SWAYAM NPTEL COURSE ON

MINE AUTOMATION AND DATA ANALYTICS

By

Prof. Radhakanta Koner

Department of Mining Engineering

Indian Institute of Technology (Indian School of Mines) Dhanbad

Module 06
Automated Tracking and VR Systems

Lecture 15 A
Introduction to VR Systems

CONCEPTS COVERED

- What is Virtual Reality
- I^3 of virtual reality
- Types of Virtual Reality
- Applications of VR
- Hardware components of VR systems

CONCEPTS COVERED

- Field of View and Visual
- Overview of Micro-displays
- Benefits of Virtual Reality
- Future of Virtual Reality
- Technical Considerations for Virtual Reality

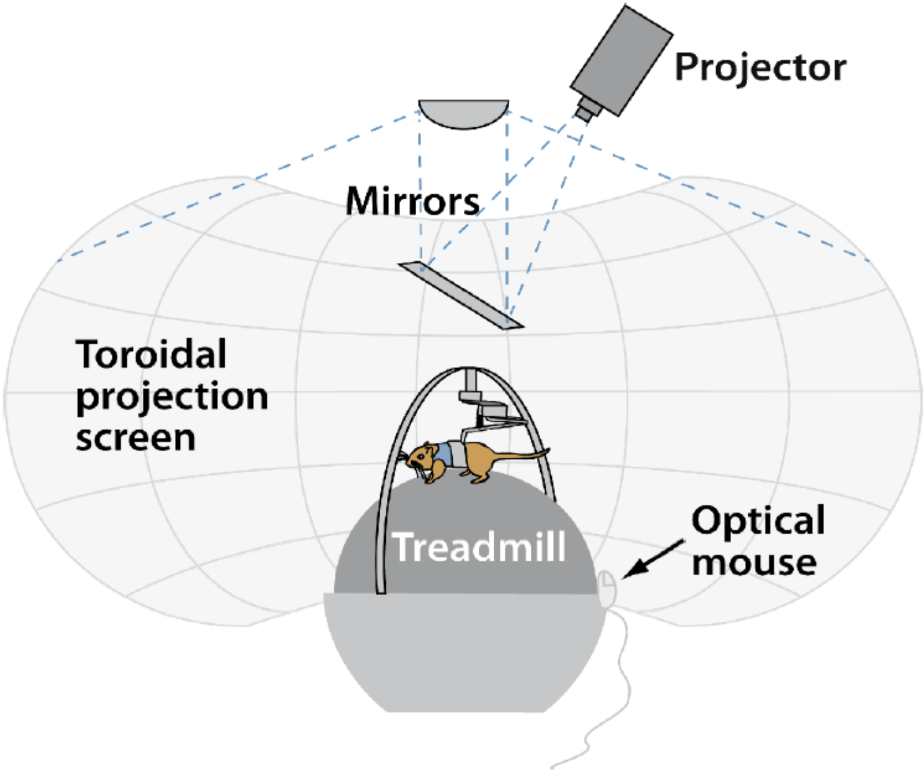
What is Virtual Reality?

Virtual Reality (VR) refers to a computer-generated simulation of an environment or situation that immerses users in a three-dimensional, interactive experience. In a virtual reality environment, users can interact with the simulated world using specialized hardware and software. The goal of virtual reality is to create a sense of presence, making users feel as if they are physically present in the virtual space.

Examples:

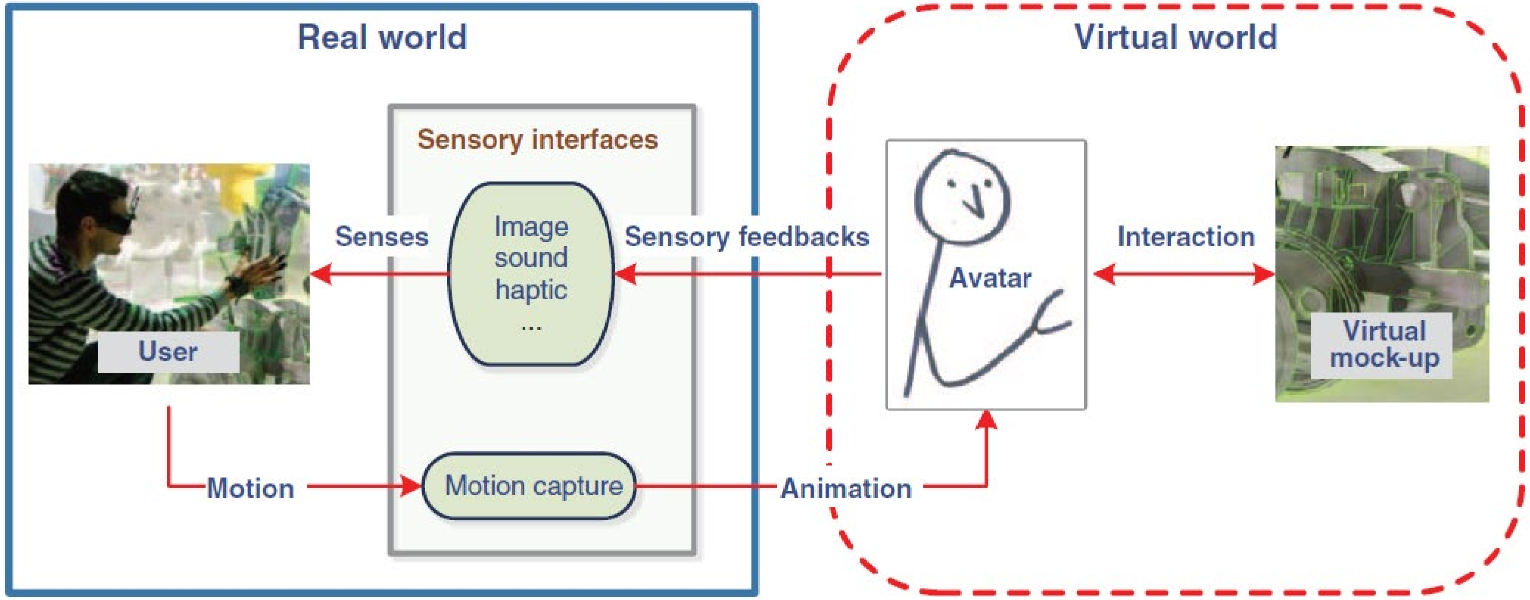
1. **A human has an experience of flying over virtual San Francisco by flapping his own wings as shown in figure below. The user, wearing a VR headset, flaps his wings while flying over virtual San Francisco. A motion platform and fan provide additional sensory stimulation. The figure on the right shows the stimulus presented to each eye.**

2. A mouse running on a freely rotating ball while exploring a virtual maze that appears on a projection screen around the mouse. An experimental setup used by neurobiologists at LMU Munich to present visual stimuli to rodents while they run on a spherical ball that acts as a treadmill

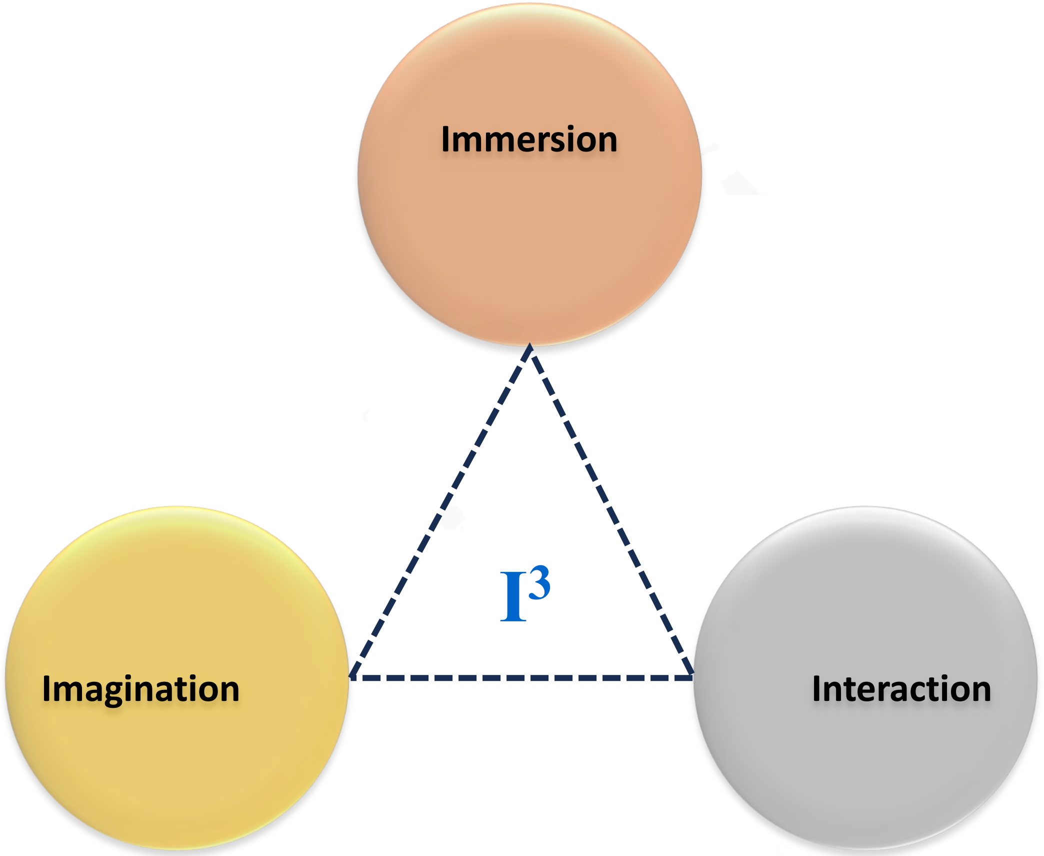


Principle of Virtual Reality

The principle is to create a relationship between the user and a virtual environment. For that, software technologies (computer graphics, real-time computing) as well as hardware technologies (human-computer interfaces) are required.



