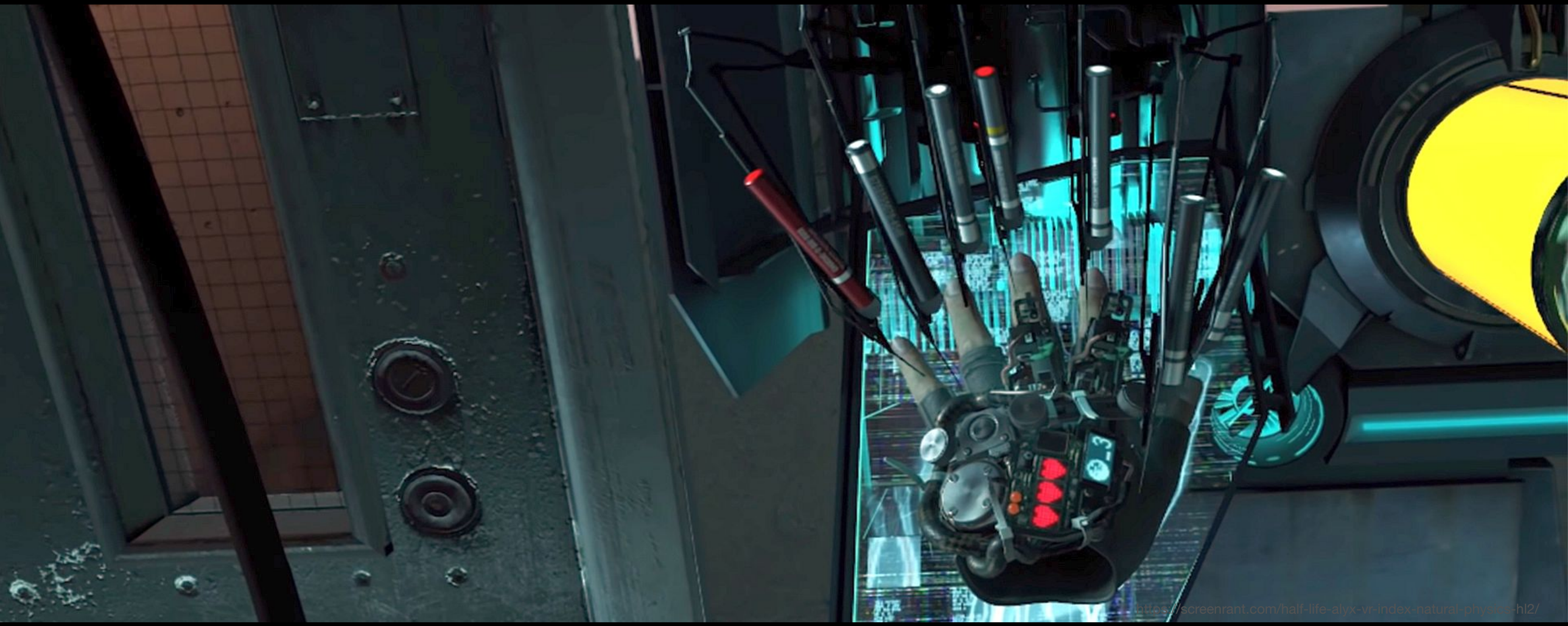
Virtual & Augmented Reality

WS 2025



VR Technology

BHT

Ergebnisse letztes Semester

Dogfight

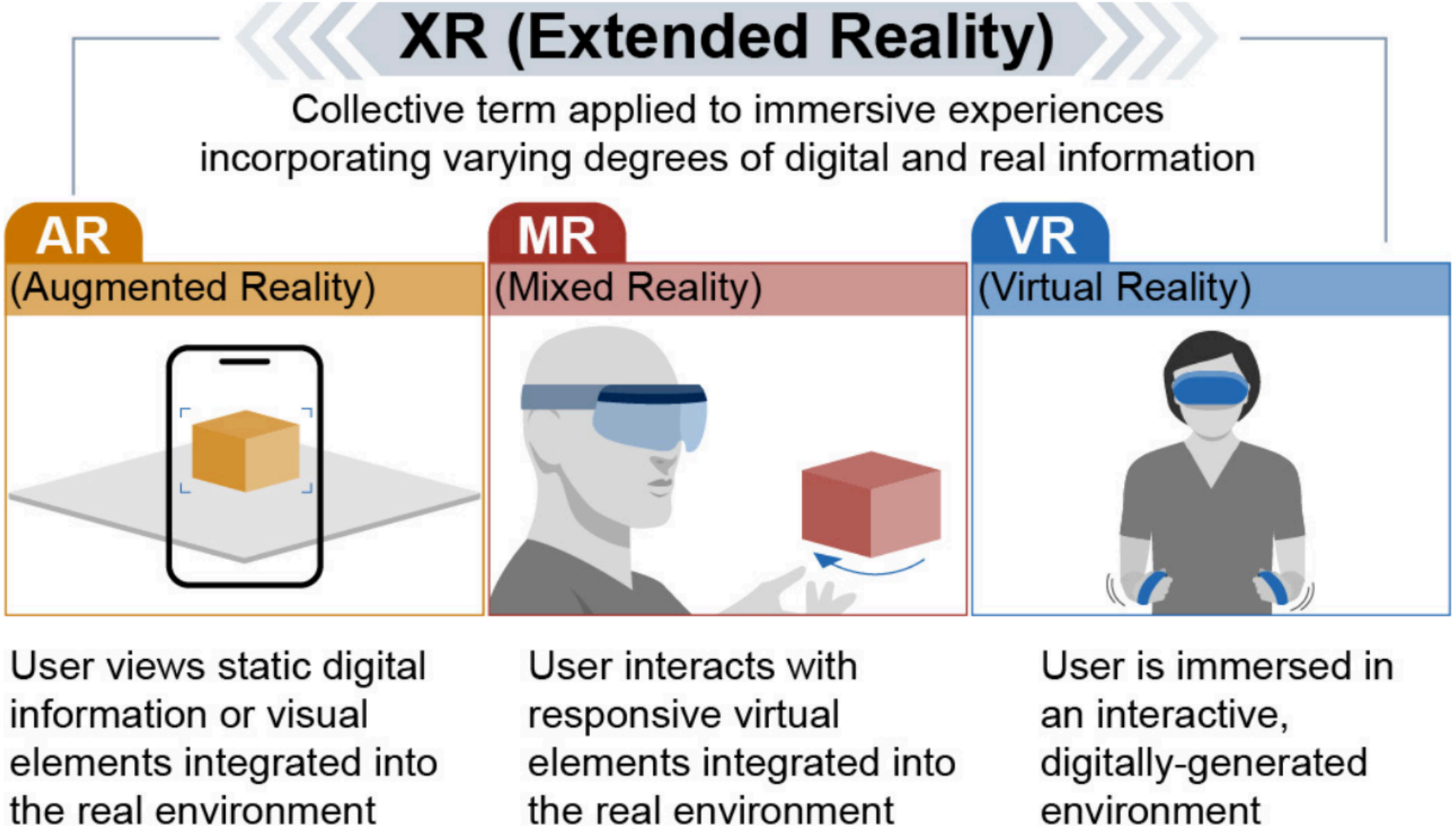
Escape Room

Galactic Dawn

Graffiti Game

https://www.gao.gov/assets/gao-22-105541.pdf

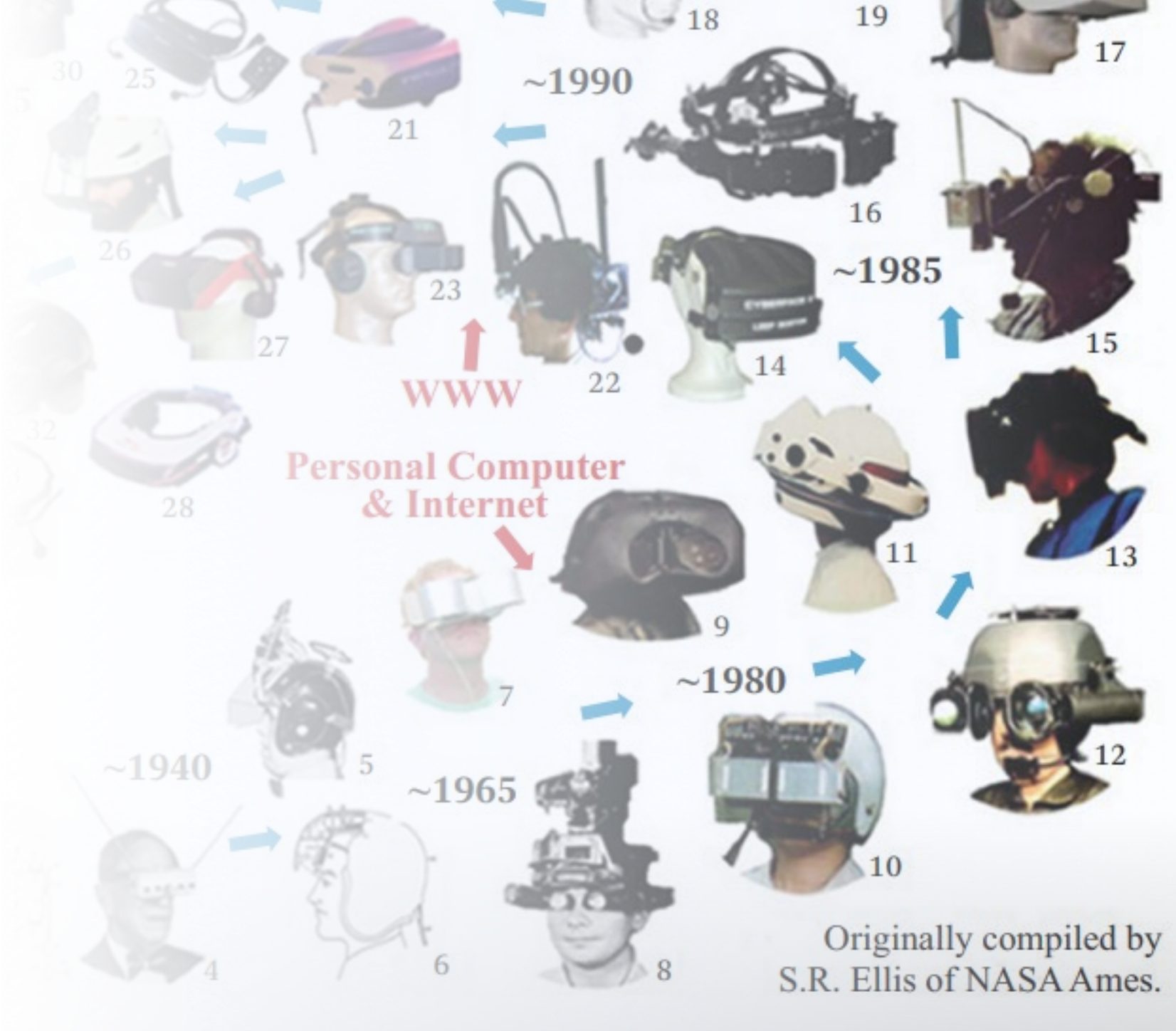
Recap



OVERVIEW

- (Quick) History of VR
- VR Rendering
- VR Tracking
- VR Devices
- VR Periphery

VR History


~1990
~1985
~1980
~1965
~1940
WWW
Personal Computer
& Internet
Originally compiled by
S.R. Ellis of NASA Ames.

HISTORY OF VR – THE BEGINNING

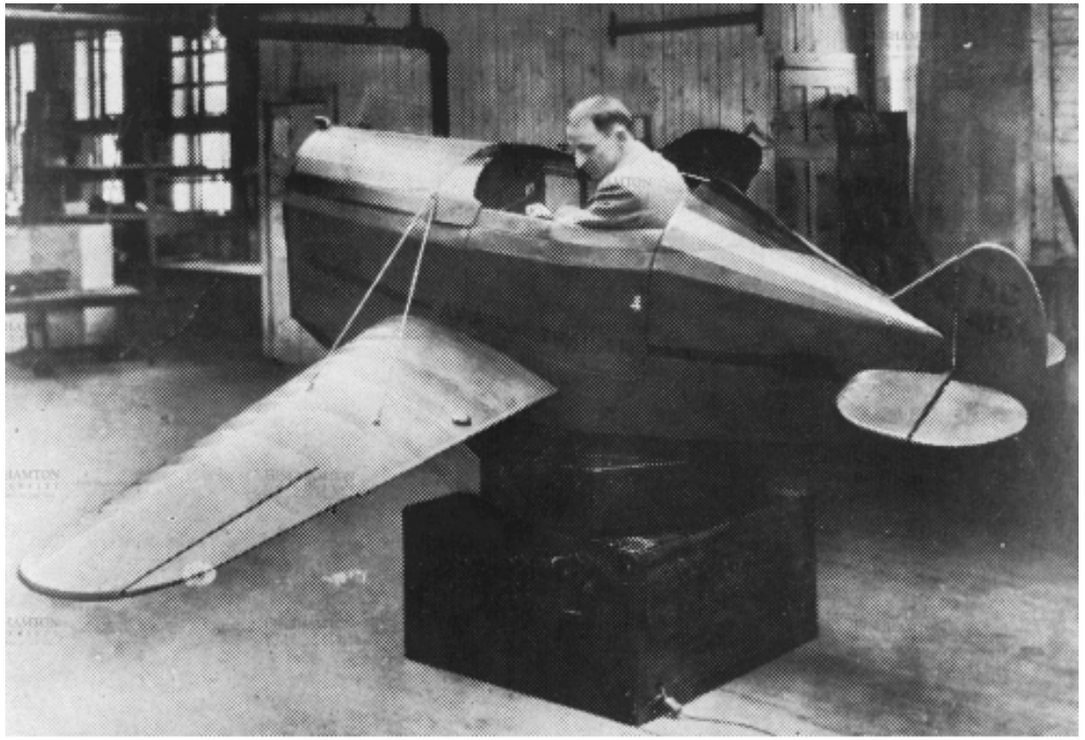
- 1832 Stereoscope was invented
- ". . . is a surprise such as no painting ever produced. The mind feels its way into the very depths of the picture." – Oliver Wendell Holmes 1851

- binocular vision

Charles Wheatstone's stereoscope.

https://www.kcl.ac.uk/charles-wheatstone-the-father-of-3d-and-virtual-reality-technology-2

HISTORY OF VR - SIMULATOR



- First flight simulator in 1928 by Edwin Link
- Motion and sensation of flying
- Even though the military financed the project, they were initially not very interested
- Sold mostly to amusement parks at the beginning
- Advanced to astronaut training and advanced flight simulation over the years

• simulierte Realität innerhalb der Realität

HISTORY OF VR - FICTION

- *Pygmalion's Spectacles* is (presumably) the first science fiction story where another world is perceived through glasses and other equipment
- 1936 – Stanley G. Weinbaum

