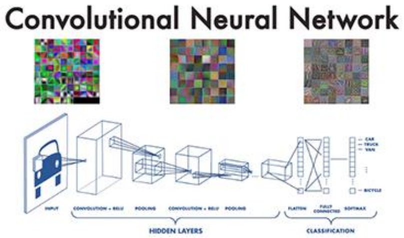
- Visualisation is the visual display or rendering of a concept or idea.
- Architects for example make drawings of buildings according to their clients' instructions.
- Most visualisation today is done on a computer.
- Moreover, visualisation for architecture and product design is almost always three-dimensional (3D).
- Some visualisations are interactive, meaning that one can rotate, manipulate and even walk through the visualisation and experience the final product long before it is manufactured.
- Looking forward, developments in haptic, auditory and olfactory simulations means that visualisation will progress to ‘perceptualisation’ in the future with almost complete sensory reproduction by computer.

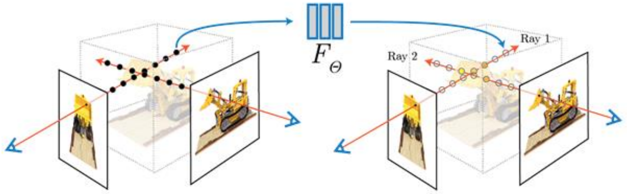




Enabling technologies

- Hardware & Software
  - GPU – Realtime high-resolution photorealistic rendering
  - Modelling software
  - Mobile devices SOC – e.g., Snapdragon 'System on a Chip'
- High Resolution Display Devices, Cameras and Scanners
  - LCD, LED, OLED
  - XR devices
  - 360 Cameras
  - Plenoptic cameras
- Computer Vision, AI and Machine Learning
  - Neural Networks, Deep learning, Convolutional Neural Networks (CNN)
  - NeRFs – Light Fields/Neural Radiance Fields
- LiDAR
  - Laser imaging Detection and Ranging
  - 3D Reconstruction
  - Consumer-level Laser scanning of buildings and environment





NeRFs and View Synthesis (Mildenhall, 2021)

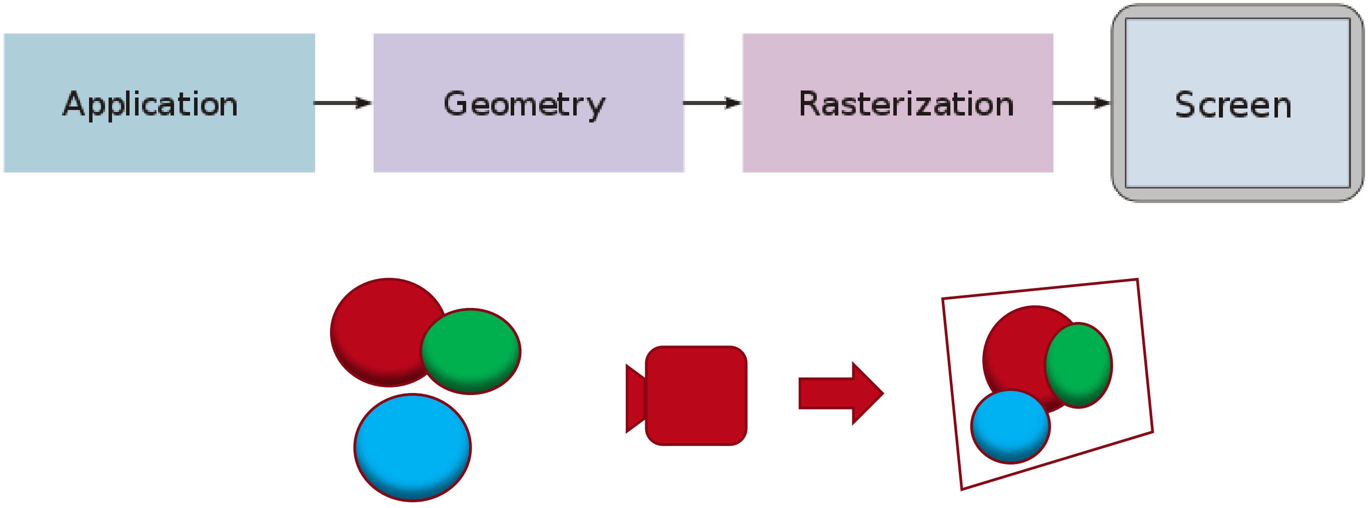
CGI: Brief History

- Edwin Catmull and Pat Hanrahan pioneered Computer Generated Imagery (CGI) development.
- Catmull was co-founder of Pixar which has created many animated movies after their first short movie Luxo Jr popularised CGI.
- They were also instrumental in the development of a dedicated graphics hardware chip (GPU) for rendering on PCs and later made high-resolution graphics possible on mobile devices.

Source: https://www.eurekalert.org/news-releases/833757. James Blinn: Davi.trip - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=60465328

Computer Graphics – Graphics Rendering Pipeline

- The graphics pipeline is how we get from a 3D model to an image on the screen.
- A graphics pipeline can be divided into three main parts: Application, Geometry and Rasterization.
- The rendering pipeline is common to all digital visualisation e.g., video games, architectural walk-throughs and VR/AR

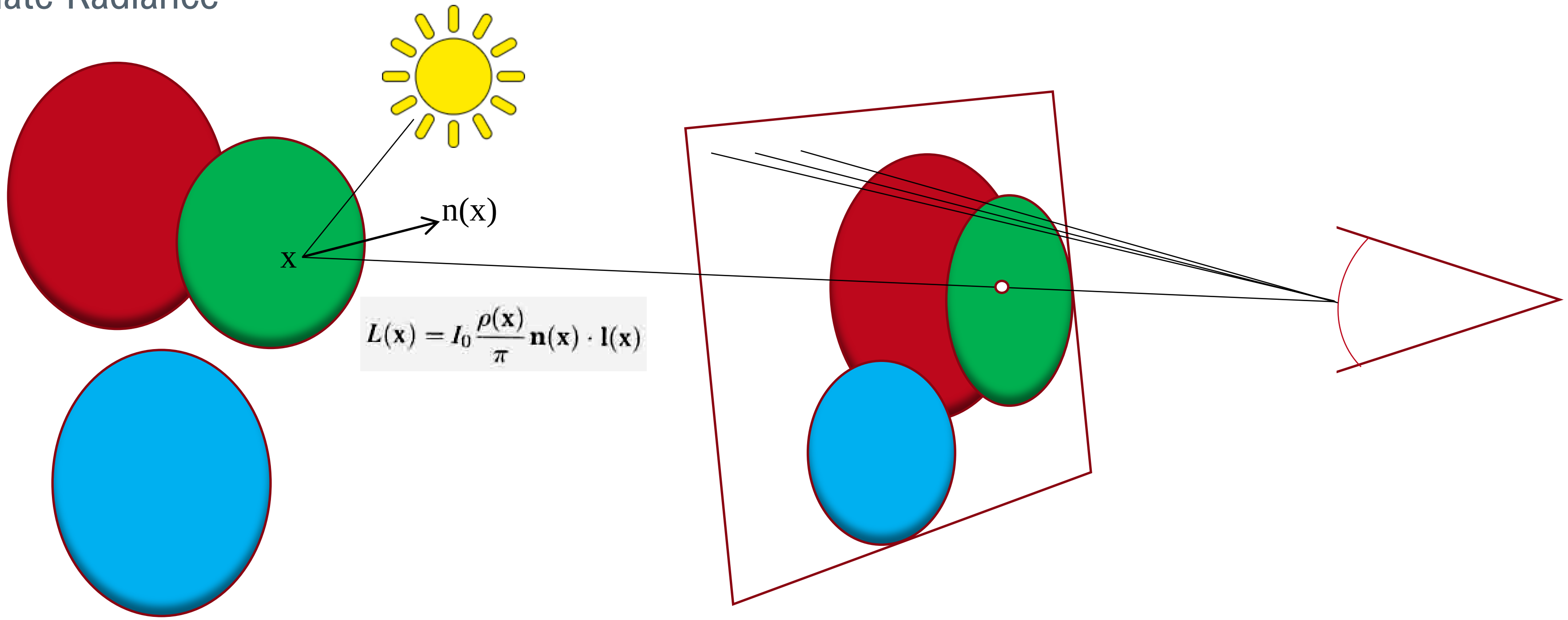


Graphics APIs:
- OpenGL
- Direct3D
- Vulkan
- Metal

Source: 1. Akenine-Möller, Haines & Hoffman 2019, p. 13 2.1 Architecture Figure 2.2

Computer Graphics – Ray-Tracing

- In ray-tracing we shoot rays from an assumed eye position, through each pixel and into the scene to calculate Radiance

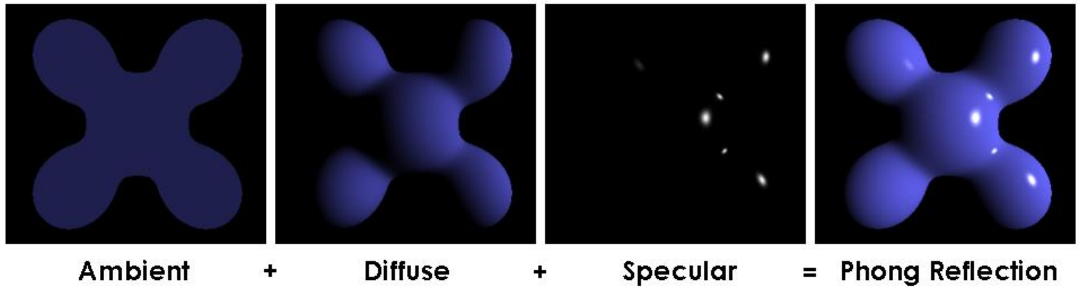


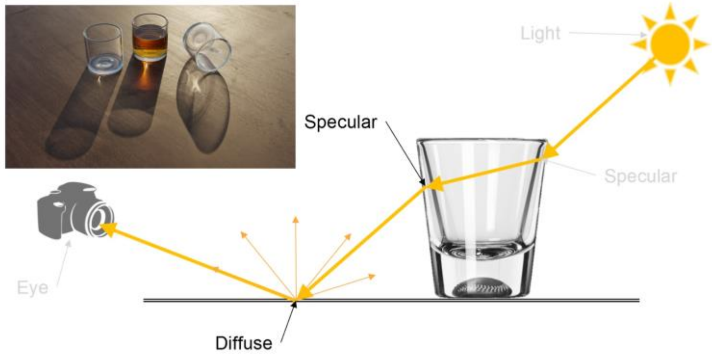
$$L(\mathbf{x}) = I_0 \frac{\rho(\mathbf{x})}{\pi} \mathbf{n}(\mathbf{x}) \cdot \mathbf{l}(\mathbf{x})$$

Source: 1. Akenine-Möller, Haines & Hoffman 2019, p. 13 2.1 Architecture Figure 2.2

Computer Graphics – Illumination Models and Shading

- Most of the early research was directed toward creating a realistic illumination models (which were not necessarily based on physics).
- The Illumination model, also known as Shading model or Lighting model, is used to calculate the intensity of light that is reflected at a given point on surface.
- One of the earliest illumination models Phong model and the Blinn-Phong model
- Modern CGI focuses on creating photorealistic imagery and researchers had to create illumination models which could simulate global illumination and other physical phenomena such as refraction and caustics.