I^3 of virtual reality



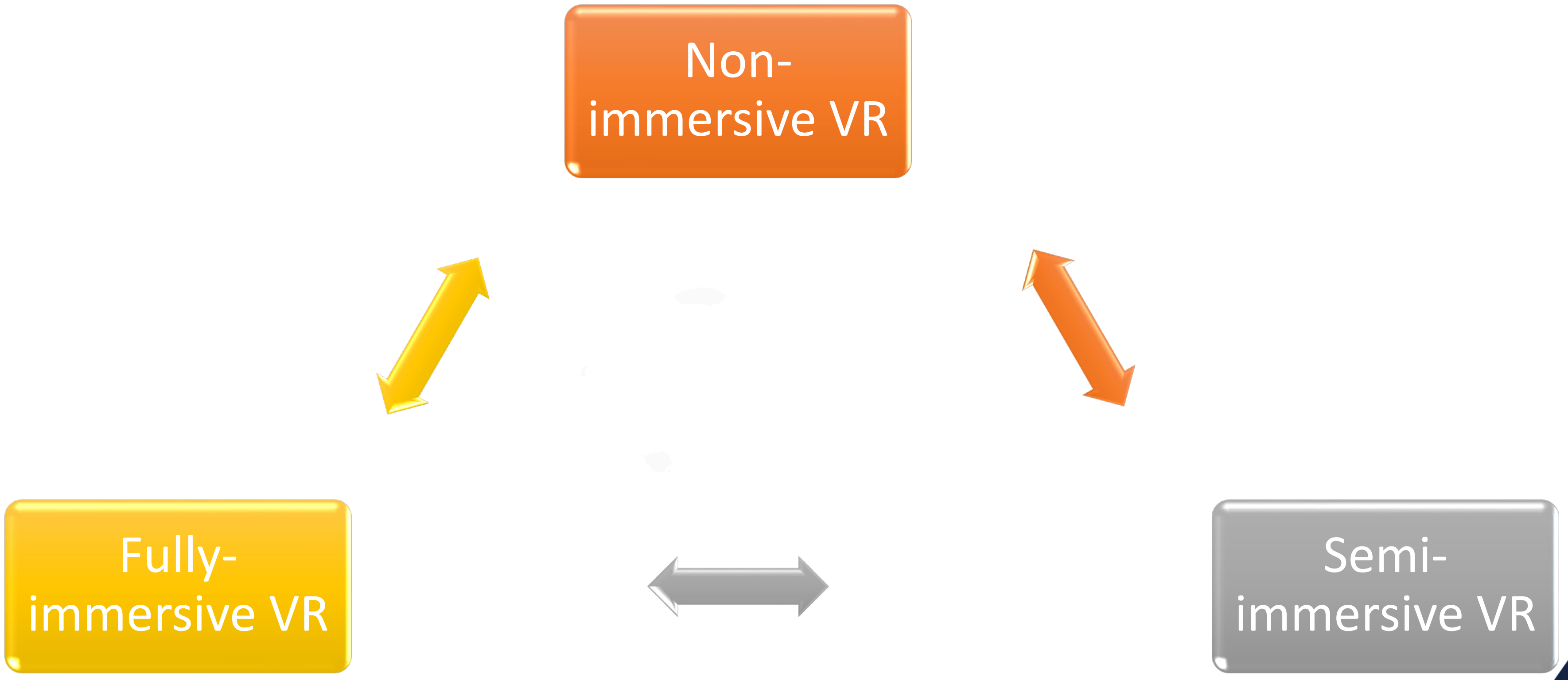
Immersion: It means that users focus on the experience in virtual scenes and forget the real environment, which is the key to virtual simulation.

Interaction: The experiencer participates in the virtual environment and gets information feedback from the virtual environment, which is the core of human-computer interaction. Users can interact with virtual objects in various forms.

Imagination: It is the purpose of virtual simulation that the experiencer conceives various sensory effects beyond reality, improves rational or perceptual knowledge and expands people's imagination space.

With the development and evolution of virtual reality technology, its theory and system are becoming more and more mature. Artificial intelligence technology will also be included in the basic characteristics of VR, and its " I^3 " feature will develop into " I^4 " feature.

Types of Virtual Reality

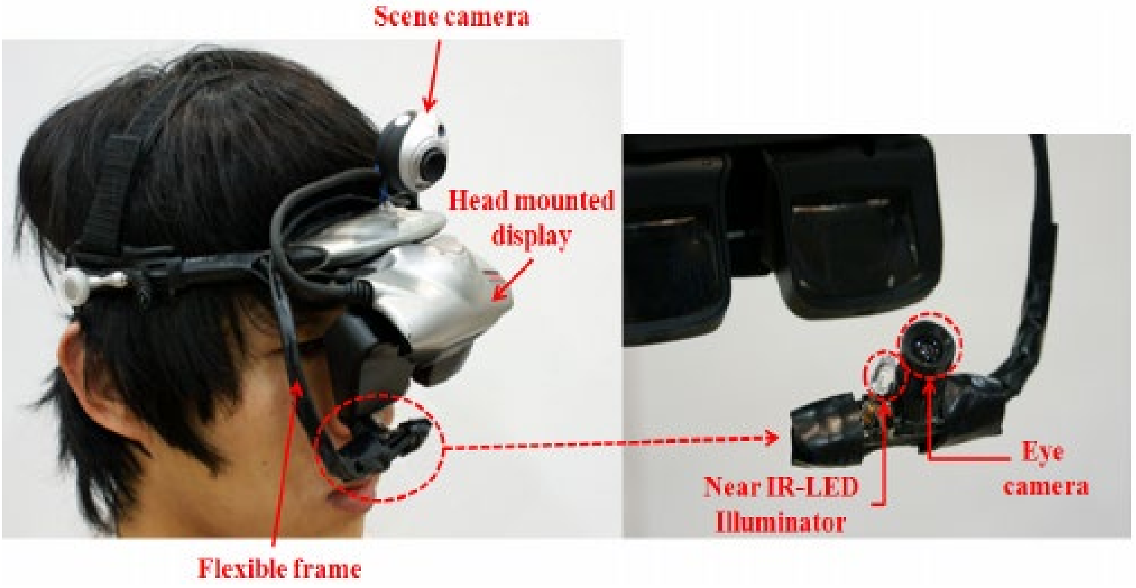


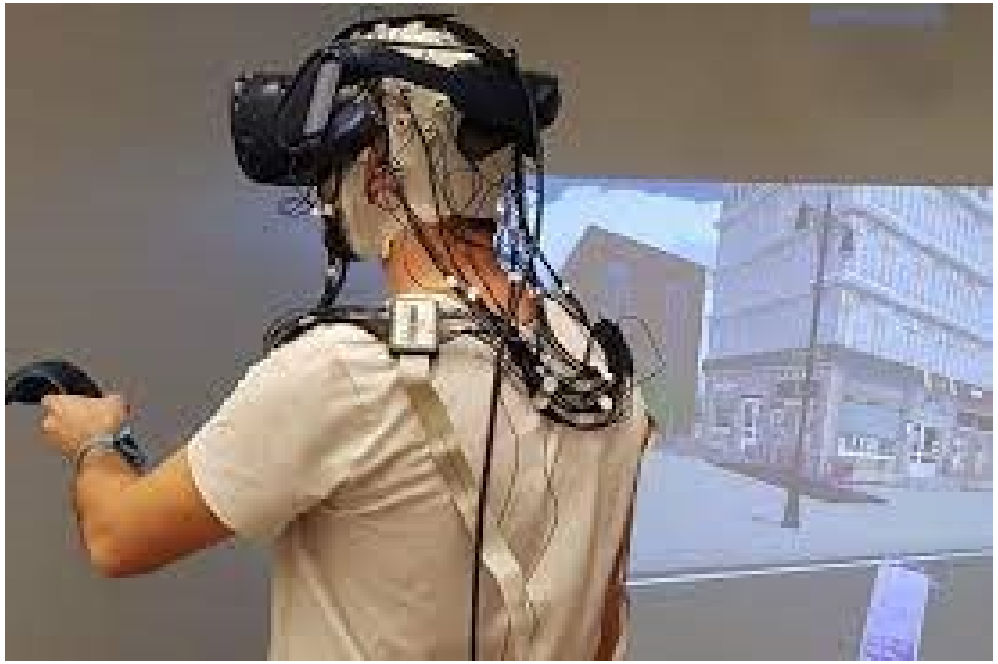
Non-immersive VR

1. Non-immersive VR, also known as desktop or 3D VR, is a basic form of virtual reality.
2. Users experience virtual environments through a computer screen or handheld devices like smartphones or tablets.
3. With non-immersive VR, users can view the virtual world on a screen while simultaneously observing their real-world surroundings.
4. Examples of non-immersive VR include virtual tours, 360-degree videos, and flight or driving simulators.