- Now a popular genre (Ready Player One, Legendary Moonlight Sculptor, Log Horizon, etc.)
    - in Filmen, Comics, Spielen, …

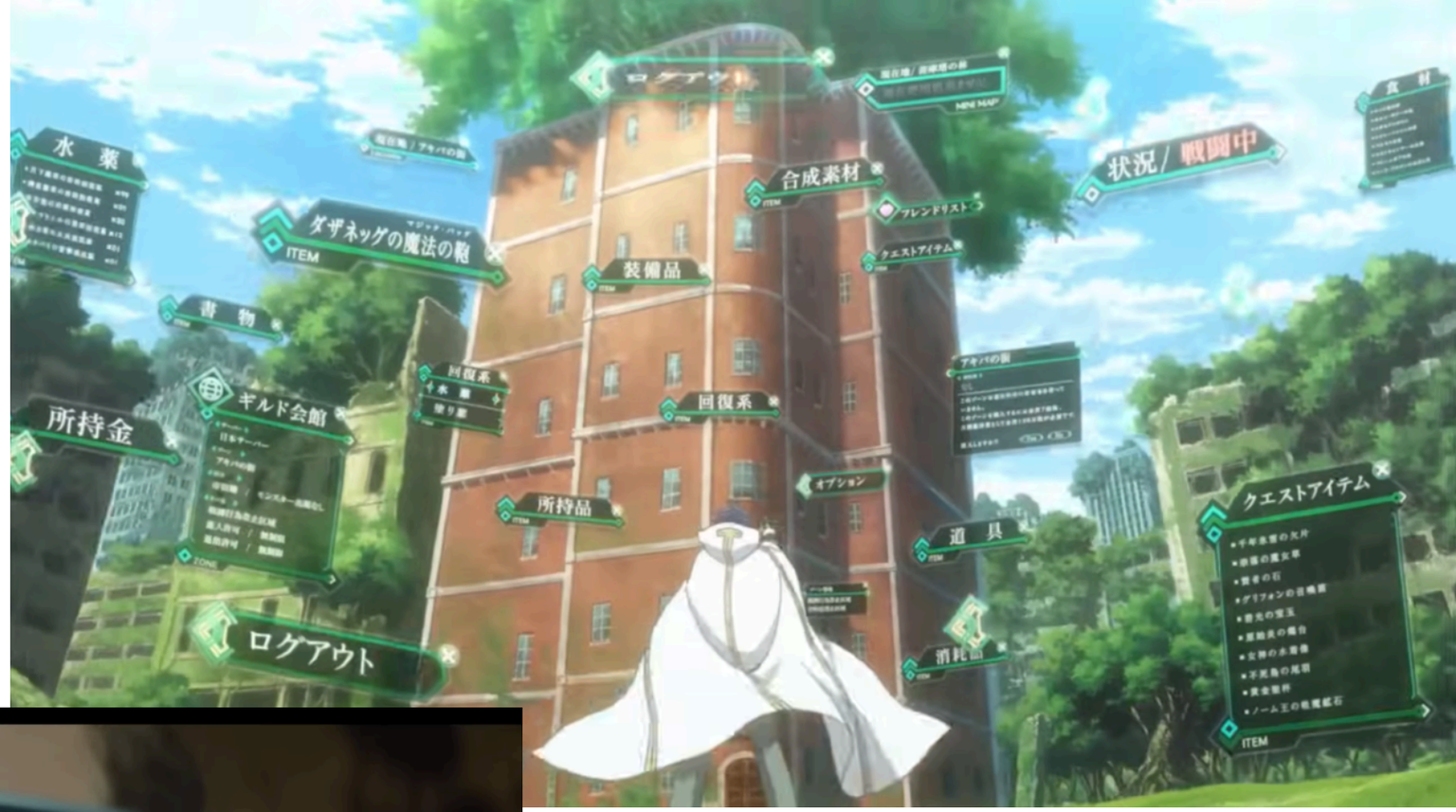

PYGMALION'S SPECTACLES

By STANLEY G. WEINBAUM

Author of "The Black Flame," "A Martian Odyssey," etc.

In the story, the main character, Dan Burke, met an elfin professor, Albert Ludwig, who invented a pair of goggles which enabled "a movie that gives one sight and sound [...] taste, smell, and touch. [...] You are in the story, you speak to the shadows (characters) and they reply, and instead of being on a screen, the story is all about you, and you are in it."