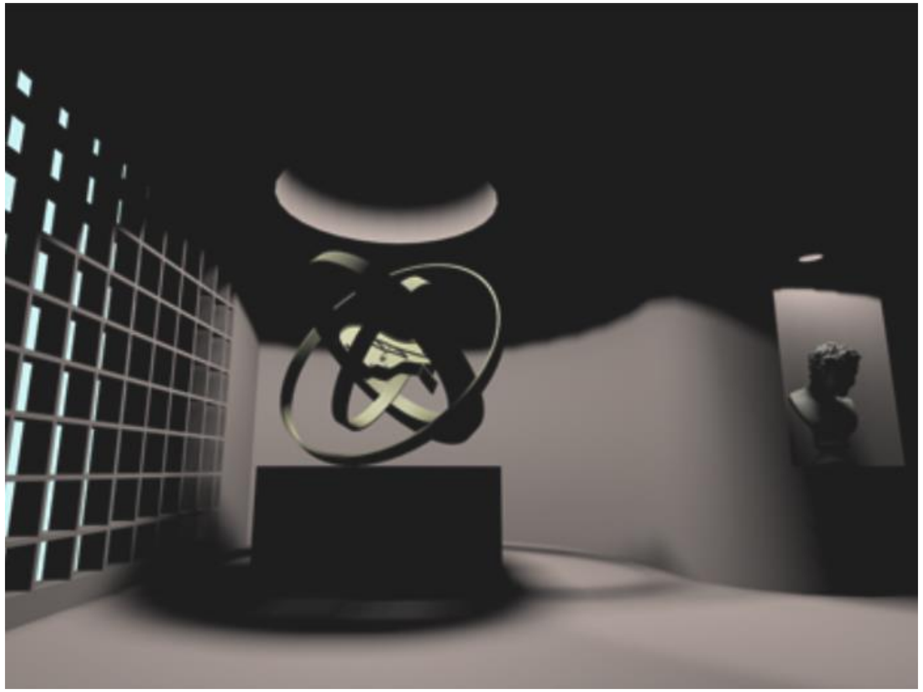


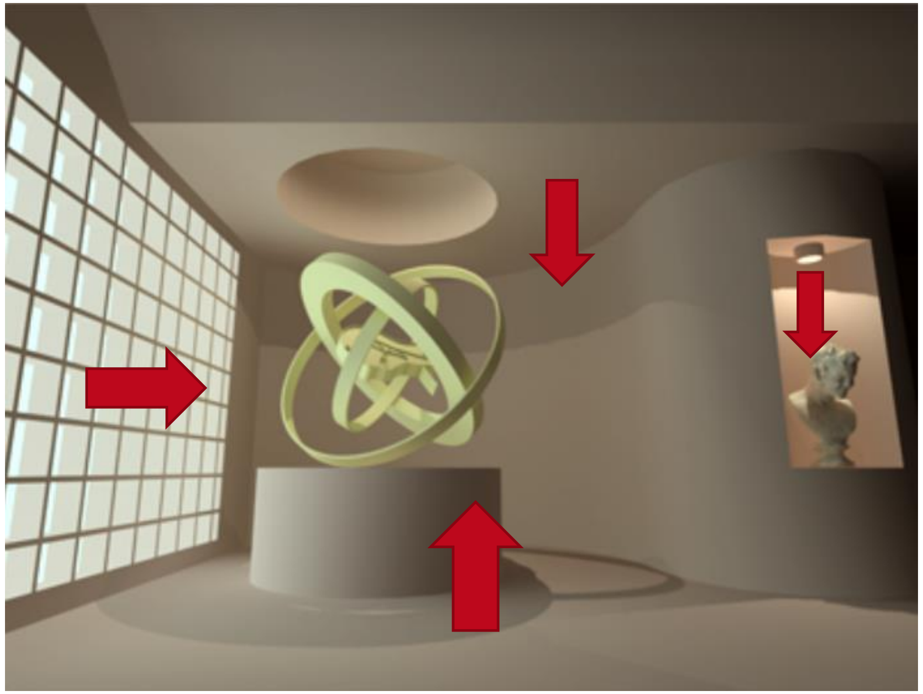


By Brad Smith - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1030364

Computer Graphics – Indirect Illumination (Global Illumination)

- The difference between the left and right images is just the presence of indirect illumination whereby nearby surfaces reflect light onto each other [7]





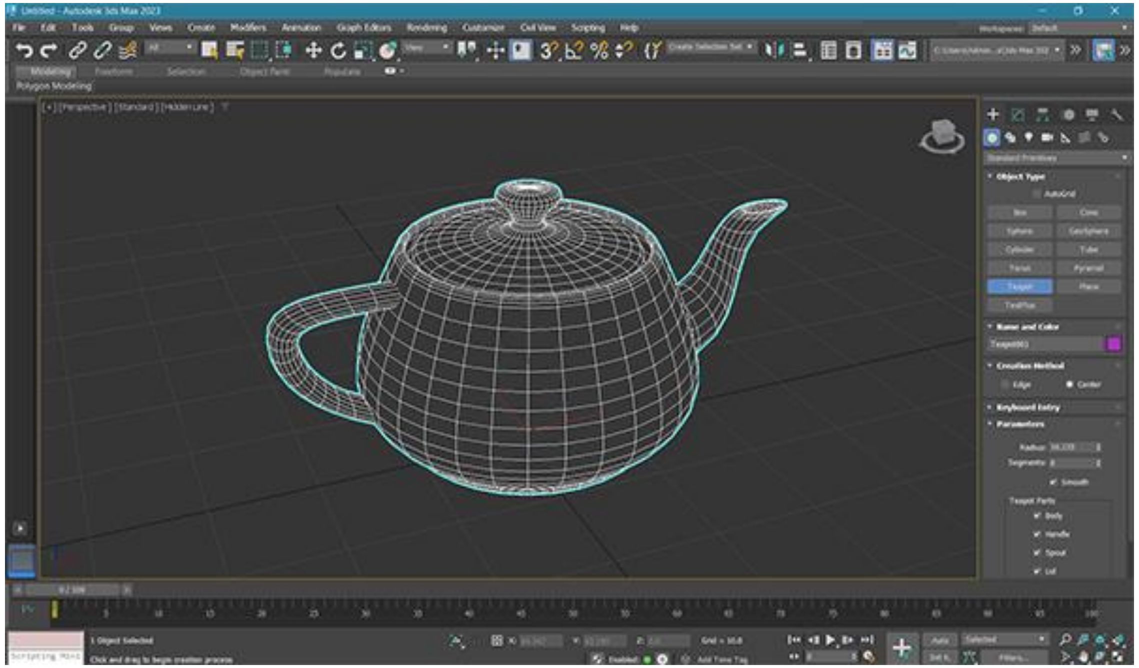
Courtesy of Autodesk

https://knowledge.autodesk.com/support/maya/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Maya-LightingShading/files/GUID-EF999FDB-BDE0-4A89-BD2A-0A2D2712C397-htm.html

Content Generation – 3D Modelling Software

- CGI utilises 3-D computer models of objects or people.
- These are created using a modelling software such as 3DS Max, Maya or Blender.
- Modelling is time-consuming and requires expert skills.
- As we will see later, research aims to develop scanning technology to create 3-D models using multiple images and/or laser scanning

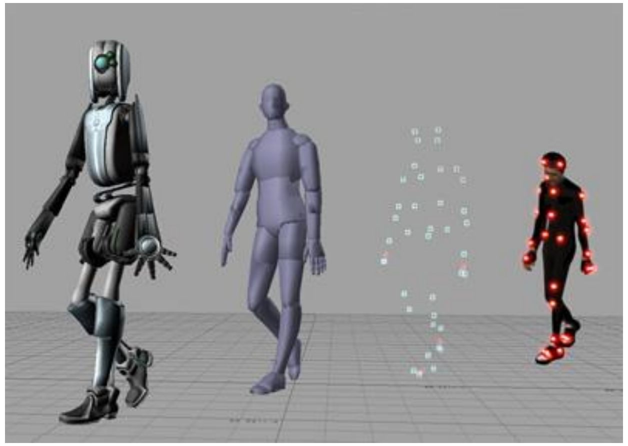
3DS Max Interface



Interesting Fact: The Utah Teapot has historically been used by graphics researchers to test their Illumination models and shaders.

Content Creation– Character Modelling and Crowd Simulation

- 3D characters can be generated using modelling software or scanning.
- Biped Characters are used for video games and metaverse applications. They consist of a polygon mesh and a hidden biped skeleton or rig for animation.
- Movements of characters can be key-framed using modelling software or real actors i.e., Motion Capture
- Crowd simulation captures the dynamics of large numbers of characters otherwise known as agents or Non-Player Characters (NPC).
- Crowd simulation can be used in Architecture and Research (e.g., Escape Route Planning, Proxemics).

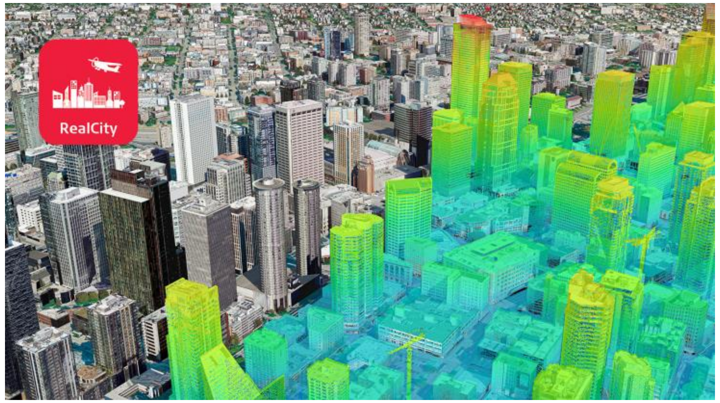


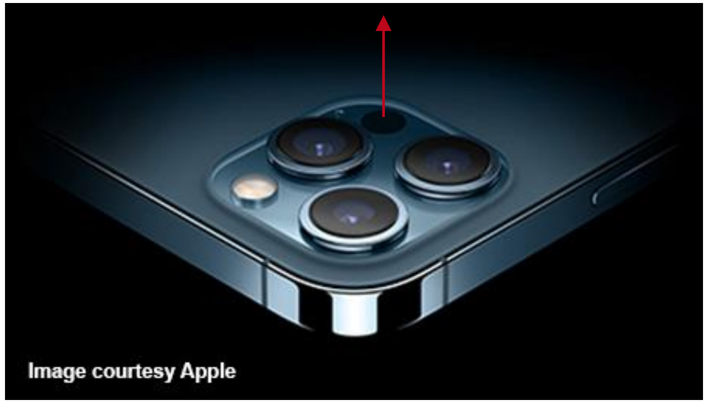
Source: Christou et al. Psychophysiological responses to virtual crowds: implications for wearable computing. In 2015 International Conference on Affective Computing and Intelligent Interaction (ACII) (pp. 35-41). IEEE.