Semi-immersive VR

- Semi-immersive VR provides a more immersive experience than non-immersive VR but doesn't fully immerse users in a virtual environment.
- Users typically wear a head-mounted display (HMD) covering only part of their field of view.
- The HMD may include motion tracking, enabling users to look around the virtual space by moving their head.





- However, body movements are not fully tracked, which may limit immersion.
- Applications of semi-immersive VR include gaming experiences and training applications where users can interact with virtual environments through head movements.

Fully-immersive VR

- Fully immersive VR offers the highest level of immersion and presence, providing a realistic and seamless virtual experience.
- Users wear special head-mounted displays (HMDs) or VR goggles that cover their eyes and ears.
- These devices allow for a 360-degree view and sound, creating a real sense of presence within the virtual world.
- High-resolution screens for each eye enhance depth perception.

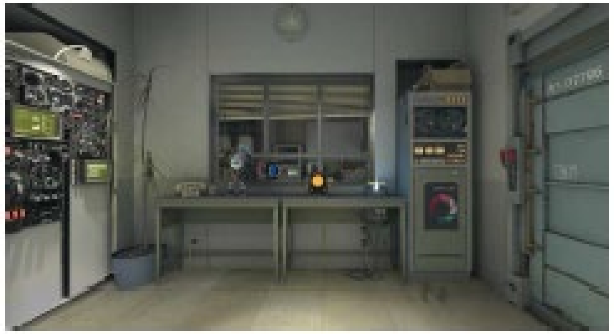
- **Users can interact with the virtual environment using both head and body movements.**
- **Additional accessories like motion controllers or haptic feedback devices may be included to enhance the experience.**
- **Examples of fully immersive VR include high-end gaming experiences, virtual simulations for medical and pilot training, and advanced architectural visualization tools allowing users to navigate virtual buildings**

Applications of VR

- Entertainment: Games
- Augmented Reality – Superimposing display
- Training
- Remote Robotics
- Distributed Collaboration
- Virtual prototyping

Applications

Entertainment: Games



(a)

(b)

(c)

(d)

Augmented Reality

The Microsoft Hololens, 2016, uses advanced see-through display technology to superimpose graphical images onto the ordinary physical world, as perceived by looking through the glasses.

Training

A flight simulator in use by the US Air Force. The user sits in a physical cockpit while being surrounded by displays that show the environment.

Remote Robotics

Examples of robotic avatars

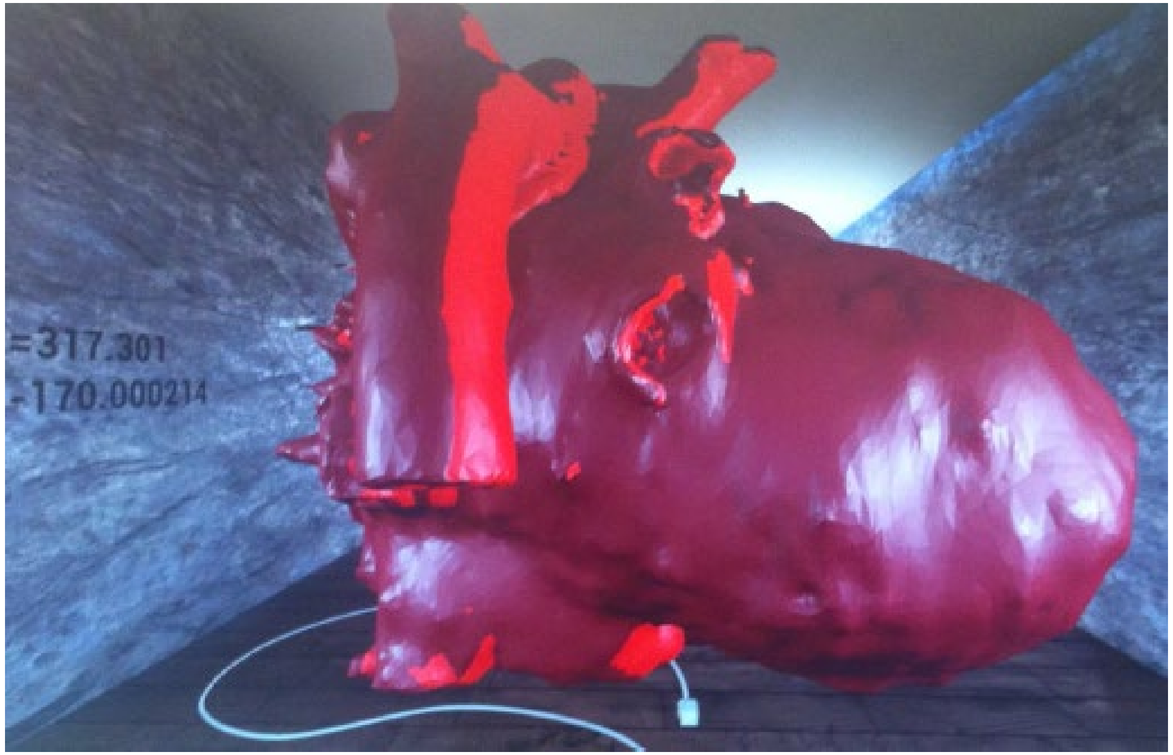
- **The DORA robot from the University of Pennsylvania mimics the users head motions, allowing him to look around in a remote world while maintaining a stereo view (panoramas are monoscopic).**
- **The Plexidrone, a flying robot that is designed for streaming panoramic video.**

(a)

(b)

Health care

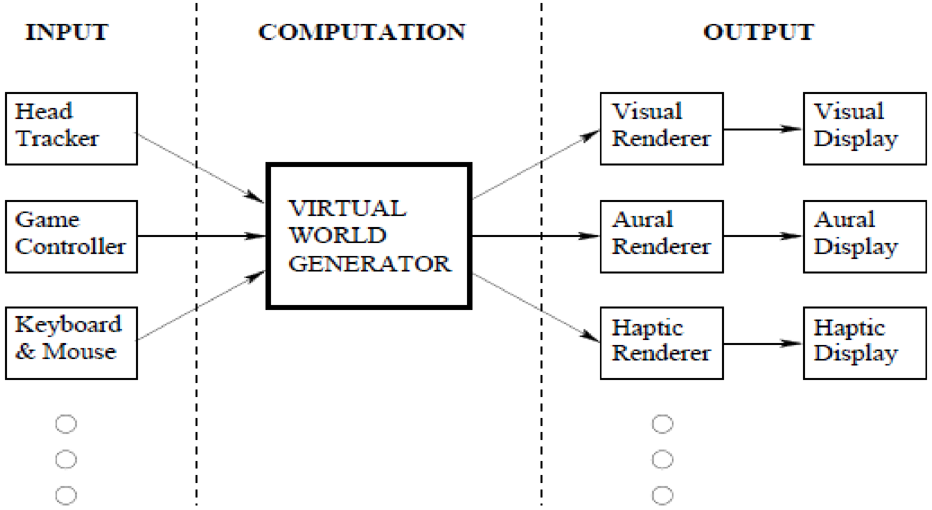
A heart visualization system based on images of a real human heart. This was developed by the Jump Trading Simulation and Education Center and the University of Illinois.



Virtual prototyping

Architecture is a prime example of where a virtual prototype is invaluable. This demo, called Ty Hedfan, was created by IVR-NATION. The real kitchen is above and the virtual kitchen is below.

Hardware components of VR systems



Displays (output)

Devices that each stimulate a sense organ.

Sensors (input)

Devices that extract information from the real world.

Computers

Devices that process inputs and outputs sequentially.