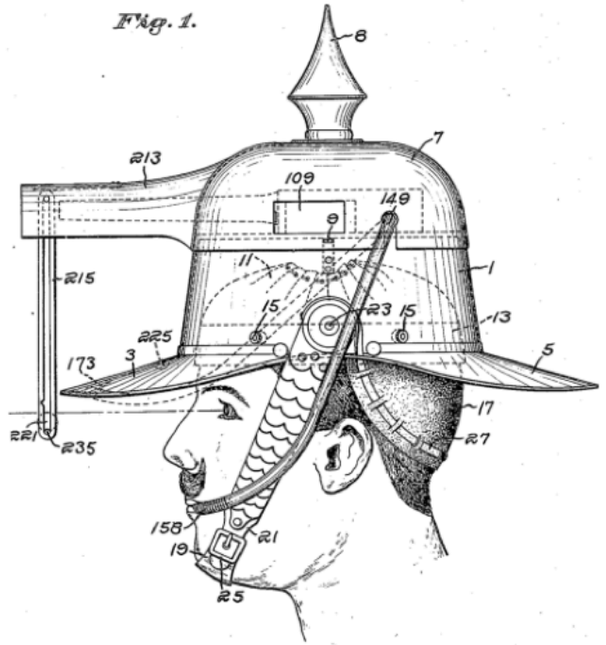
Ready Player One



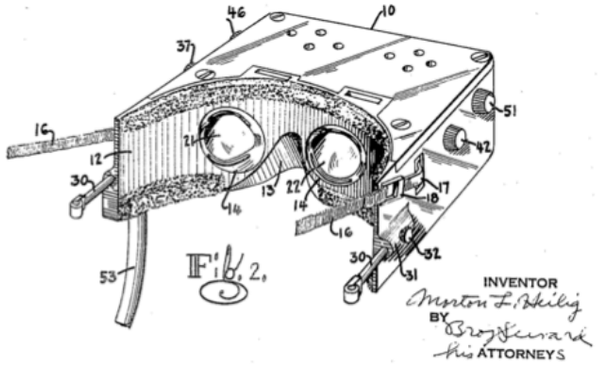
Log Horizon

HISTORY OF VR - CONCEPTS

During the years different patents and concept for VR have been proposed



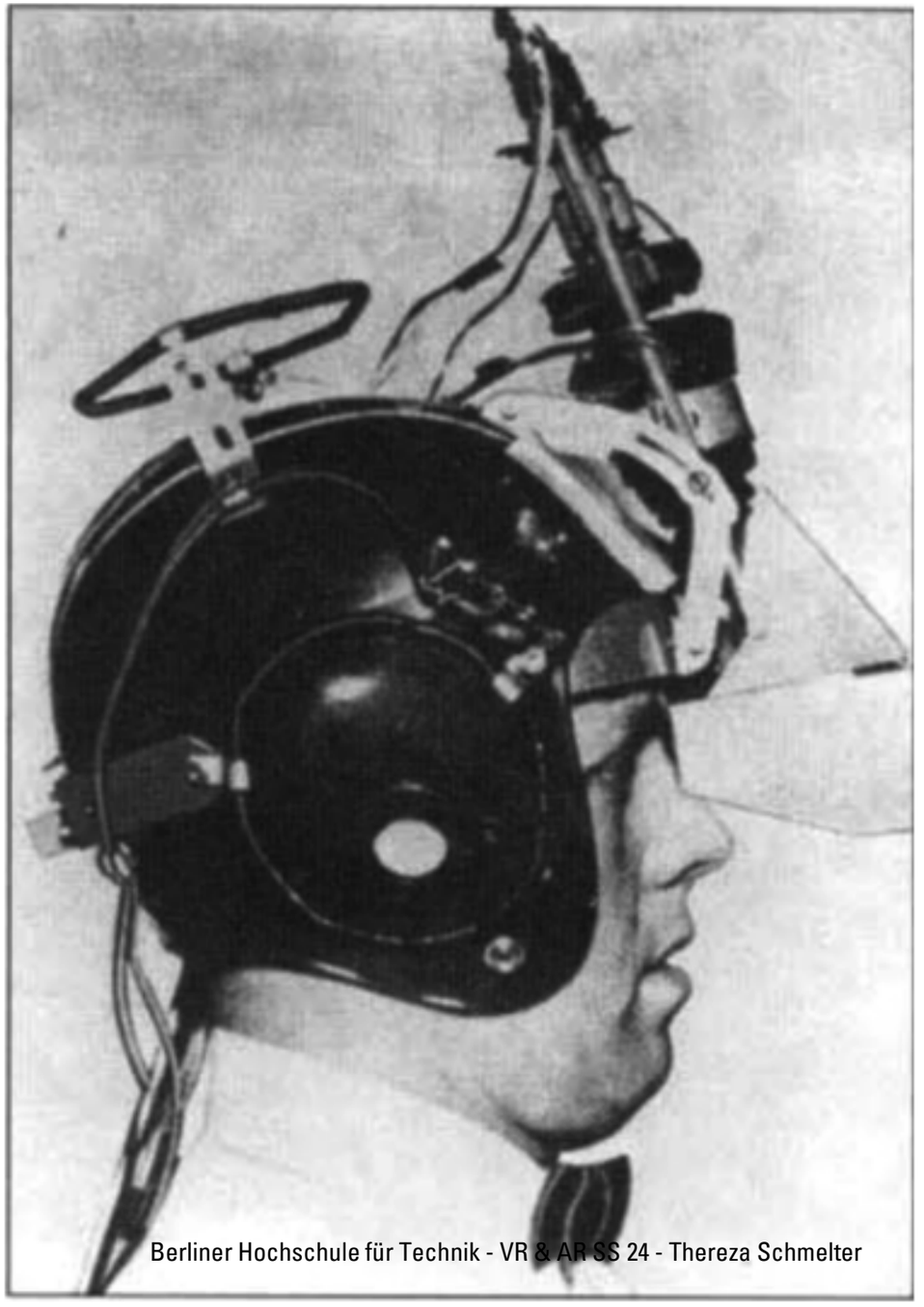
Albert B. Pratts
Pistolenhelm (1916)



Morton Heilig
Stereoscopic Television Apparatus
for Individual Use (1960)

Morton Heilig
Sensorama
(mit Geruchssimulation!)

https://commons.wikimedia.org/wiki/File:Morton_heilig_patent_fig2.png
https://en.wikipedia.org/wiki/Sensorama



https://www.virtual-reality-shop.co.uk/philco-headsight-1961/

HISTORY OF VR – FIRST HEADSET

- The Philco Headsight 1961
- First ever tracked headset
- Movement of the headset was connected to a camera in another room
  - User could see in the other room as if he was there

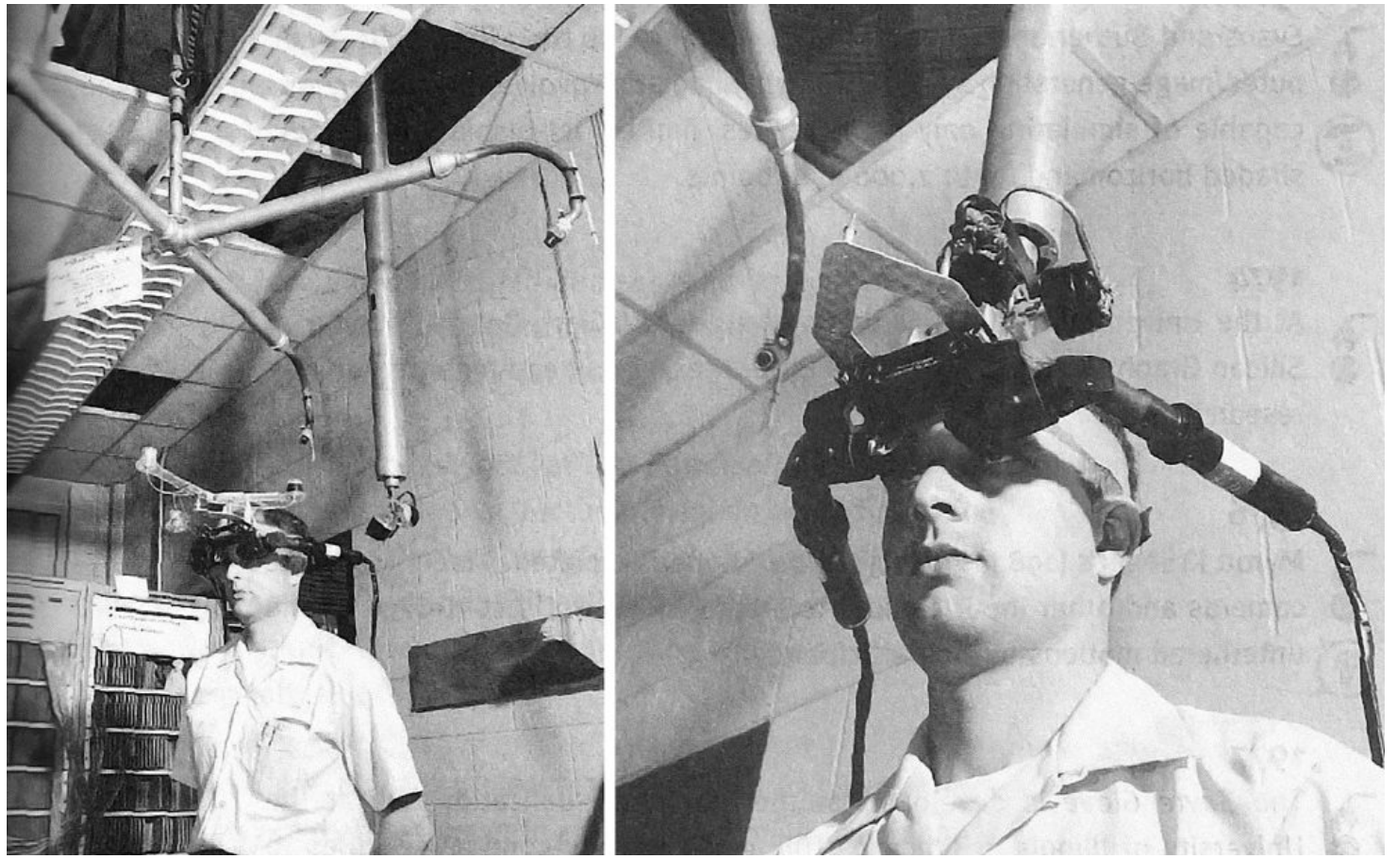
Maker: Philco Corporation
Released: November 1961
Type: PC Powered
Display: Single CRT Panel