Current Trends: Creating 3D Models using LiDAR

3D LiDAR scanning

- Light Detection and Ranging. The acronym LiDAR is often used to name this remote sensing method.
- It **uses light to measure distances** and is also known as laser scanning or 3D scanning.
- LiDAR is available on consumer devices such as iPad Pro

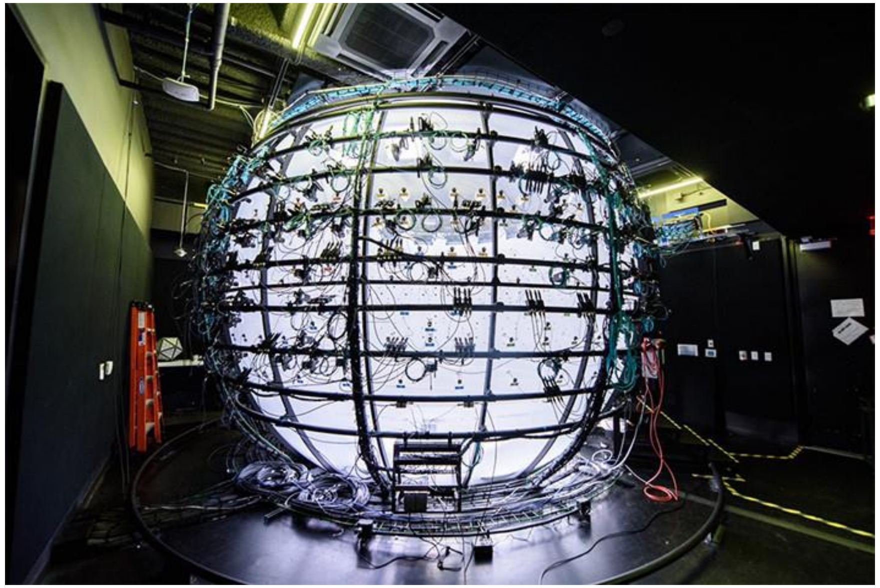




Source: https://leica-geosystems.com/products/airborne-systems/solutions/leica-realcity

Current trends: Codec Avatars (PiCA)

- Facebook Reality Labs has been developing head and body scanners. The former is a domelike enclosure called Mugsy, the walls and ceiling are studded with 132 Canon lenses and 350 lights focused on a chair. The body scanner can be used to create whole-body avatars for Metaverse implementations.



Courtney Linder, Courtney Linder

Source: https://tech.fb.com/ar-vr/2019/03/codec-avatars-facebook-reality-labs/

Current Trends: Google Welcome to Light Fields

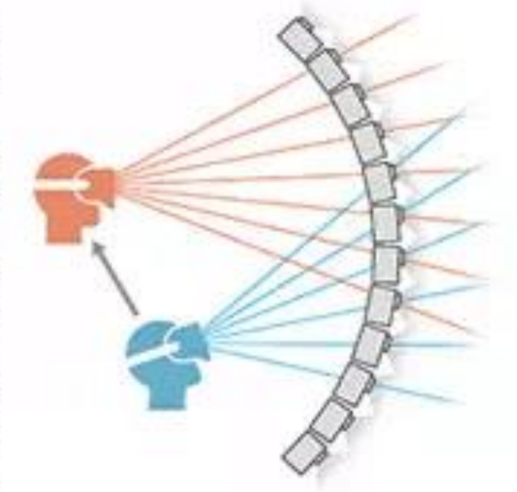
- Available on Steam for HTC Vive and Meta Quest

Courtesy of Google

Content Creation– Character Modelling and Crowd Simulation

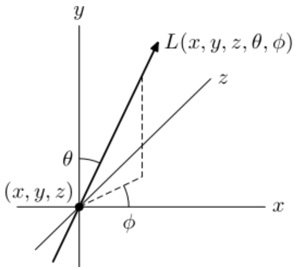
- Benefits of Light Fields over regular 360 cameras:

  - You can move your head around
  - Motion Parallax
  - Handles direction dependent effects such as specularities (i.e., mirrors, shiny surfaces)

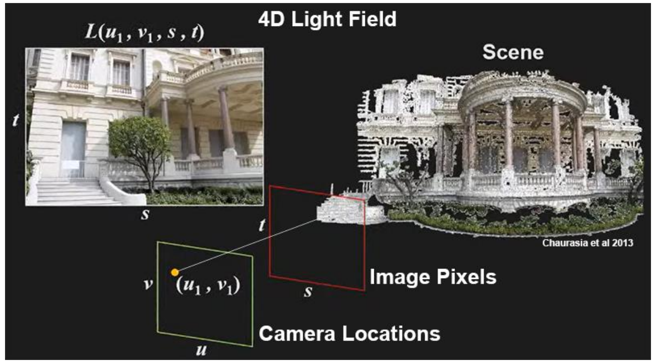


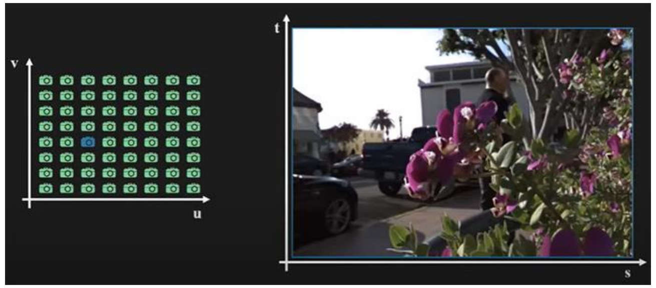
Courtesy of Google

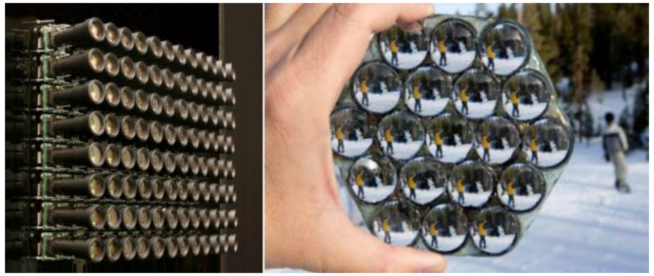
Current Trends: Light fields



- A Light Field is a vector function that describes the amount of light flowing in every direction in space.
- The plenoptic illumination function is an idealized function used in computer vision and computer graphics to express the radiance at any possible viewing position at any viewing angle at any point in time.
- Light Fields may be generated by photographs of the real world or 3D
- Virtual Environments.
- For photographs specialist (Plenoptic) cameras may be used
- Neural Networks[5] may be used without a specialist camera.







https://youtu.be/OEUHalxanuc

Current Trends: NeRF – Neural Radiance Fields

A neural radiance field (NeRF) is a fully-connected neural network that can generate novel views of complex 3D scenes, based on a partial set of 2D images.

- Based on multi-layer Perceptron (Convolutional Neural Networks)
- Volumetric representation.
- Requires training.
- Sparse dataset of images taken from known positions are used to create novel views.
- Can be used for fly-throughs and walk-throughs
- Beneficial for VR

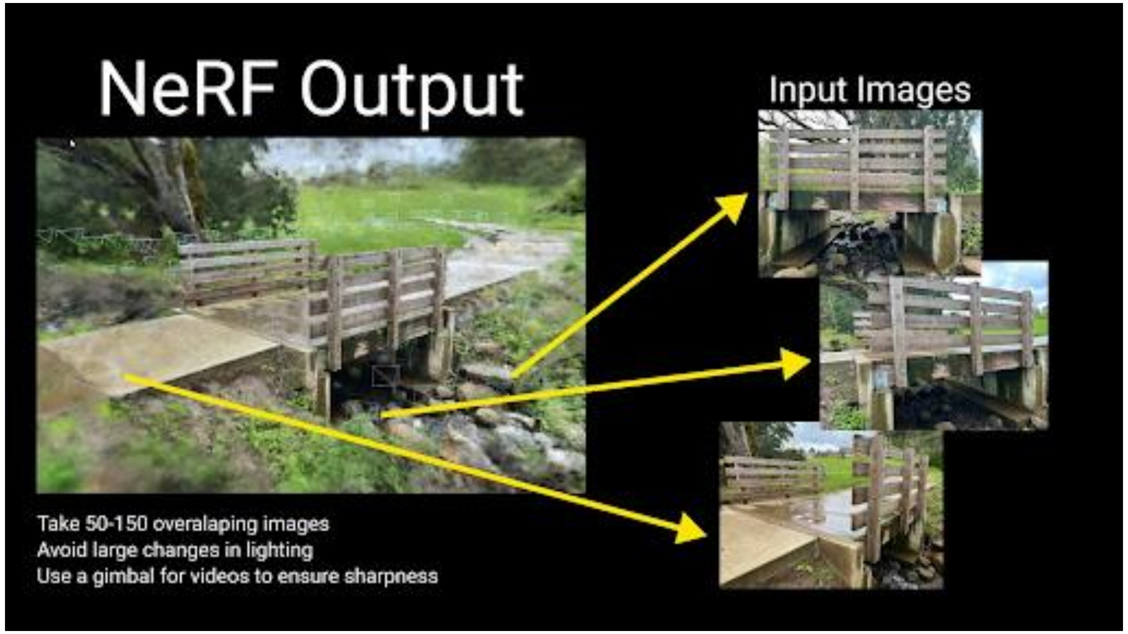


Image Courtesy of NVidia

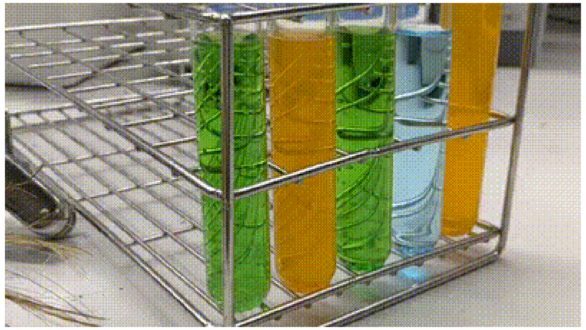
https://developer.nvidia.com/blog/getting-started-with-nvidia-instant-nerfs/

NERF – Neural Radiance Fields View Synthesis [8]

Deep Network (Non-convolutional)
Mildenhall et al ECCV 2020 [8]

https://developer.nvidia.com/blog/getting-started-with-nvidia-instant-nerfs/ https://www.matthewtancik.com/nerf

NERF – View Synthesis



View synthesis - generate new views of a scene given a subset of posed training images.