Field of View and Visual

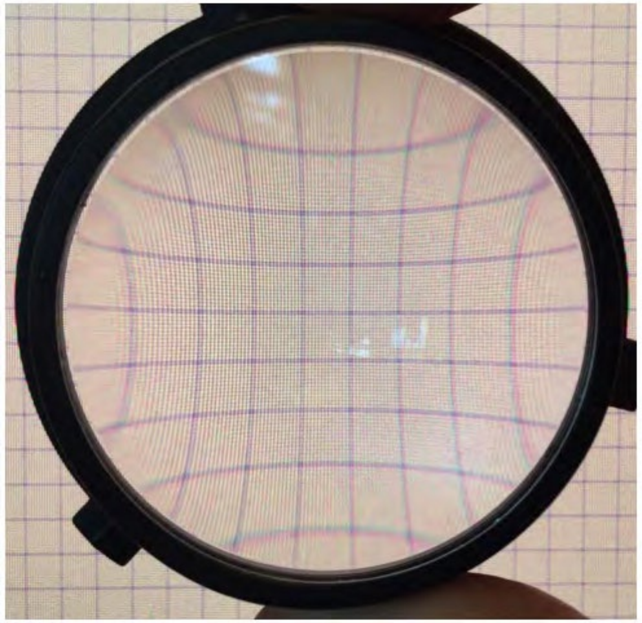
Lens Distortion Correction

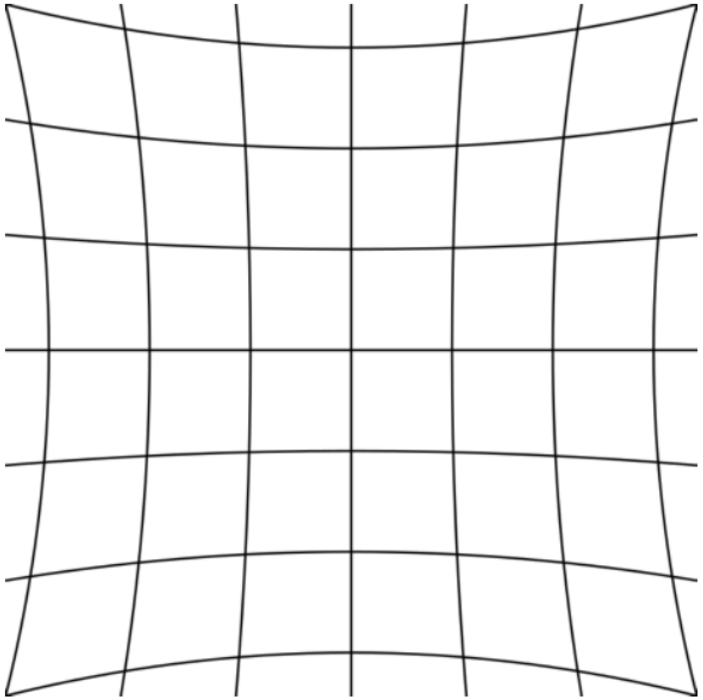
All lenses introduce image distortion, chromatic aberrations, and other artifacts – we need to correct for them as best as we can in the software

Lens Distortion

- grid seen through HMD lens
- lateral (xy) distortion of the image
- chromatic aberrations:

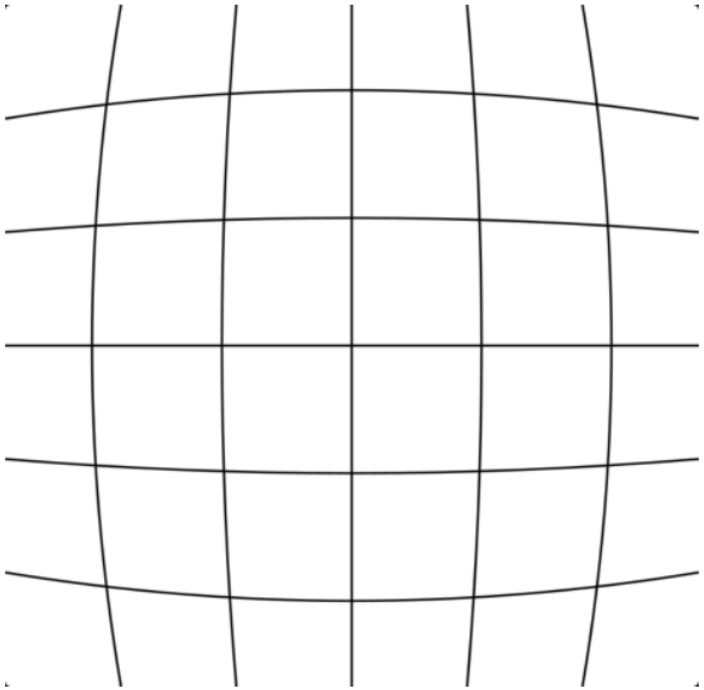
distortion is wavelength-dependent





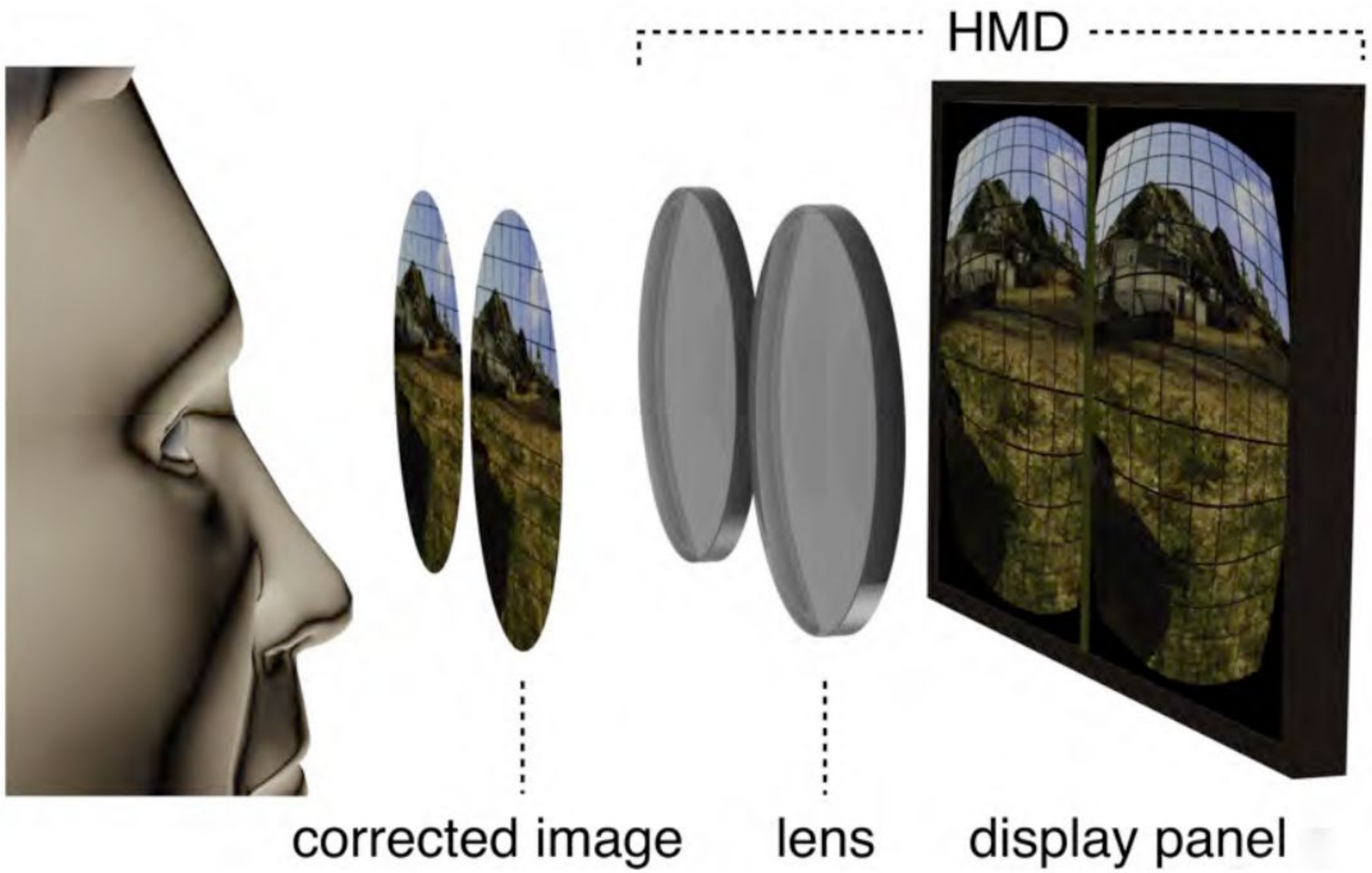
Pincussion Distortion

<u>optical</u>

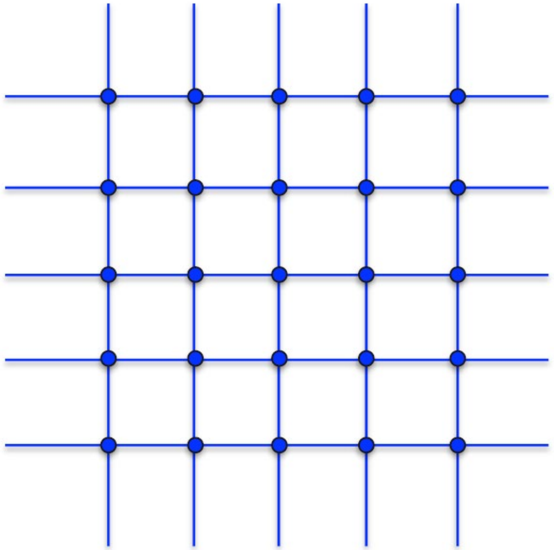


Barrel Distortion

<u>digital correction</u>


HMD
corrected image
lens
display panel

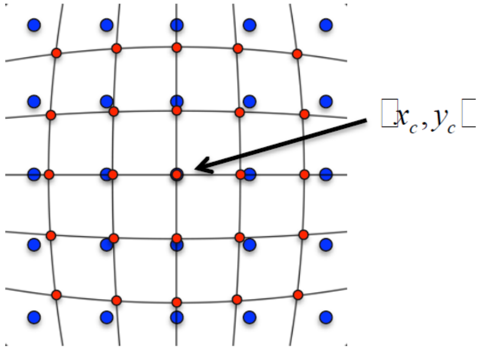
- x_u , y_u **undistorted point**



- x_u, y_u undistorted point
- $x_d \approx x_u(1 + K_1 r^2 + K_2 r^4)$

  $y_d \approx y_u(1 + K_1 r^2 + K_2 r^4)$

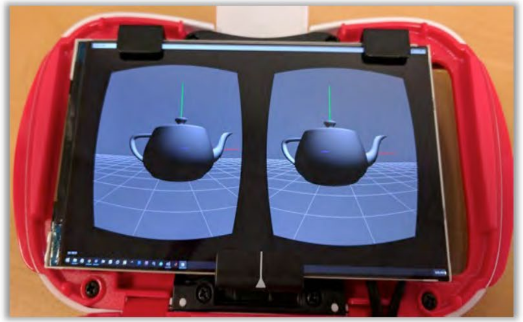
x_d, y_d	distorted point coordinates
K_1, K_2	distortion coefficients
r	normalized distance from center
x_c, y_c	center of optical axis



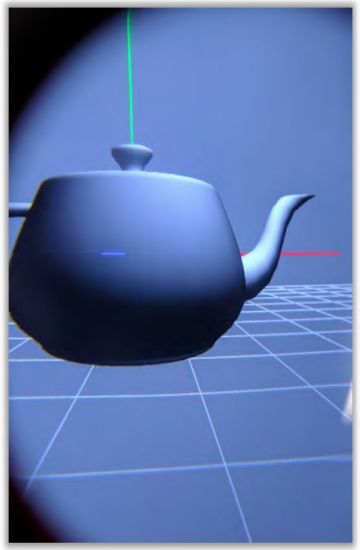
Barrel Distortion

digital correction

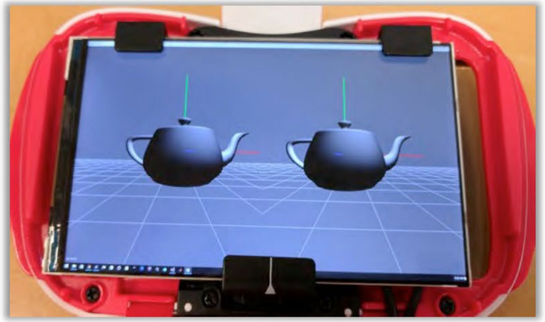
Lens Distortion Correction Example



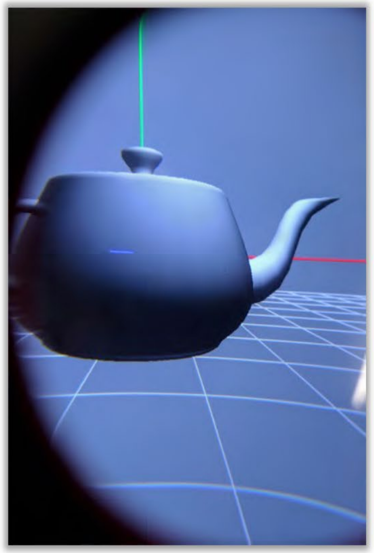
stereo rendering with lens distortion correction



Lens Distortion Correction Example

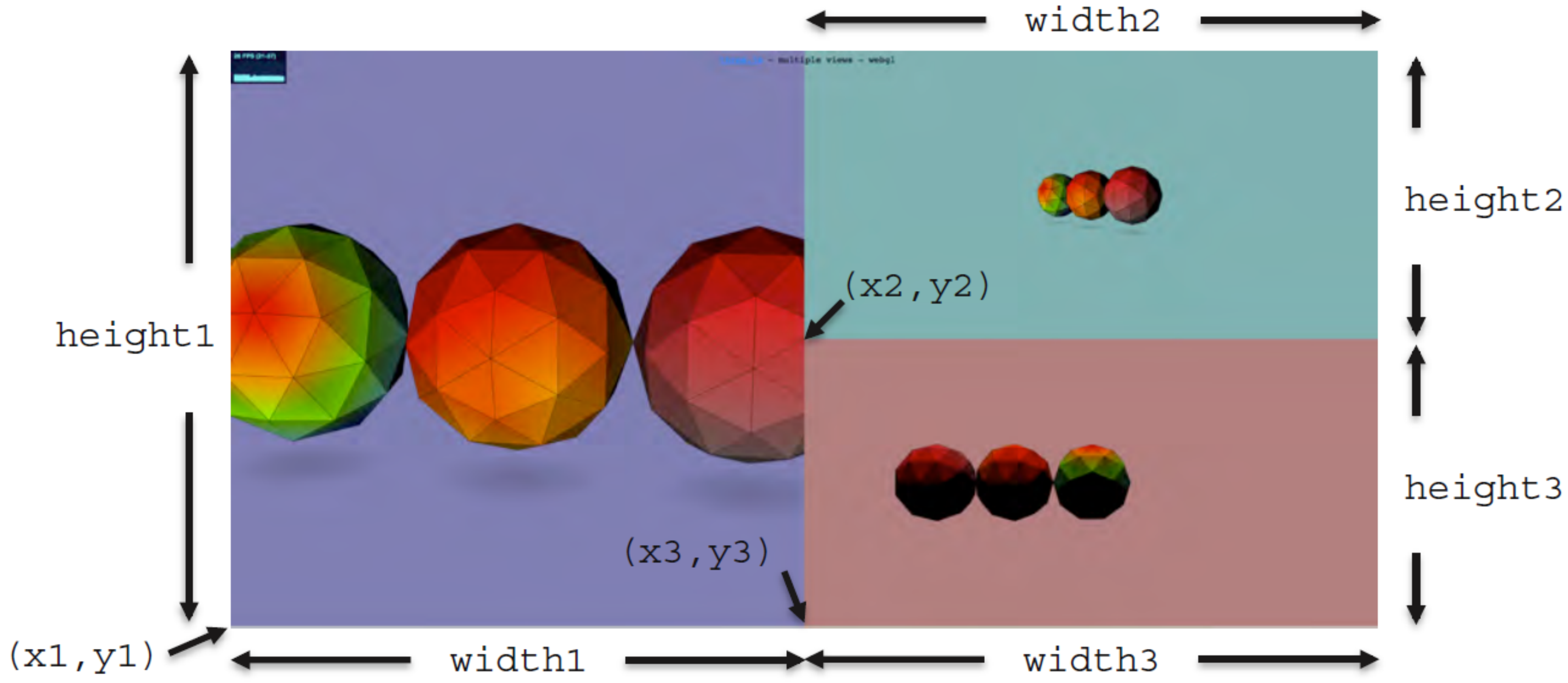


stereo rendering without lens distortion correction



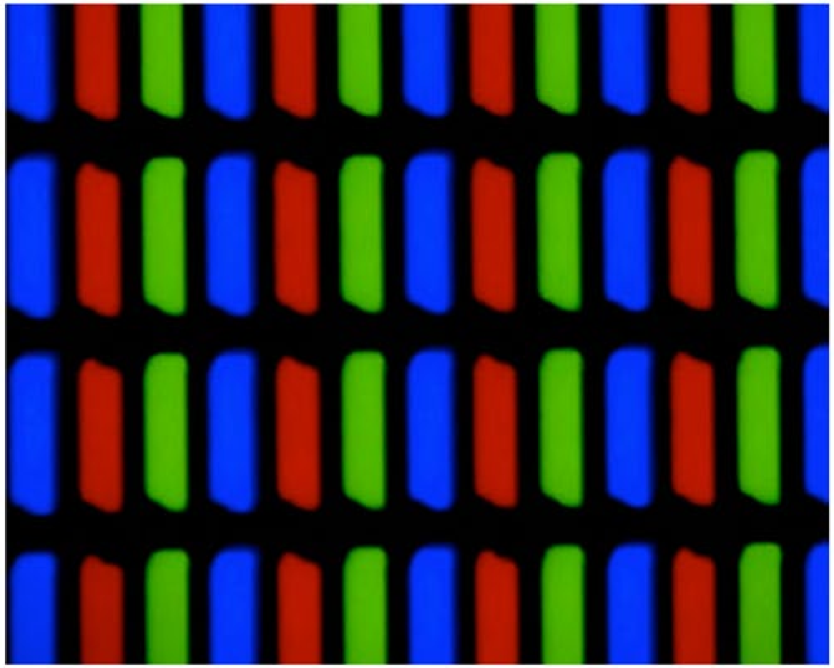
How to Render into Different Parts of the Window?