Field of View(FOV): 40°
Refresh Rate: 10 Hz
Launch Price: Never Sold To Public
Weight: Unknown

https://en.wikipedia.org/wiki/The_Sword_of_Damocles_(virtual_reality)

HISTORY OF VR – HMD WITH CG IMAGES

- 1969 Sword of Damocles
- First HMD – headset with computer generated images
  - Floating wire frame cube



HISTORY OF VR – 80S AND 90S

- In 1980 – 2000 first afforable VR systems were invented
- ← 1988 NASA View System
- After 1990 mulitple VR companies were founded and big companys (Disney, Sega, General Motors) started to experiment with the new medium
- Mid 90s WIRED Magazine predicted that within five years more than one in ten people would wear HMDs while traveling buses, trains and planes

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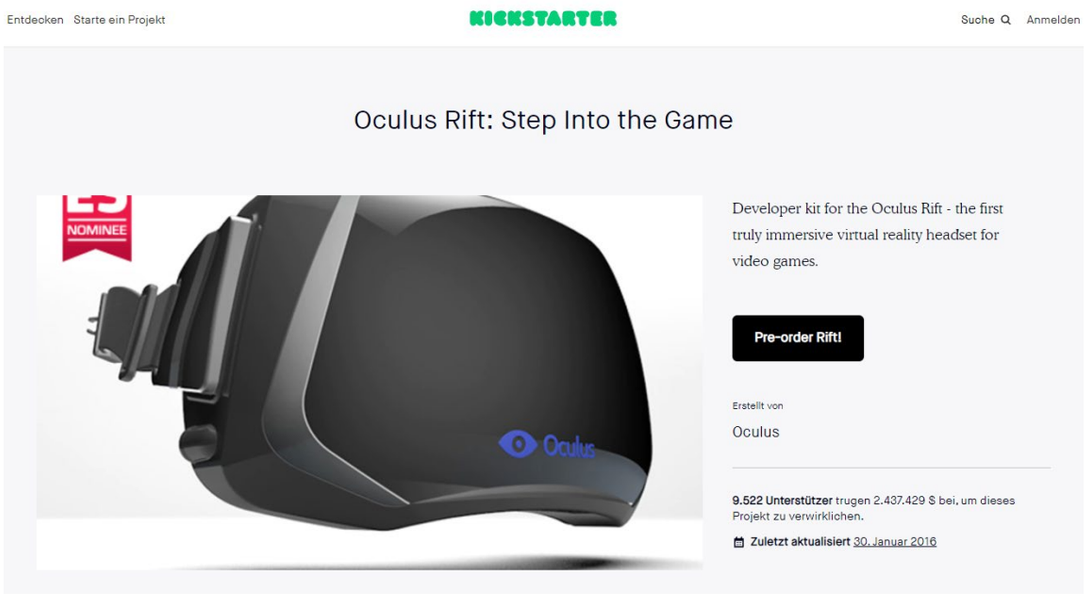
Sora



HISTORY OF VR – OCULUS KICKSTARTER

- After a period of no obvious progression – the 2012 Kickstarter of the first Oculus took of
- 2,4 Mio Dollar with 974%
- Facebook bought Oculus in 2014 for 400 Mio
- Started a new era of VR the hype

John Carmack

- Doom
- Quake
- Erfinder mehrerer Software-Technologien
  - BSP for Games
  - Stencil Shadows
  - Megatextures
  - Virtual Textures
- Mitgründer von id Software
- (war) CTO von Oculus VR

oculus

id

id TECH 5


98
AMMO
86%
HEALTH
2 3 4
5 6 7
ARMS
187%
ARMOR
BULL 400 / 400
SHEL 98 / 100
ROKT 100 / 100
CELL 600 / 600


40
23

VR CONSUMER HEADSETS

Little Overview over some HMDs:

- Since 2014 Google Cardboard and other Smartphone VR systems
- März 2016 Oculus Rift (Consumer Version)
- April 2016 Pimax 4K
- April 2016 HTC Vive
- Oktober 2016 PSVR
- 2018 Pico Neo
- March 2019 Oculus S
- May 2019 Oculus Quest
- May 2019 HP Reverb
- June 2019 Valve Index
- Oktober 2020 Oculus Quest 2 (Meta Quest)
- May 2021 HP Reverb G2 Omnicept
- May 2021 Pico Neo 3
- June 2021 Vive Pro 2
- October 2022 Meta Quest Pro
- October 2023 Meta Quest 3
- …

HEADSET DESIGN

- HMDs evolved over time to be smaller and lighter
- Wireless is often a goal

FUTURE OF HEADSETS

- Diverse HMDs for different user groups
- Multiple Companies are working on HMDs
  - Unfortunately divides the VR users and developer
  - A lot exclusive content
- New Iterations of known headsets
- Hohe Erwartungen an Apple’s Vision Pro

FEATURES OF HEADSET RESEARCH

- Higher pixel density
- Bigger Screen
- Bigger Field of View (FOV)
- Weight
- Specific Display Technology (movable displays, multi-display for different focus distances)

Hardware Specs Quest 2

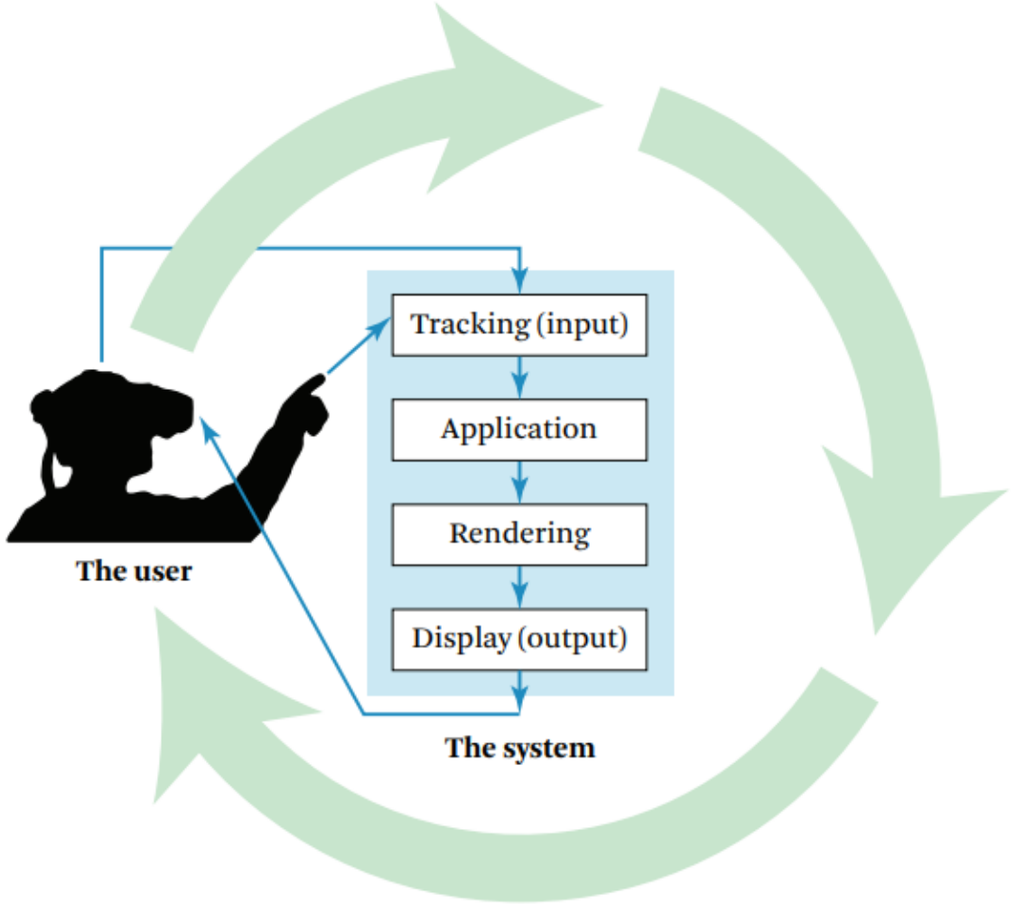
Operating system	Meta Horizon OS, based on Android source code. **Original:** Android 10[1] **Current:** Android 12.1
System on a chip	Qualcomm Snapdragon XR2
Memory	6 GB LPDDR4X[2]
Storage	64 GB, 128 GB, 256 GB
Display	RGB LCD 1832 x 1920 per eye @ 72 - 120 Hz[3]
Graphics	Adreno 650 @ 587 MHz (Up to 902 GFLOPS FP32)[4][5][6]
Sound	2 built in speakers / 2 built in microphones / 3.5mm headphone jack
Input	6DOF inside-out tracking through 4 built-in cameras and 2 controllers with accelerometers and gyroscopes
Controller input	Oculus Touch
Camera	4 infrared cameras
Connectivity	USB-C Bluetooth 5 Wi-Fi 6[2]
Online services	Quest Store
Weight	503 g (17.7 oz)