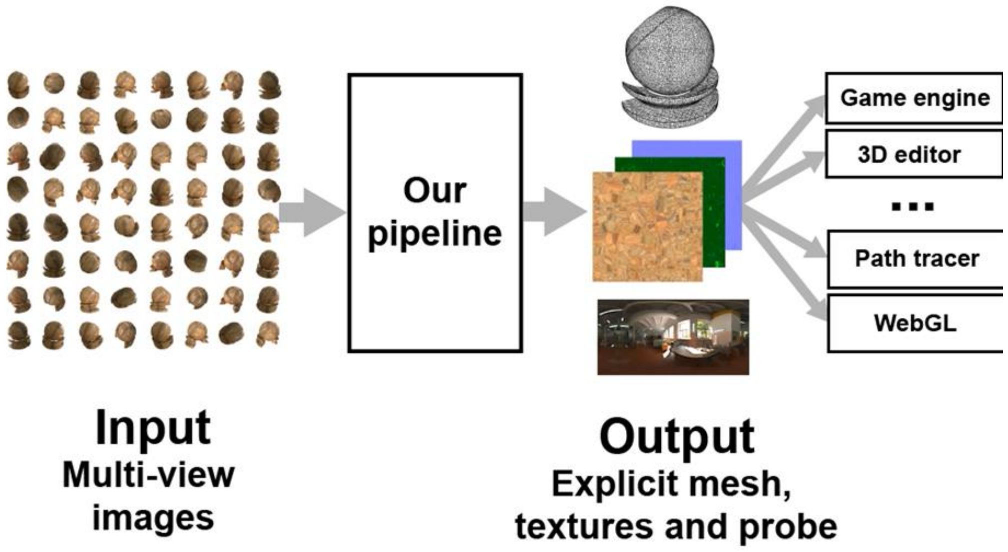
Predicts integrated radiance along ray paths for image generation

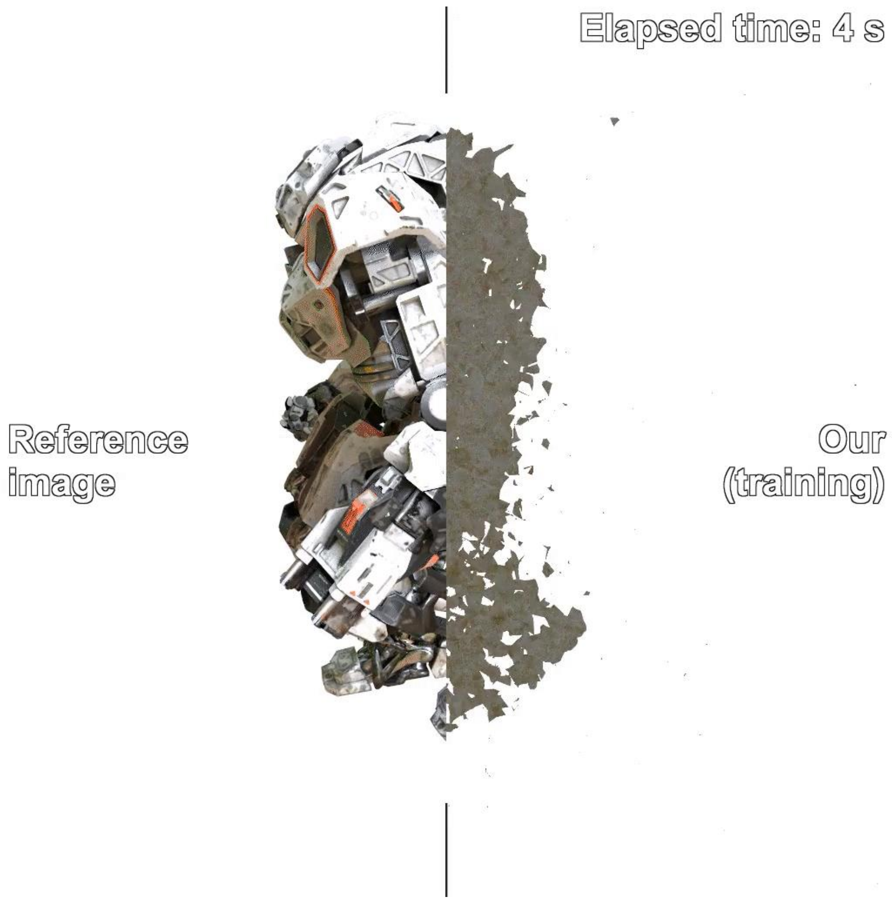
Benjamin Attal (2022) et al.
https://arxiv.org/abs/2112.01523

Source: https://docs.nerf.studio/

Current Trends: NeRF – Extracting Polygonal Models

- Munkberg et al (2022) [12]
- Optimized ray-marching method to triangulate neural shape representation





https://nvlabs.github.io/nvdiffrec/

Session 9: Trends in Visualization Technology

2. Extended Reality (AR & VR)

Disclaimer

- Dr. George Koutitas wishes to declare that he is working for the company Pfizer Hellas S.A, Center for Digital Innovation, Thessaloniki and that the content of this presentation does not reflect Pfizer's position.

The difference between VR, AR, MR

Virtual Reality
(VR)

Augmented Reality
(AR)

Mixed Reality
(MR)

Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR)

- **Virtual reality (VR)** is a simulated experience that employs pose tracking and 3D near-eye displays to give the user an immersive feel of a virtual world

- **Augmented Reality (AR)** is the integration of digital information with the user's environment in real time. Unlike virtual reality (VR), which creates a totally artificial environment, AR users experience a real-world environment with generated perceptual information overlaid on top of it

- **Mixed Reality (MR)** is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time. Mixed reality is largely synonymous with augmented reality

Head Mounted Devices (HMDs)

VR Headsets

AR Headsets

Head Mounted Devices (HMDs)

- VR & AR have one thing in common. They require an HMD device that works as the interface of the virtual experience
- Head-mounted displays were prohibitively expensive until 2010 costing in the region of $20k and suffered from low resolution and lack of immersion
- The breakthrough came with Palmar Luckey's Kickstarter project for the **Oculus Rift Development Kit** which saw great success ($2.4m) in 2012. Many developers used the development kit (DK1) offered by Oculus to generate apps which surpassed that of predecessor HMDs for less than a tenth of the price
- In 2014 Google released software to the readers of the New York Times in combination with a cardboard cut-out that could be folded into a hand-held headset. Using their phones as displays and cheap plastic lenses the general public could experience immersive VR at trivial cost. Subsequently, after 2 years of independent R&D Palmer Luckey's company Oculus was purchased by Mark Zuckerberg's Facebook Inc. for $2bn
- Currently the HMD market is worth US$16.63 billion, projected to reach US$32.94 billion by 2027 and register a CAGR of 38.9% between 2022 to 2027

Application Areas

Hard to find the Niche- Both VR and AR have struggled finding the key application area. These are the main applications met today

- **Gaming-** For VR, gaming was the dominant sector of application but Enterprise applications started gaining a lot of momentum since they brought the first revenues
- **Learning and Development-** VR and AR are great tools to reduce cost of training, demolish learning boundaries across geographical areas and enable both Cognitive and Muscle Memory
- **Remote Collaboration & Social Networks-** with working & travel restrictions due to COVID, VR and AR are great solutions to enhance remote - home work and social interactions. VR is the dominant technology in this sector due to the
- **Industrial (manufacturing/construction)-** AR is the dominant technology in this sector since it allows a physical interaction of the engineer with the environment

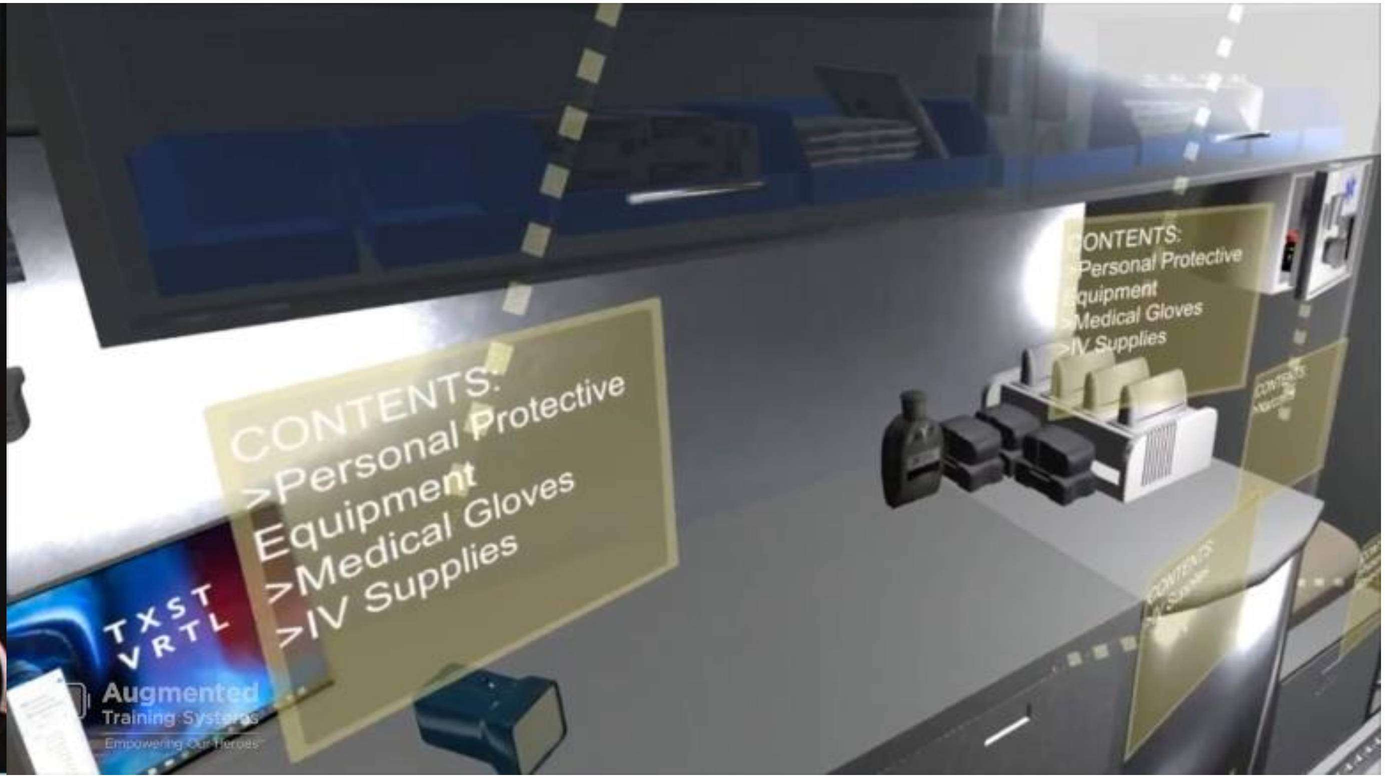
Gaming

The main application area of consumer level VR is immersive gaming with revenues expected to reach $2.4bn by 2024