- `WebGLRenderer.setViewport(x,y,width,height)`
- `x,y` lower left corner; width, height viewport size



Overview of Micro-displays

Liquid Crystal Display (LCD) - Subpixels

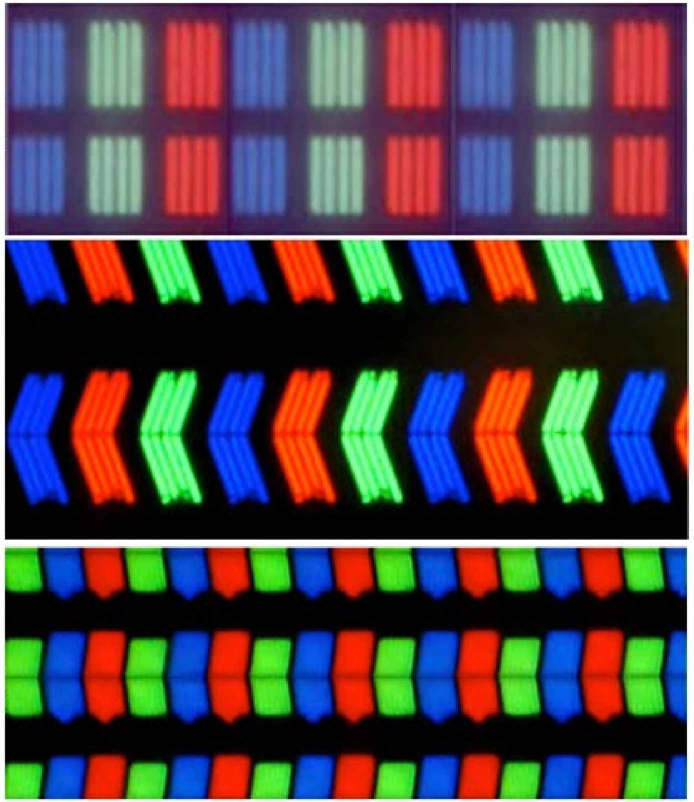


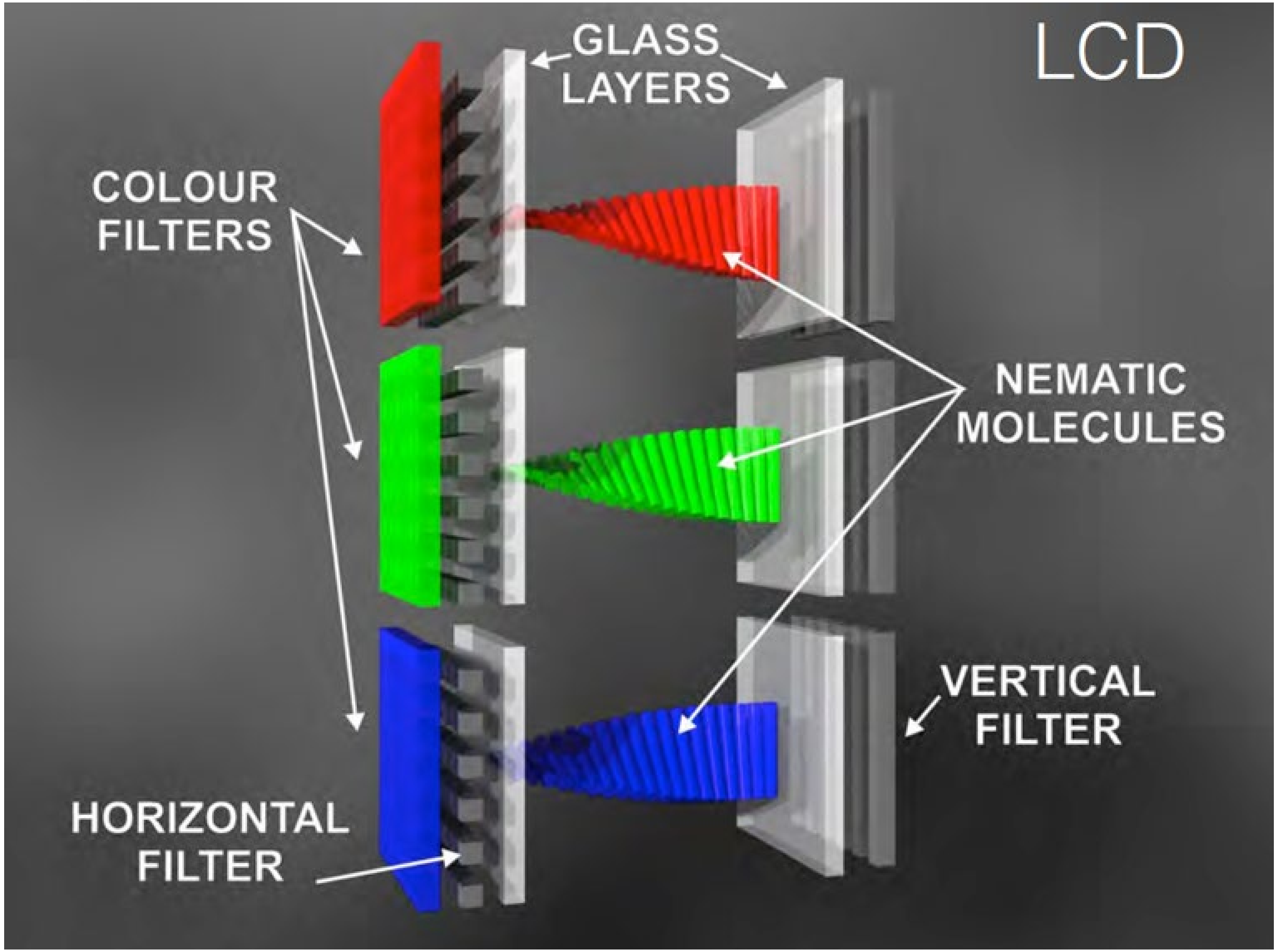
TN subpixels

IPS

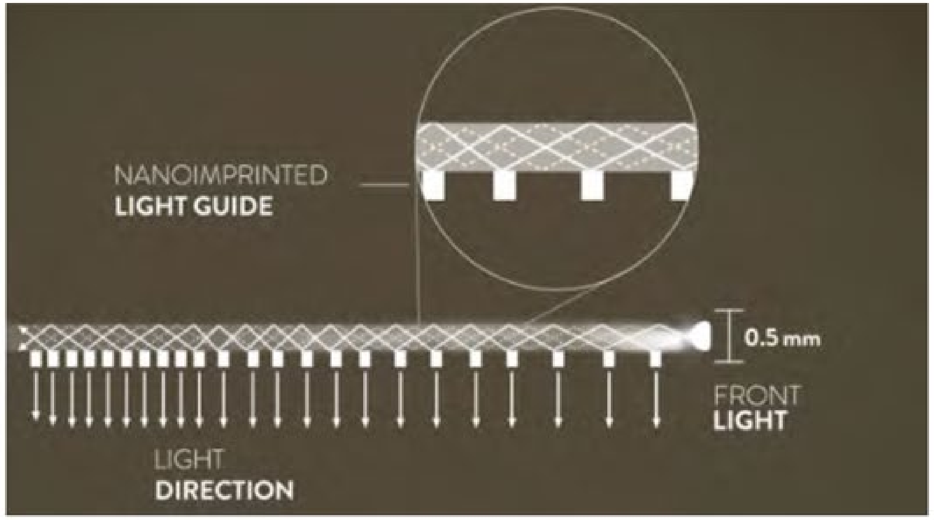