VR Rendering

VR Rendering

Zusammenfassung

- Lens Distortion
- Chromatic Aberration
- Stereoscopic Rendering
- VR Rendering Optimizations
  - VR Frustum
  - Foveated Rendering
  - Space Warp

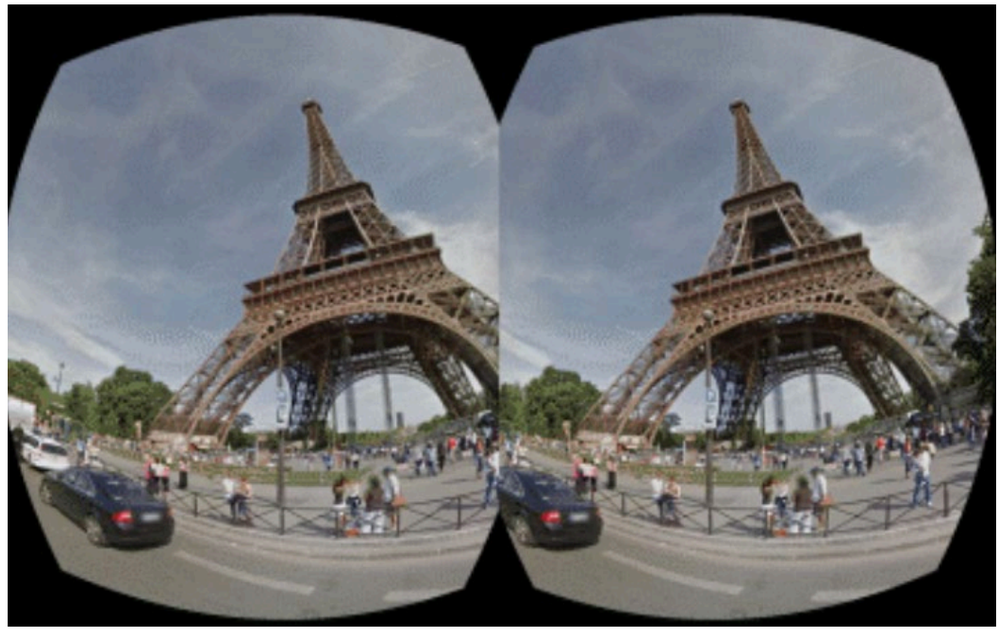


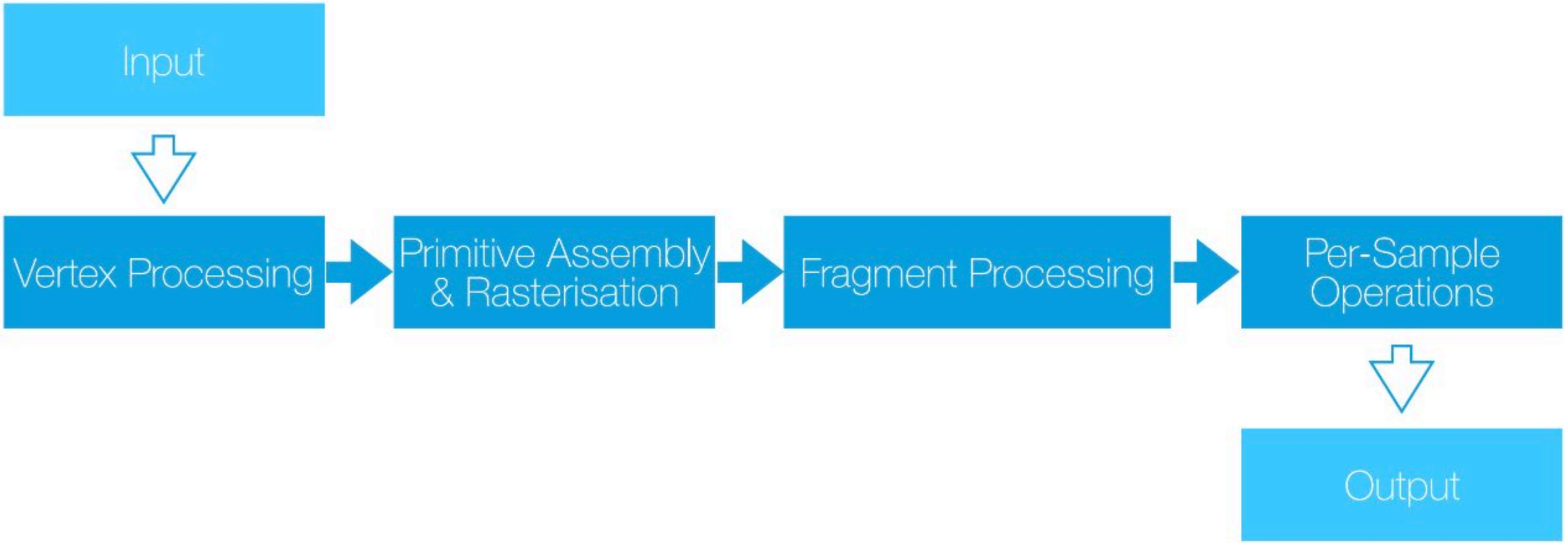
VR SYSTEMS

- Input is all collected data from positions to buttons pressed
- The application processes input and calculates
- For each eye the scene is rendered
- The rendered image is sent to the headset (currently the bandwidth of cables or wireless is a big performance bottleneck)

VR RENDERING

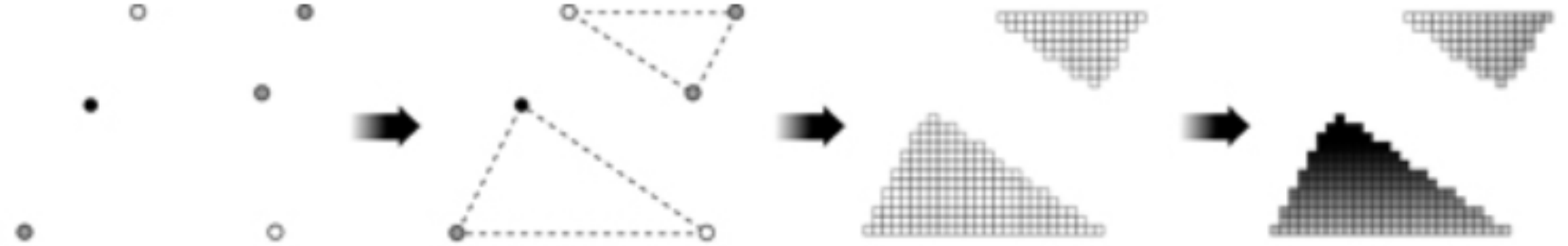
- Application scene is rendered for each individual eye.
- Rendering process depends on Render Pipeline (Forward Rendering or Deferred Rendering)
- Rendering with a slight offset, ideally based on the calibrated eye distance
- Performance impact because your rendering time is doubled
- In case of a third (for example: observer) view even tripled