Remote collaboration

Agriculture

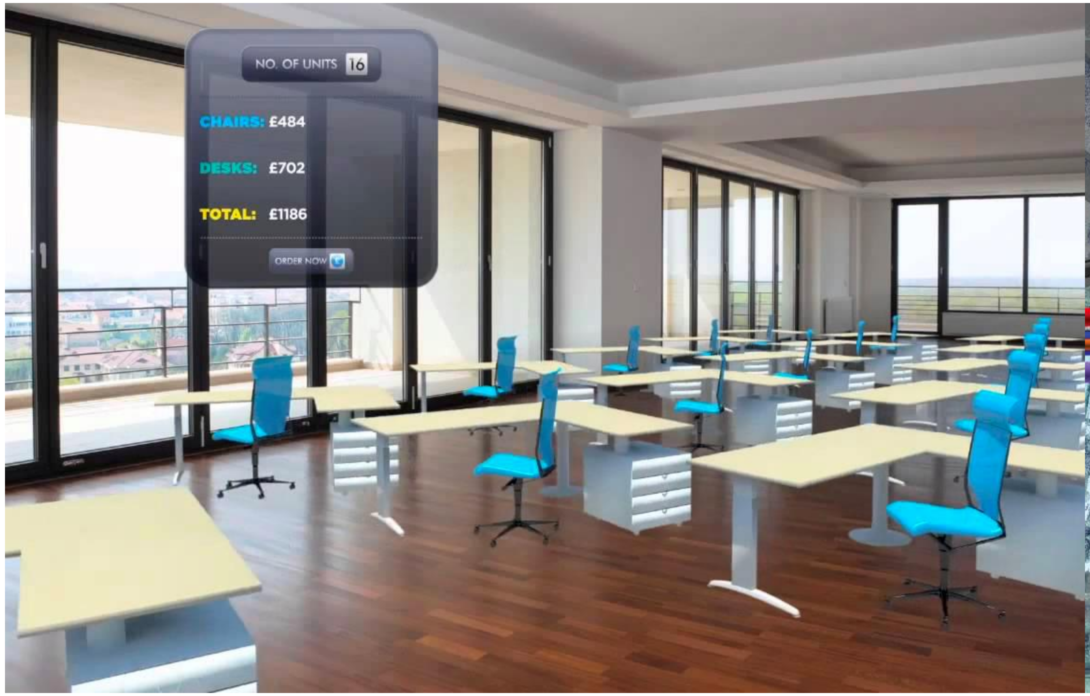
Learning & Development

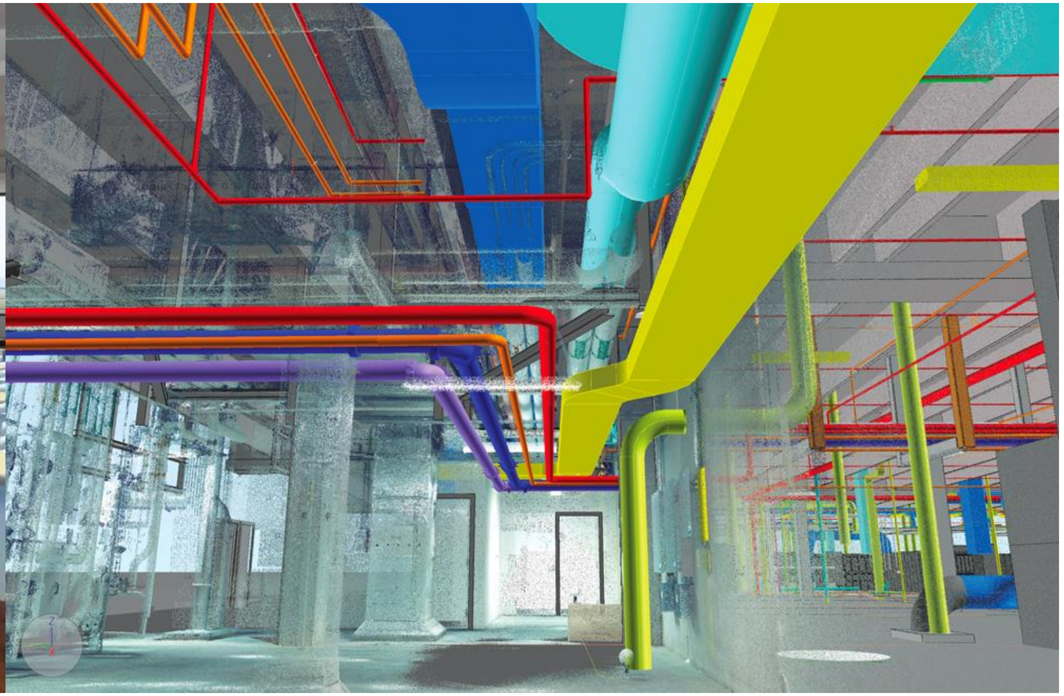


Health

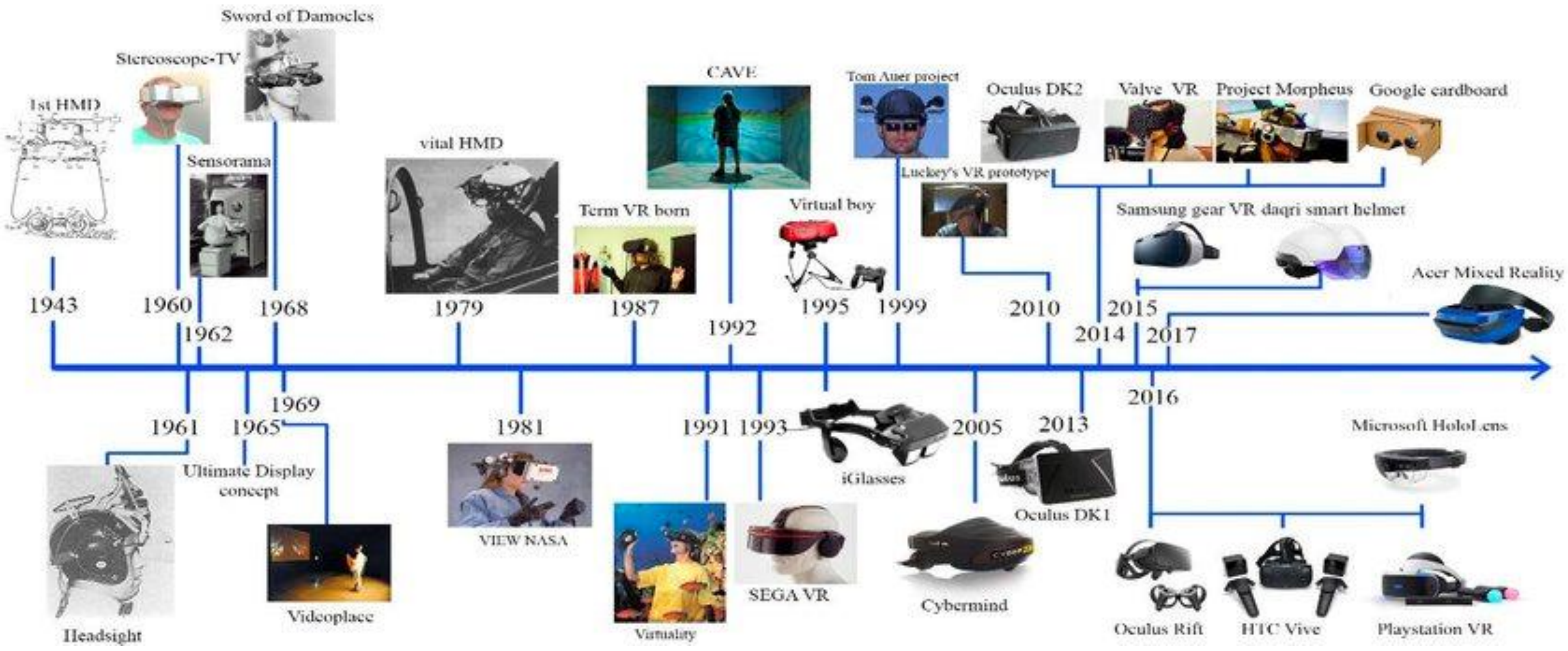
Manufacturing / Industrial

Architecture / Construction





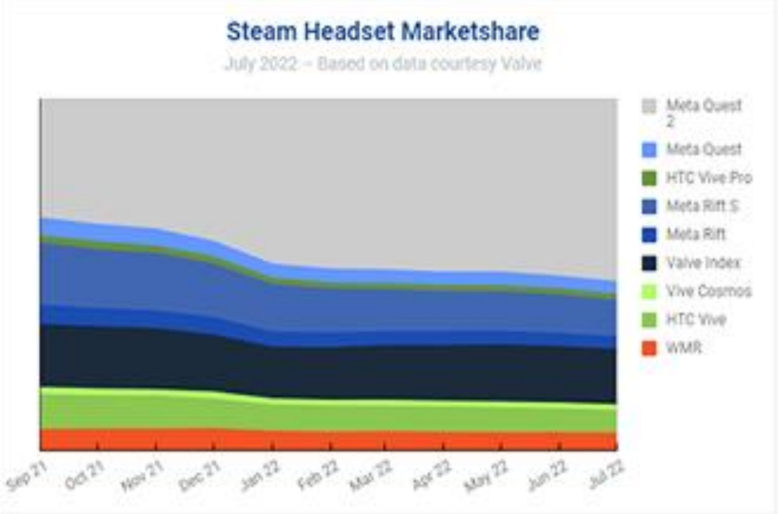
A timeline of extended reality evolution



Al-Adhami, Mustafa & Ma, Ling & Wu, S.. (2018). Exploring Virtual Reality in Construction, Visualization and Building Performance Analysis. 10.22260/ISARC2018/0135.

An overview

- The VR HMD market is diverse with many high-end headsets being used for manufacturing and business while others are used mainly targeted at consumer entertainment. Meta's subsidization of the Quest 2 was targeted at the consumer market (immersive games and social VR interaction). To a certain extent this has succeeded (at great cost to the company) with Quest being very popular in the game market. Leading manufacturers are:
  - Meta Oculus (Rift, Quest, PC VR). Meta has a commanding lead on the Steam platform with 67.3% of the 3.4 million headsets in use within this platform
  - Google (Daydream – discontinued, Cardboard VR)
  - HTC Vive (Vive pro, Cosmos, Focus 3)
  - ByteDance (Pico Neo3, Pico 4)
  - Samsung (Odyssey)
  - Sony (PSVR)
  - Pimax (Vision 8K)
  - LG
  - Varjo (XR 3, VR 3, Aero)
  - Lenovo Think Reality VRX (Standalone, Colour pass-through MR)

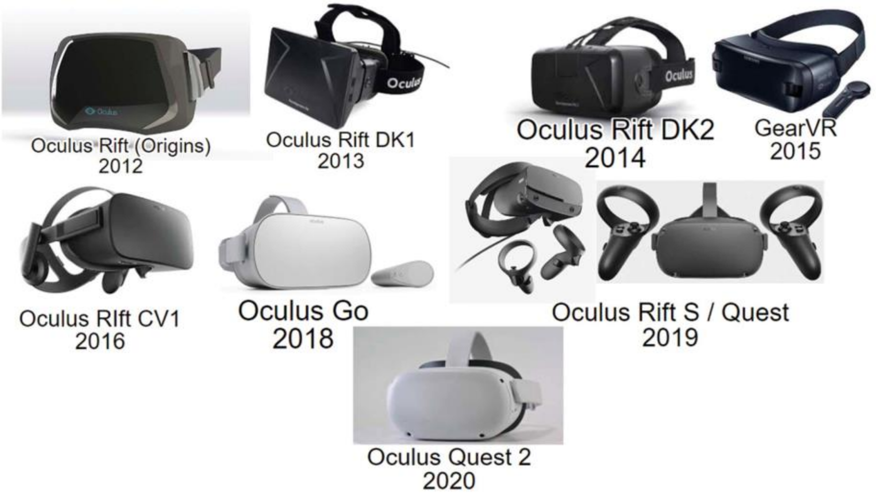


Sensorama

A video of how the immersive multi-sensory experience introduced in 1962 can be found at https://youtu.be/vSINEBZNCks

Evolution of Oculus Quest

- From a passive VR experience without controllers it moved to an active VR experience by introducing the joystick
- RIFT was connected to PC since it required processing power
- GO and QUEST work with battery. All required processing is now at device level
- META QUEST PRO introduces Gestures, Joystick and Mixed Reality operation
- QUEST headset is the most popular with 75% of the total consumer HMD market



An overview

- AR development is also fast paced in terms of R&D with existing applications in many fields (e.g. engineering, manufacturing etc.) and product interest from governments, private firms, and venture capitalists. Application areas include consumer electronics, aerospace and defence, healthcare, retail, and advertising. Consumer adoption of AR is critical for the development of what we refer to as real-world metaverse. Key investors in AR include. Leading AR Manufacturers are:
  - Microsoft (Hololens)
  - Magic Leap
  - Meta (e.g. SparkAR)
  - Google Glasses
  - ByteDance
  - TENCENT
  - Alibaba (Nreal)
  - YF Capital (Nreal)

What happened with Magic Leap?