S-IPS

IPS

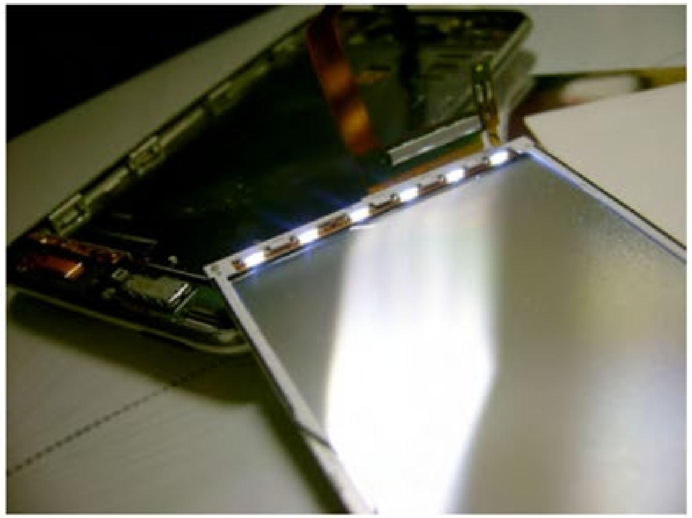



LCD
GLASS
LAYERS
COLOUR
FILTERS
NEMATIC
MOLECULES
VERTICAL
FILTER
HORIZONTAL
FILTER

LCD Backlight

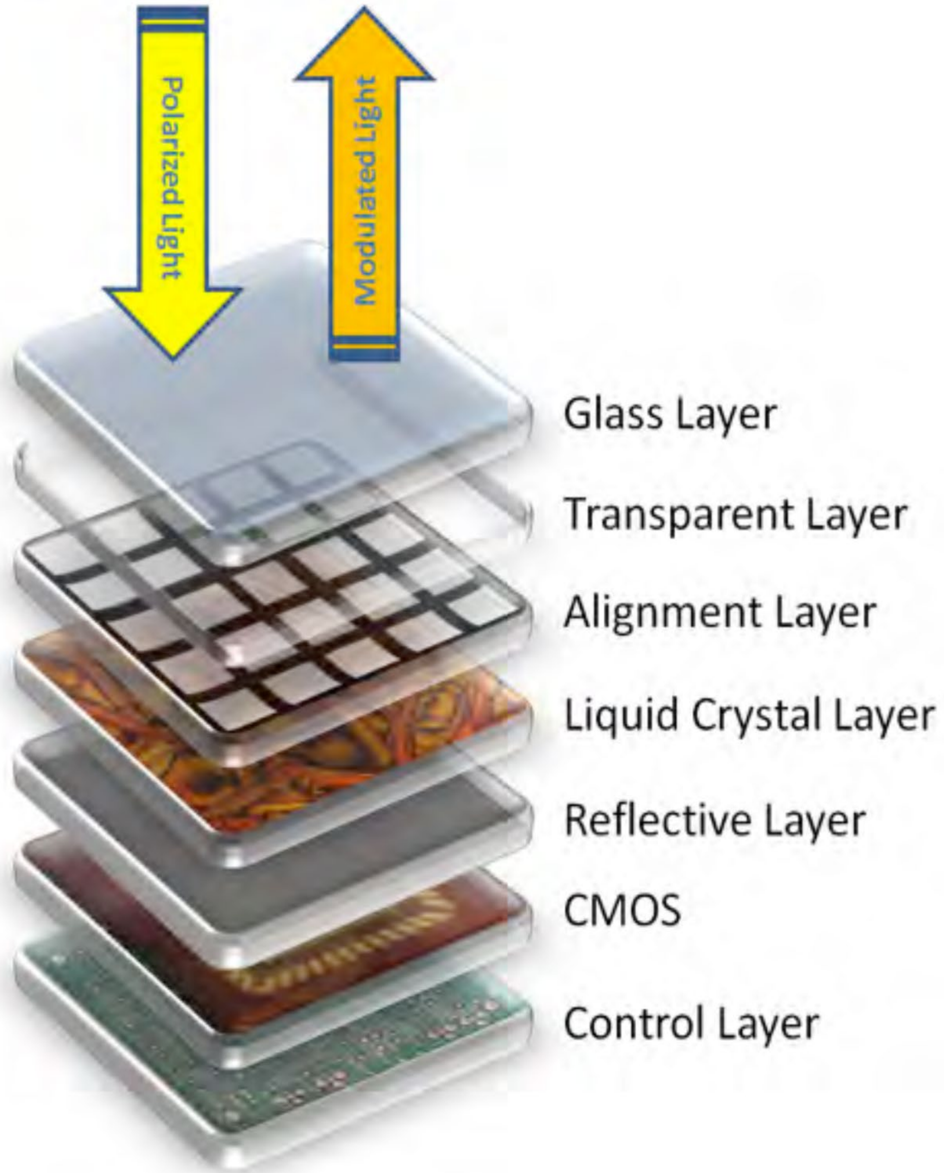


wikipedia

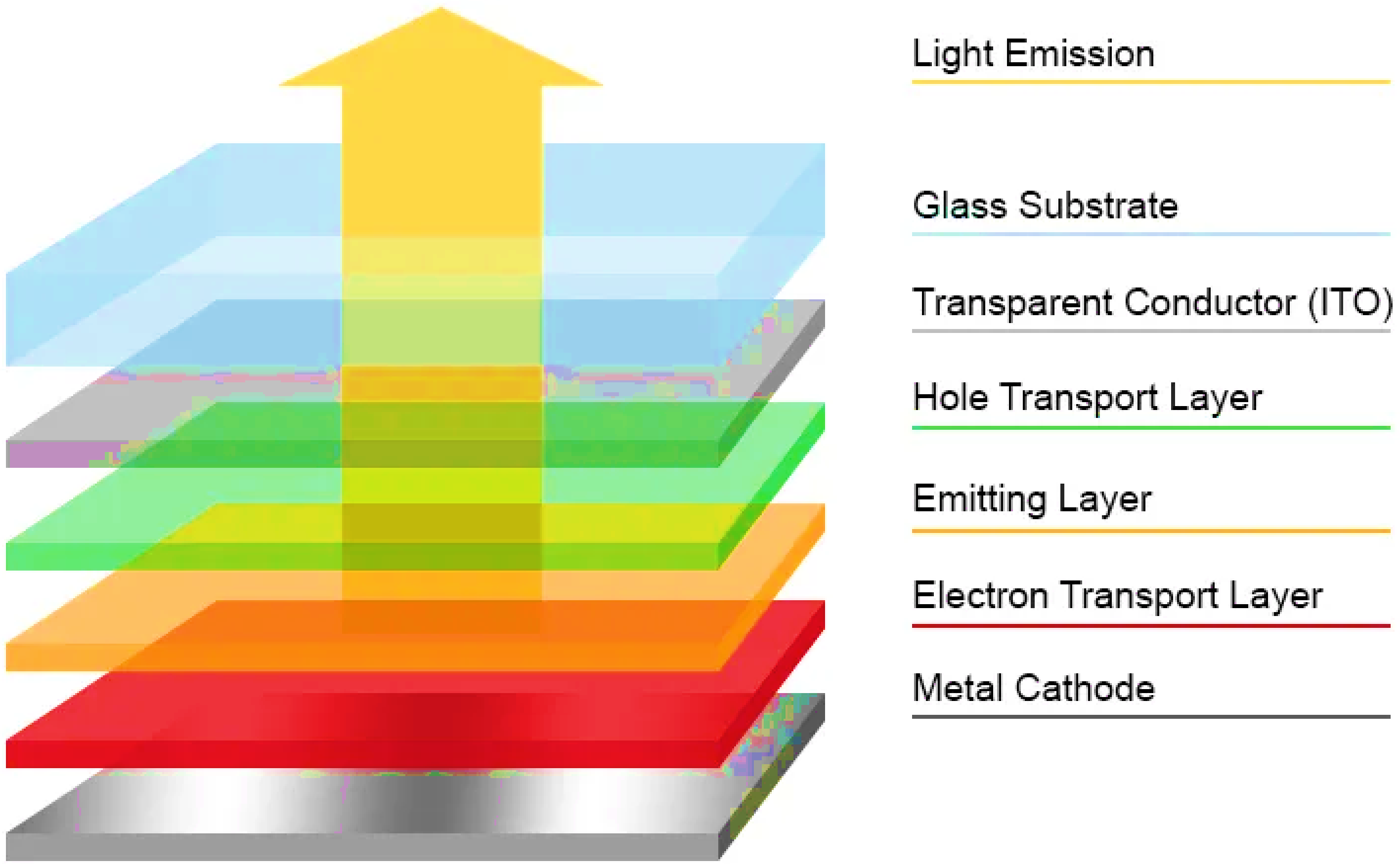


Liquid Crystal on Silicon (LCoS)