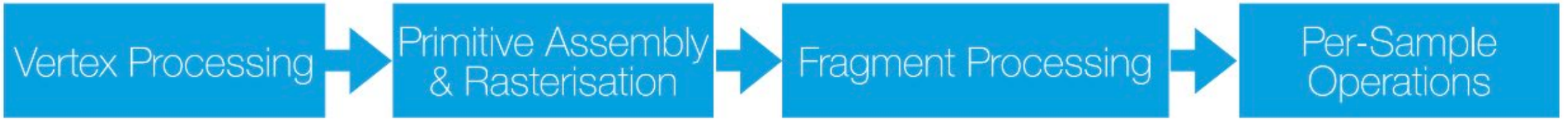


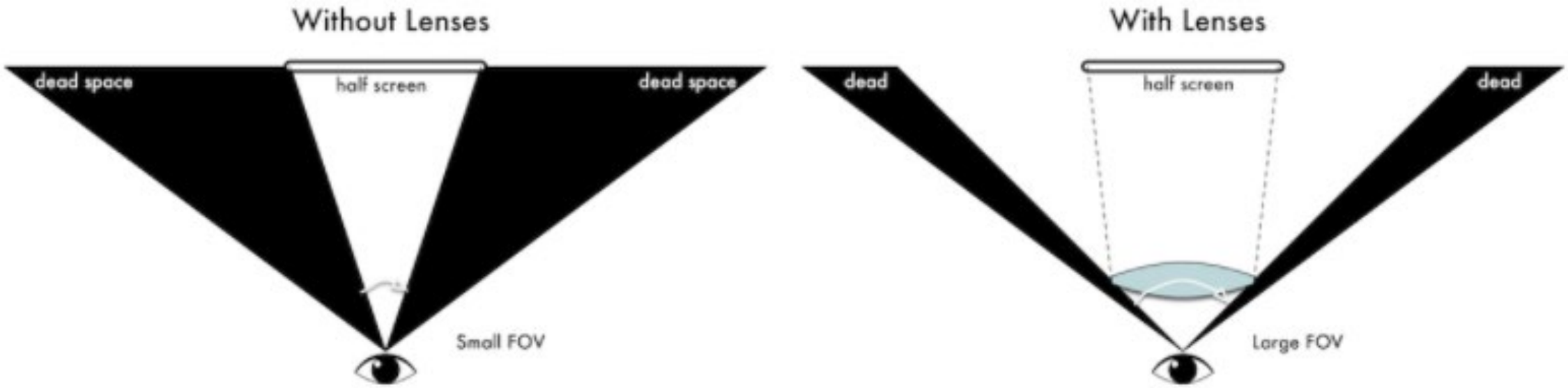


BASE RENDER PIPELINE

RENDER PIPELINE – VERTEX TO PIXEL







LENSES IN VR HEADSETS

- lenses in an HMD map an up-close display to a wide field of view
- provide a more comfortable distant point of focus

- **Fresnel lenses** are commonly used in VR headsets
  - Create a distortion and chromatic aberration
  - Distortion and chromatic aberration need to be handled during rendering

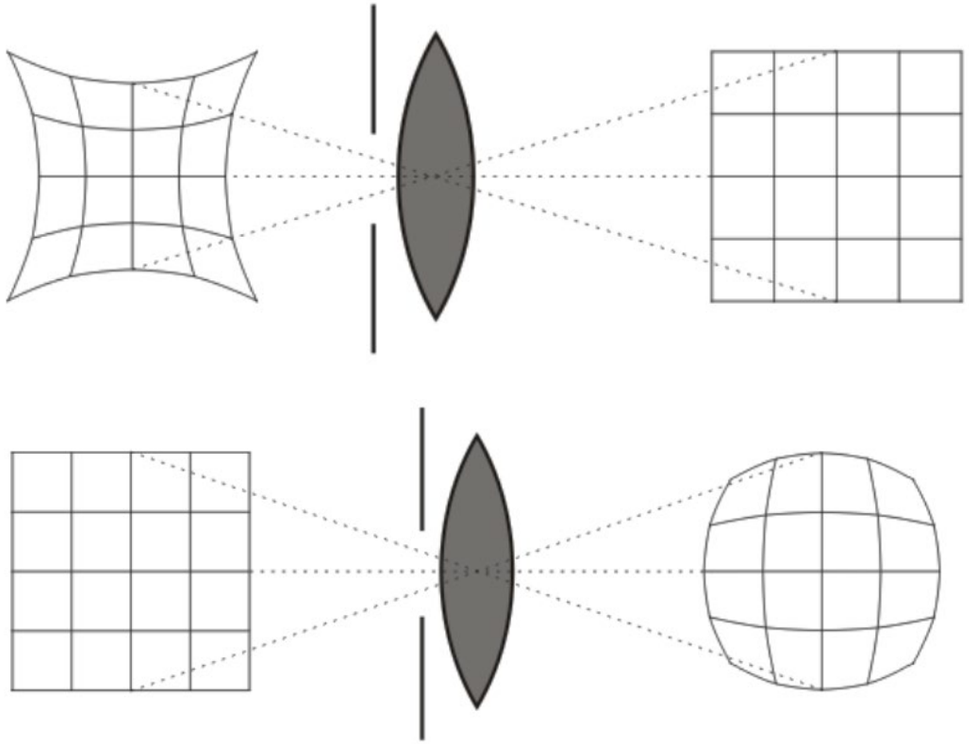
LENSES IN VR HEADSETS

Linsenverzerrungen

- virtuelle Welten sehen normalerweise nicht so aus

DISTORTION

- for lenses with a wide field-of-view the distortion becomes stronger
  - for example: fish-eye lenses have a very strong noticeable distortion
- If the image is not corrected during rendering, user will perceive a strong pincushion effect (upper image)
- By applying a barrel distortion, the image will look correct (lower image)



left: perceived image; right: rendered image

RENDERING DISTORTION

r_u denote the undistorted radius
r_d denote the distorted radius
c_1 and c_2 are suitably chosen constants.

$$r_d = f(r_u) = r_u + c_1 r_u^3 + c_2 r_u^5,$$

If $c_1 < 0$, then barrel distortion occurs.

If $c_1 > 0$, then pincushion distortion results.