- Initial overhype. Market was promising but technology could not deliver
- October 2014, raised $542M in $2B valuation without a product and a tested market!
- Initially focused on public market but then focused on Enterprise AR use cases
- A more niche market can bring the required revenues
- Now focus on enterprise and health

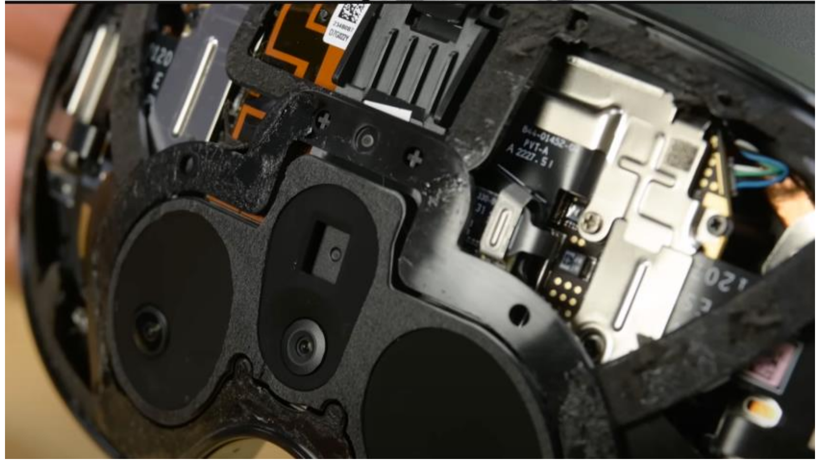
"Magic Leap raised billions but its headset flopped. Now it’s trying again" https://edition.cnn.com/2022/03/10/tech/magic-leap-new-headset/index.html

Other companies in the AR/VR and Metaverse space

- Companies involved in the research and **manufacture of components** used in VR/AR devices include:
  - OPTIARK
  - Google
  - HiMax
  - Lumus Optics [https://lumusvision.com/]
  - Nokia
  - Dispelix of Finland
  - Optivent (https://www.optinvent.com)
  - Essilor
  - Digilens
  - HARMAN International (Samsung Electronics)
  - Vuzix
  - Rokid (https://vision.rokid.com/)
- Companies involved in the **Metaverse** sector include:
  - Google (Alphabet)
  - Microsoft (e.g. partnership with UAE NBD)
  - Nvidia
  - Epic Games
  - Matterport, Inc. (NASDAQ:MTTR)
  - Animoca Brands
  - Roblox Corporation (NYSE:RBLX) Market Capitalization
  - Unity Software Inc.
  - Autodesk, Inc.
  - QUALCOMM Incorporated (NASDAQ:QCOM)
  - Tencent Holdings Limited (OTC:TCEHY)
  - Meta Platforms, Inc

Inside a Headset device

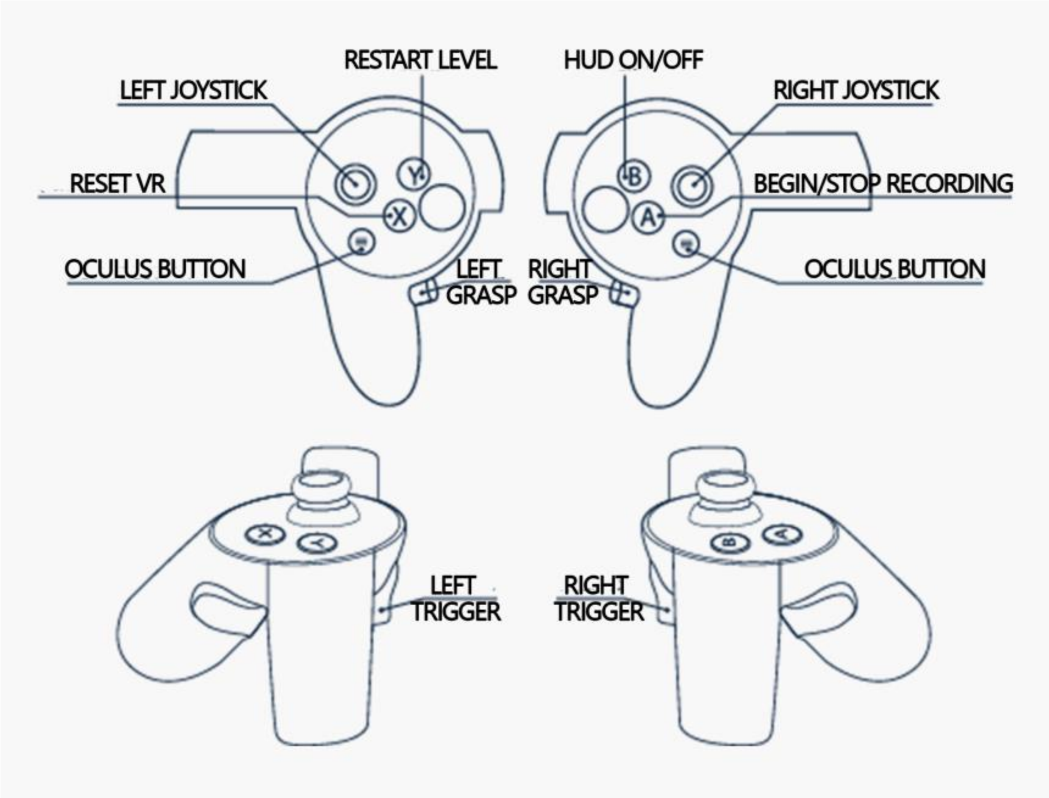
- Meta Quest PRO
  - Front cameras for MR (depth cameras)
    - Proximity
    - Gesture tracking
  - Eye tracking sensors
    - Facial expression tracking
  - Inertial Measurement Unit (IMU)- report acceleration, orientation, angular rates, and other gravitational forces and include 3x accelerometers, gyroscopes, and magnetometers
  - Time of Flight sensor (distance measurement)
  - Qualcom XR2 processing
  - Mini LED panels at 1800x1920 resolution per eye
  - Twin cell 20Wh battery
  - Speakers
  - Controllers
    - Qualcom Snapdragon 662 SoC processing
    - Cameras for better position detection
    - IMUs



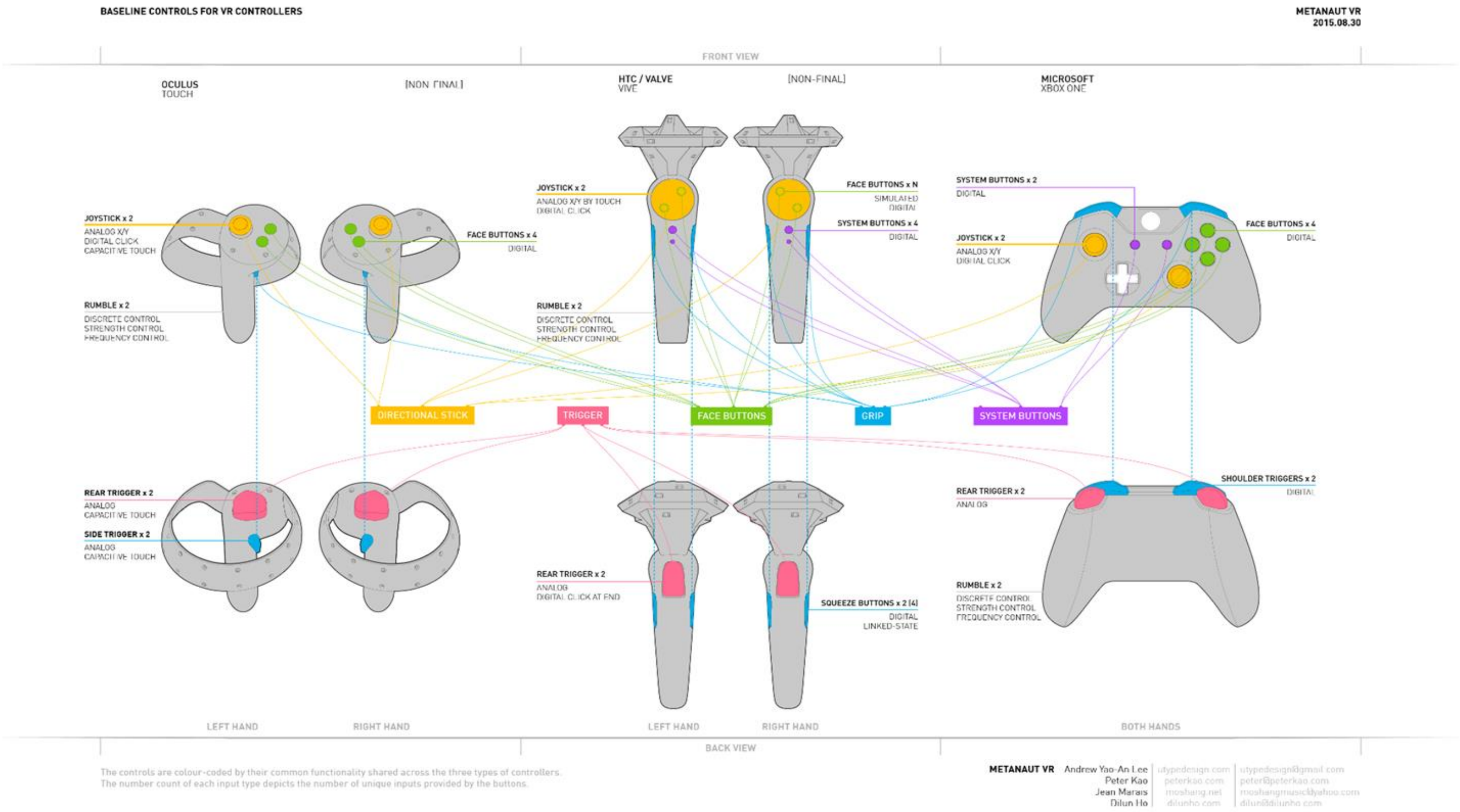
https://youtu.be/LDUJLnrCgow

Controls in VR

- The evolution of gaming console joystick for VR experience
- Two hand UX
- Wireless
- Accurate position
- Accelerometer sensor