- basically a reflective LCD
- standard component in projectors and head-mounted displays
- used e.g. in google glass

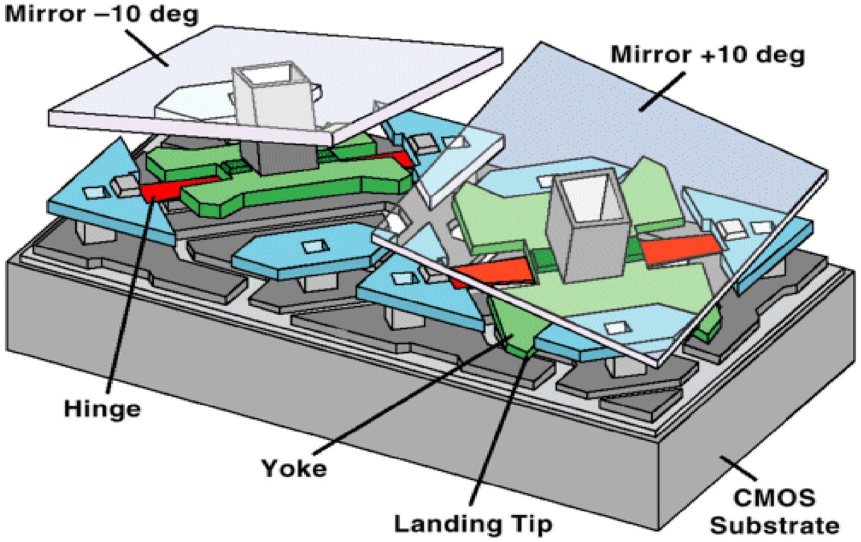


Organic Light Emitting Diodes (OLED)



Digital Micromirror Device (DMD)

- developed by Texas Instruments
- MEMS device
- binary states (e.g. +/- 10 degrees)
- gray-level through pulse width modulation (PWM)



Texas Instruments

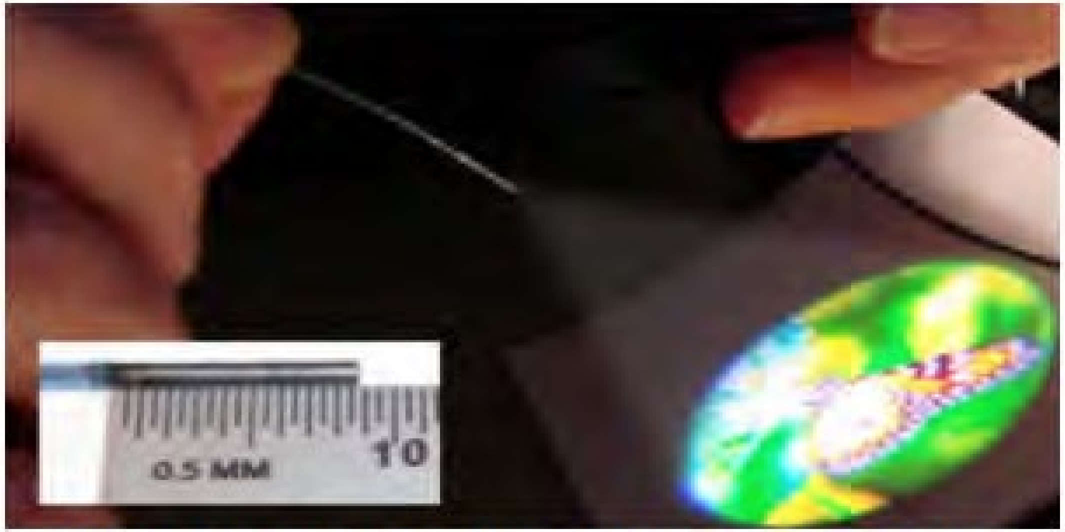
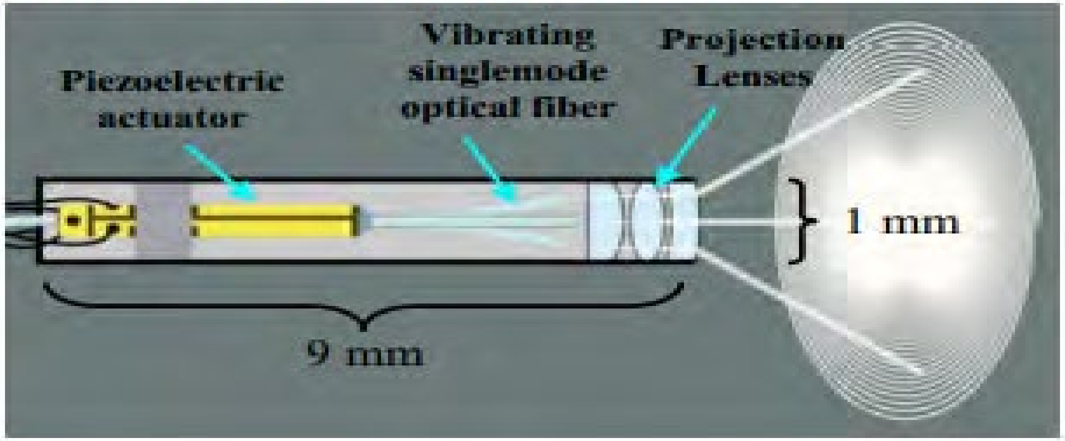


Figure 1. 1 mm x 9 mm scanning fiber projector.



3D Displays Using Scanning Laser Projection.

Benefits of Virtual Reality

- It provides high-quality visualization with countless sensations.
- A fully immersive VR can simulate potentially menacing real-world situations like flight operations or surgery.
- As a tourist, virtual reality technology helps you decide if any upcoming trip is worth it or not.
- The types of VR provide consumers with an engaging experience.

Benefits of Virtual Reality

- Virtual reality is of great help to pilots, firefighters, astronauts, and police officers to practice in a safe environment before getting into a jeopardized situation.
- This technology is handy in day-to-day activities.
- It makes watching more enjoyable, thereby creating interest.
- Virtual reality can effectively overcome language barriers.

Future of Virtual Reality

AI and VR integration

Artificial Intelligence (AI) will play a significant role in creating dynamic and adaptive VR experiences. AI algorithms can personalize content based on user behaviour, preferences, and real-time interactions, making VR applications more engaging and tailored to individual users.

Expanded applications in education and training

It is likely that VR will find broader applications in education and professional training. It will be used not only for medical simulations and pilot training but also for soft skills development, team-building exercises, and language learning.

Entertainment and gaming

VR gaming will continue to grow, with more sophisticated and interactive experiences and scenarios becoming available. Game developers are likely to invest in VR titles, pushing the boundaries of storytelling, graphics, and gameplay.

Enhanced hardware

In terms of the hardware used, future VR devices will probably become more lightweight, comfortable, and user-friendly. Advancements in display technology may lead to higher resolutions, wider field-of-view, and reduced motion sickness.

Technical Considerations for Virtual Reality

Accuracy

VR application development requires significant attention to detail with respect to stimulus generation, internal calculations, and outcome data. For example, in research, it is necessary to generate a consistent, repeatable stimulus. Additionally, the sequence of when physics (e.g., positions, forces) are computed, applied, and rendered can vary depending on the application.

Flexibility

Flexible VR architectures for research need to be both modular and scalable, and the underlying framework should support further development. For example, strategic development of base VR features should be platform agnostic. Though user interfaces would need to change based on a final use case, minimizing the need for content adaptation increases the utility. To this end, a VR application could easily be made for an HMD or a large-scale theater.

REFERENCES

- S. M. Lavalle. Virtual Reality. Cambridge University Press, 2023. 2
- https://www.optimum.com/articles/internet/the-realities-of-virtual-reality
- https://dl.acm.org/doi/fullHtml/10.1145/3482632.3482643
- image from: https://www.slideshare.net/Mark_Kilgard/nvidia-opengl-in-2016
- Organic Light Emitting Diodes (OLED), https://images.app.goo.gl/jiWpPKAf3EmoFKMj7

CONCLUSION

- Provided an overview of the concept of Virtual Reality (VR) technology.
- Introduced the three main components of VR: immersion, interaction, and imagination.
- Explored different classifications or categories of VR technology based on usage and implementation.
- Discussed various practical applications of VR technology across different industries and fields.
- Examined the essential hardware components required for VR systems, including headsets, controllers, and sensors.

CONCLUSION

- Explored the importance of field of view and visual in Virtual Reality (VR) experiences.
- Provided an introduction to micro-displays and their role in VR technology.
- Discussed the advantages and positive impacts of VR technology in various domains.
- Explored potential advancements and developments expected in the future of VR technology.
- Examined key technical factors and considerations relevant to the design and implementation of VR systems.


THANK YOU