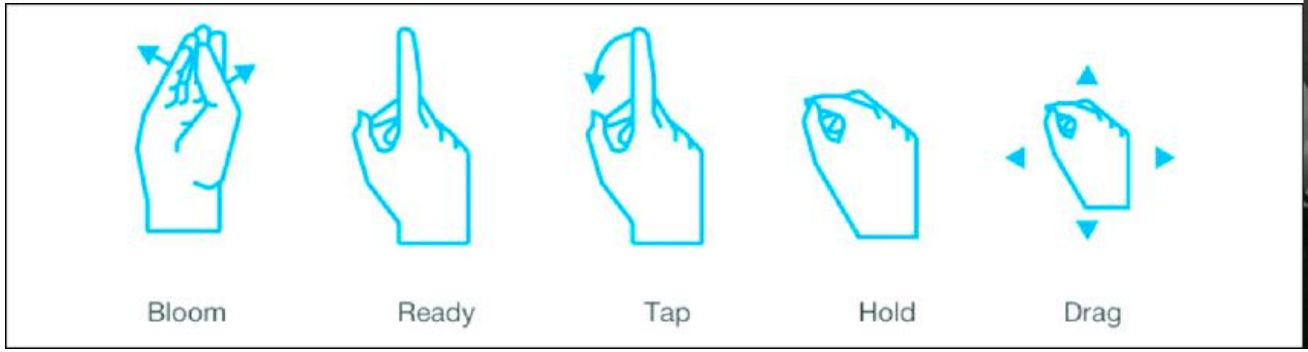


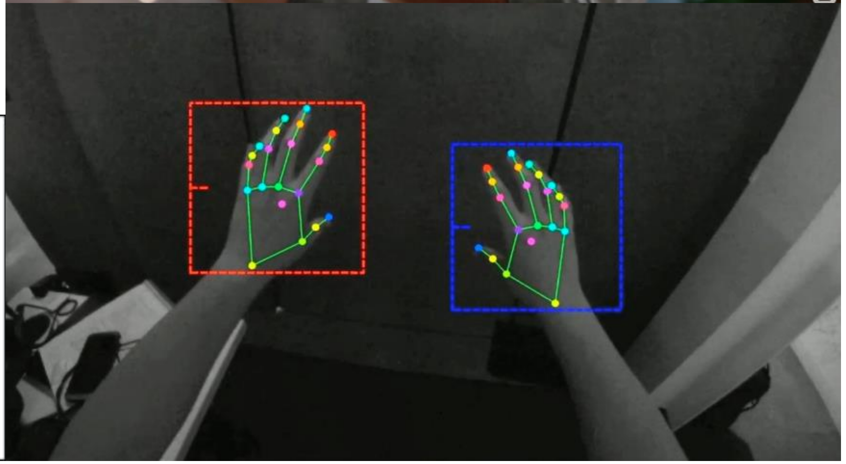
Controls in VR



Gestures in AR and MR

- No controllers are required
- Front cameras of the headset understand motion of fingers and classify specific actions
- MR devices that have Hand tracking allows the user to interact with all virtual objects like in real physical environment
- AR devices have specific gestures to interact with the virtual environment

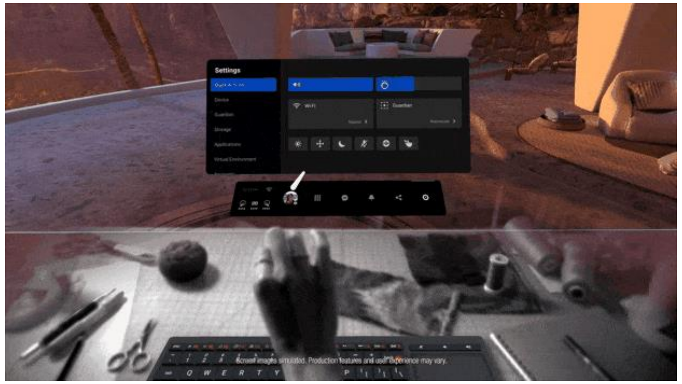




Delivery of VR and AR experiences

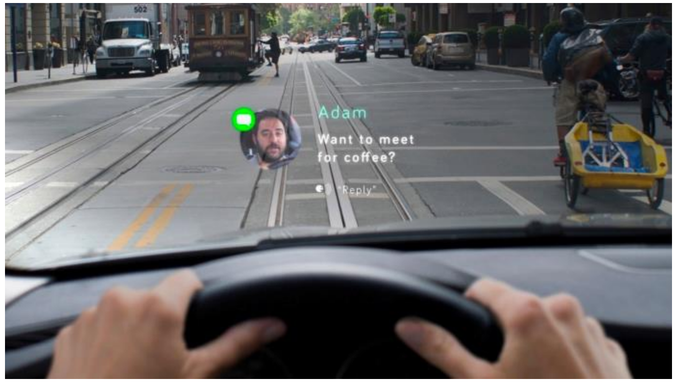
- **VR Cardboards:** Cardboard uses the smart phone that acts as the display. 360 Images and Videos create the immersive experience. There is very basic interaction of the user with the VR experience
- **VR headsets:** VR headsets can use both 360 images and videos but also 3D graphics to represent the virtual environment. The user can interact with the virtual environment using gestures and controllers
- **WebVR (Browser):** Similar to VR Headset but the overall experience is delivered on a web browser that supports WebVR. Gestures are not applicable and obviously the level of immersion is low. WebVR is similar to a typical online game. The advantage of WebVR is that is can allow a user without a VR Headset to experience a VR game/training using her laptop
- **AR smart glasses:** A simple display that presents digital content. it is not interacting with the physical space and is used mainly to improve information flow to the user. An example is Google Glass
- **Mobile AR**: The first AR experiences are using the smartphone. The depth camera of the phone and its display provide an interactive AR experience. The most dominant example is PokemonGO
- **AR Headsets:** The use of the headset improves the overall immersion level and enables gestures to interact with virtual environment

Delivery of VR and AR experiences


WebVR


Smartphone


VR headset



Smart glass


VR Cardboard


AR headset

Haptics in VR

- Haptics is defined as a technology that transmits tactile information using sensations such as vibration, touch, and force feedback. Virtual reality systems and real-world technologies use haptics to enhance interactions with humans
  - Gloves
  - Suits

Devices to increase level of immersion

To increase level of immersion, there are external devices connected to the VR headset and experience. They enable parts of human body to participate in the experience and provide input to the game.

- **Treadmills**→ enable motion input from legs
- **Flying simulators**→ enable motion input from hands and body rotation
- **Theme parks**→ actuators in response to VR experience

Comparing Unreal and Unity

- **Unity**→ Unity brings state-of-the-art, affordable multiplatform tools and services to developers of interactive content everywhere. Unity is the ultimate game development platform. Use Unity to build high-quality 3D and 2D games, deploy them across mobile, desktop, VR/AR, consoles or the Web, and connect with loyal and enthusiastic players and customers. Unity has numerous libraries and great support. It can be preferred for cases where instructional design of the VR experience is of high importance.

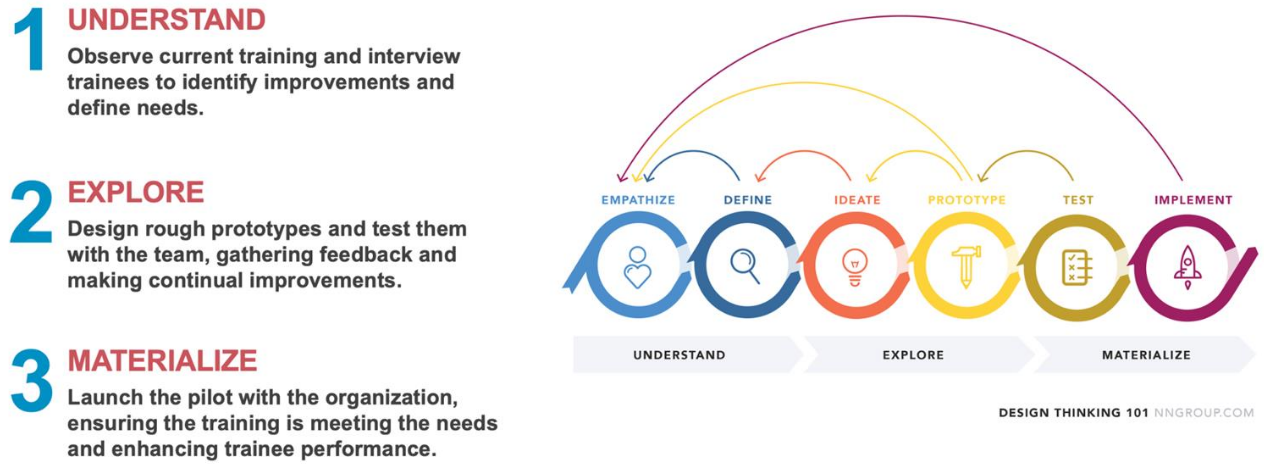
- **Unreal Engine**→ A suite of integrated tools for game developers. It is a game engine that helps you make games. It is made up of several components that work together to drive the game. Its massive system of tools and editors allows you to organize your assets and manipulate them to create the gameplay for your game. Unreal is a great engine for realistic high quality graphics. It is preferred for gaming use cases.

Session 9: Trends in Visualization Technology

3. Development Challenges

Agile development processes from idea to product

- Create MVP with 360 Images or 360 Videos. Use an interactive web sbased 360 video app (Instavr, veer, kuula, etc)
- Receive feedback
- Create native VR experience using Unity/Unreal
- Publish to a VR store (Oculus Quest store, Steam, etc)
- Scale



George Koutitas, Scott Smith & Grayson Lawrence, "Performance evaluation of AR/VR training technologies for EMS first responders", Virtual Reality volume 25, pages: 83–94 (2021)

Common questions at various Development Stages

- Which program to use?
- How much resolution to keep speed high but UI acceptable?
- Should I develop on Unreal or Unity?

Create 3D Environment → Instructional Design → Immersion / Special Effects → Embed Analytics / Metrics → Package / Publish App

Instructional Design

- What is the flow of my experience?
- Is there a story line to follow?
- Who creates it?
- Are there standards to use?

Immersion / Special Effects

- What type of special effects should I create to improve immersion?
- How to leverage Gestures to improve immersion?

Embed Analytics / Metrics

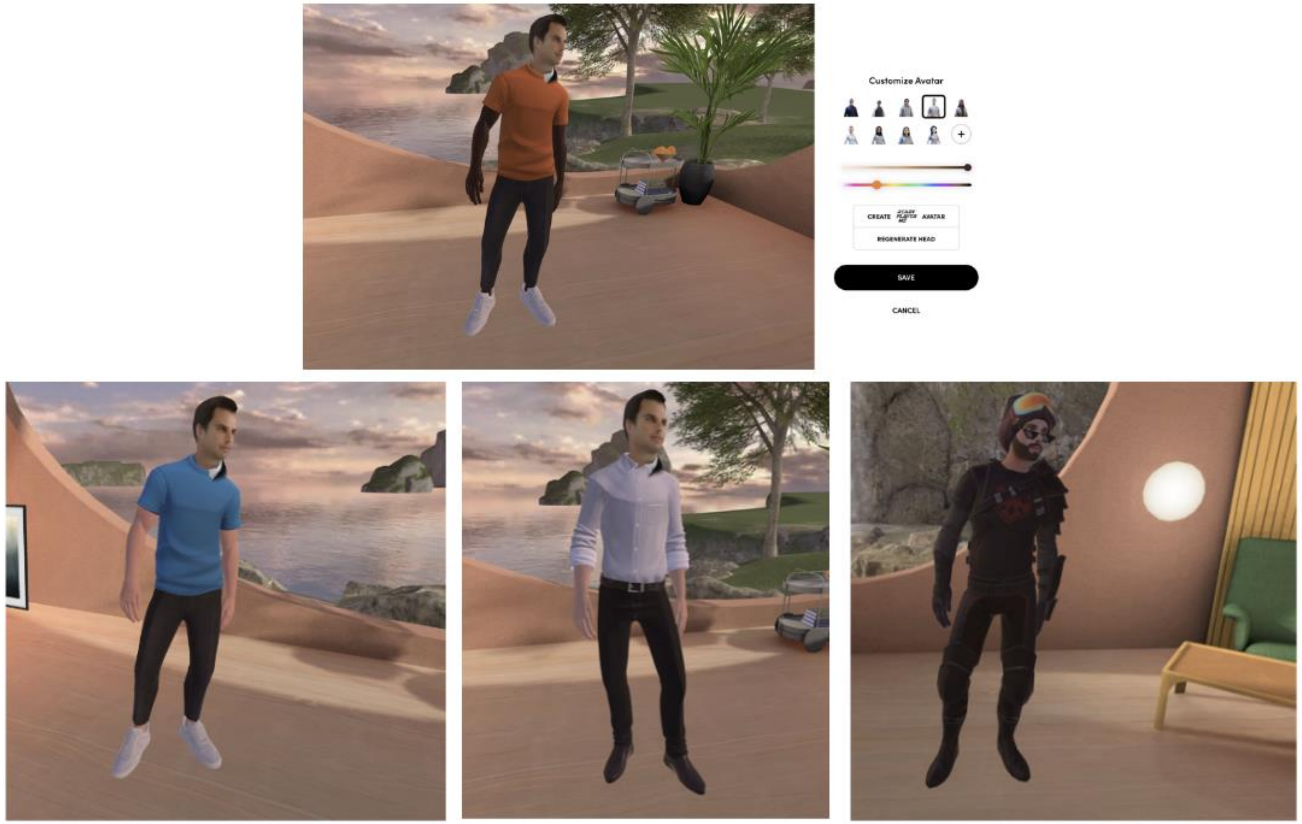
- Do I need to measure specific metrics during the experience?
- How do I transfer them to main server?

Package / Publish App

- Install .apk file to device?
- Publish on a marketplace (Oculus store, Sidequest, etc)?

Creating my avatar

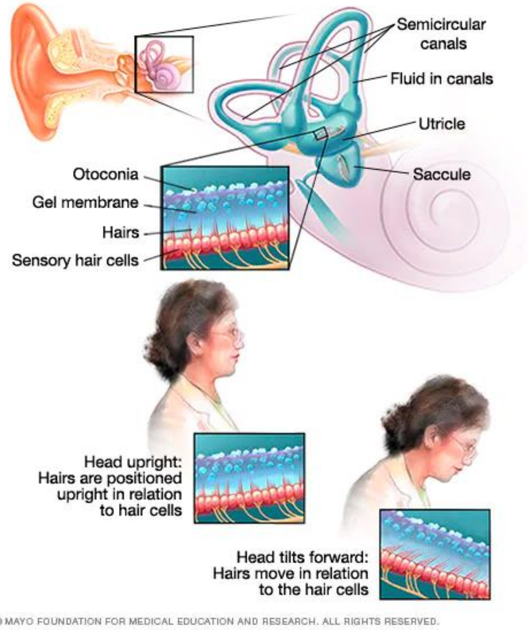
- Ownership
- Diversity
- Customizable
- Transferable to different worlds
- Personalized or totally de-identified
- Inclusion criteria



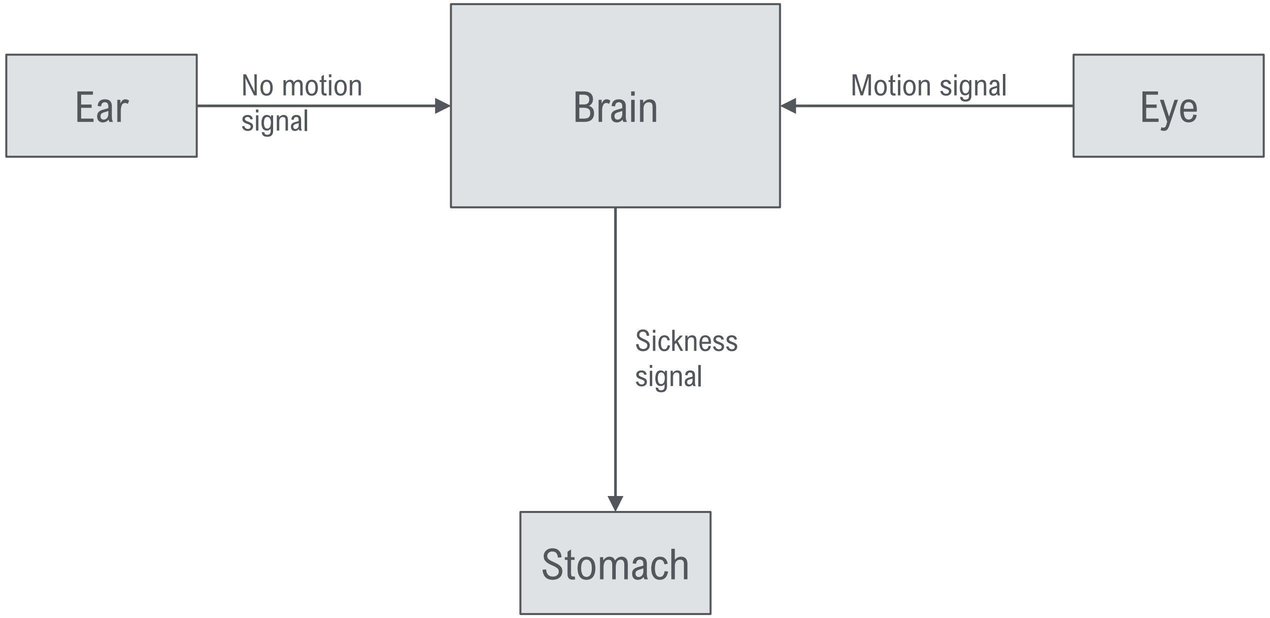
Spatial Platform http://spatial.io/

Motion Sickness

- **Humans perception of motion mainly depends on two sensors**
  - **Eye**→ sends a motion signal to brain when there is motion in the surrounding environment captured in the field of view of the ete
  - **Ear**→ has sensory hair cells in the Utricle that generate a motion signal according to the position of the body
  - **Body tissue**→ these sensors understand moving air
  - Human brain trusts all its sensors (Eye, Ear, Body tissue)
  - Motion sickness occurs when there are conflicting signals from the body sensors
- Motion sickness can also occur due to the low frame rate of the video presented on the display
- Symptoms can be Disorientation, Sweating, Nausea, Headaches, Disorientation, Eye strain and even vomiting in severe cases
- **Brain defends itself by generating a sickness signal to the stomach so that human body will stop all current activities :)**



Motion sickness during VR experience



- Technological solution
  - Headset manufacturers developed a new set of experimental headphones or integrated actuators in the headphone that use electrical impulses to fool your inner ear into thinking your body is physically moving
  - Use of a VR Treadmill to actually have physical motion together with the VR experience. This is only applicable in experiences that include walking/running

Overcoming Motion Sickness

- Use headset with HD high frame rate and with electric impulse actuators
- Avoid eating heavy foods before long periods of screen time
- Avoid electronic screens when in a moving vehicle

There are some ways to prevent VR motion sickness before it starts. Here are some of the most common suggestions:

- **Using a fan**: Aim the fresh air at your face and keep the room ventilated and free of strong odors.
- **Eat ginger beforehand**: As weird as it sounds, Ginger has long been used as an alternative medication to prevent nausea.
- **Aromatherapy**: Now that diffusers and essential oils are popular, using a room diffuser or placing a few drops of lavender or ginger essence on your wrist, for example, may help reduce nausea.
- **Wear a Wristband**: Some people say that this doesn't work, but it is based on the ancient healing art of acupressure, a form of traditional Chinese medicine. You use a band at point P-6, also called Neiguan, which is located on your inner arm near your wrist. Performing acupressure on this point can help relieve nausea and vomiting.

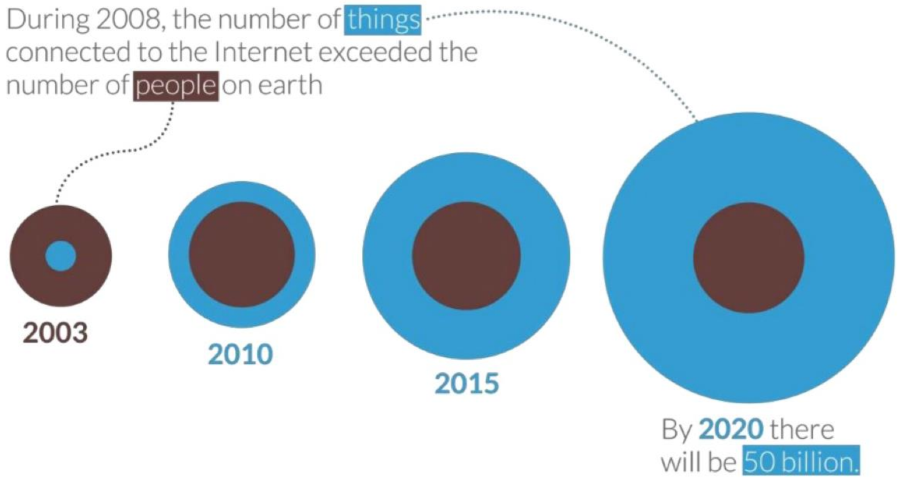
Teleportation

- **Holoportation→**
  - multiple cameras in the room. two cameras capable of capturing depth information to create a 3D representation of an object. However, the more cameras we have, the better the quality of the 3D model.
  - Transfer human volume information together with skin interface
  - better resolution and speed
- **Teleportation→**
  - kinect camera in front of human
  - transfers pixels
  - low resolution and speed
- Challenges **i) bandwidth** (use compression to solve issue), **ii) changing lighting and background, vibrations**

Sources: 1. Teleport to Any Reality – Introducing Varjo's Vision - Varjo.com, 2. Holoportation™ - Microsoft Research

Virtual Environment of Things

- Non-human centric > human centric data by 2025
  - **Key Challenge: What will be the Human-to-Thing interface?**



touch

dashboard

Virtual Environment of Things

- Integrating real-world smart things and virtual-world avatars/holograms in a computer generated virtual environment so that entities in either worlds can interact with one another in a real-time manner.
  - Low latency + High bandwidth communication is an enabler of this service

Session 9: Trends in Visualization Technology

4. Conclusions

Takeaways from week 9

- In this session we have provided an overview of trends in visualization and VR and AR technologies which will become the displays for all metaverse applications in the future
- There was an extended coverage of the historical evolution of the sector and the current state of headsets.
- We have introduced the concept of VR/AR controls and Gestures and how Haptics can increase level of immersion
- There was a discussion on the key use cases and applications for both AR and VR and the challenges and new opportunities of the sector

Further reading

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Further reading

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- The History of Oculus VR (Meta) - How a Small Kickstarter Birthed a new Industry - YouTube
- Seven years after raising $542M at a $2B valuation, Magic Leap raises $500M at a $2B valuation | TechCrunch

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