Unfortunately, polynomial functions generally do not have inverses that can be determined or even expressed in a closed form. Therefore, approximations are used. One commonly used approximation is

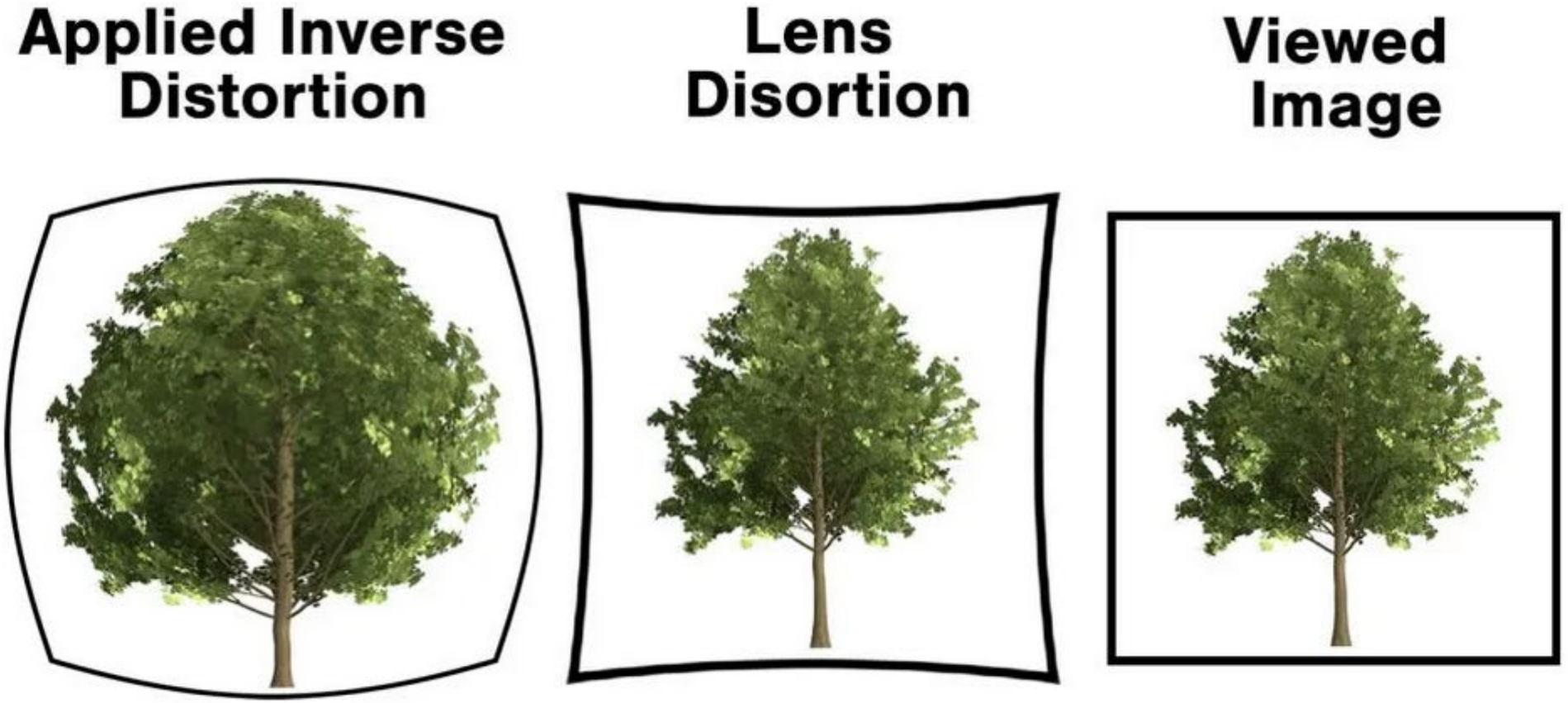
$$f^{-1}(r_d) \approx \frac{c_1 r_d^2 + c_2 r_d^4 + c_1^2 r_d^4 + c_2^2 r_d^8 + 2c_1 c_2 r_d^6}{1 + 4c_1 r_d^2 + 6c_2 r_d^4}$$

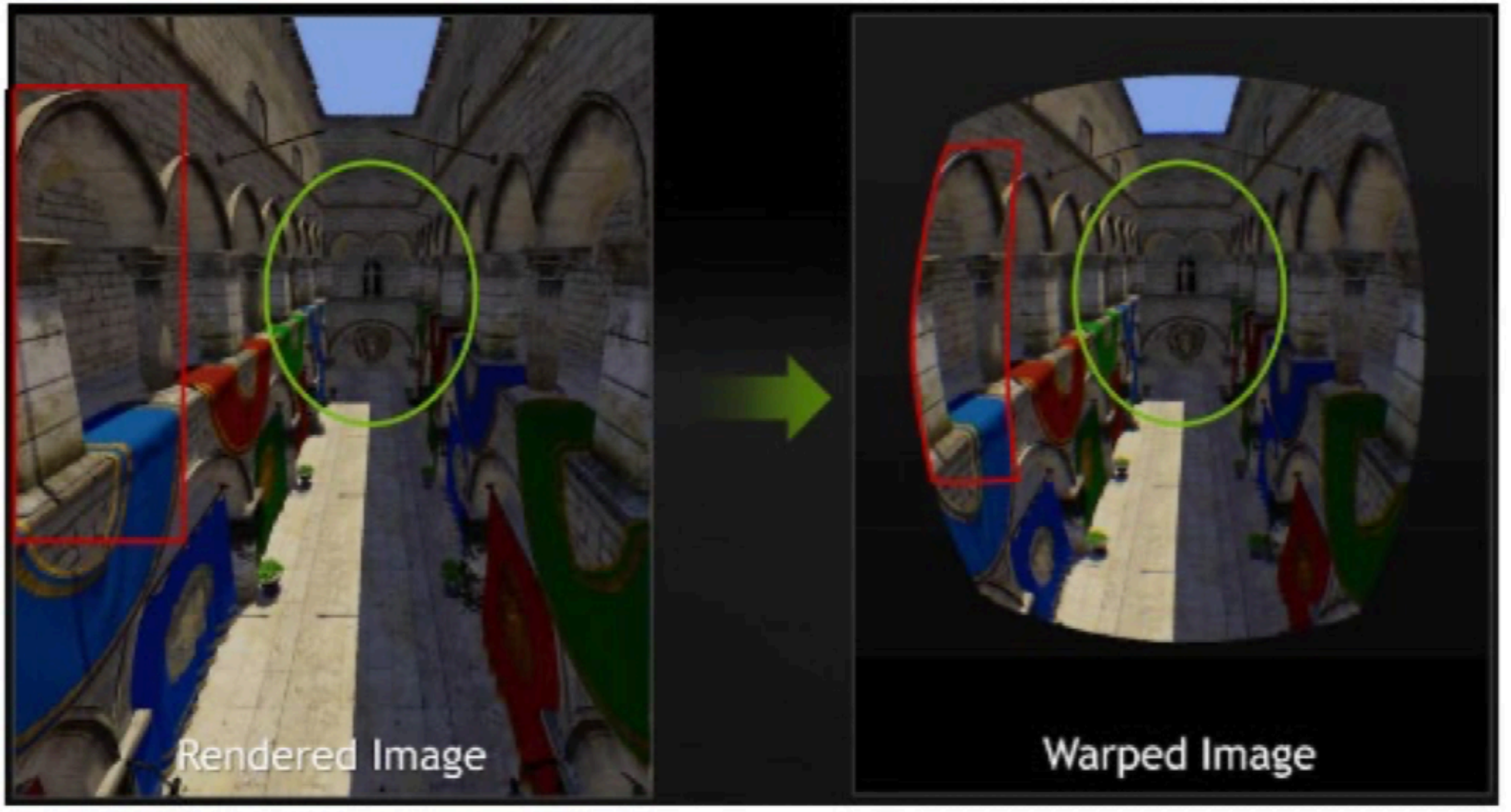
- Radial distortion function needs to be determined for a specific Headset
- Distortion needs to be corrected in the software
- Inverse of distortion function needs to be applied

- Could either be applied during perspective transformation or during the post processing shading stage
- Handled by SDKs

https://lavalle.pl/vr/node211.html

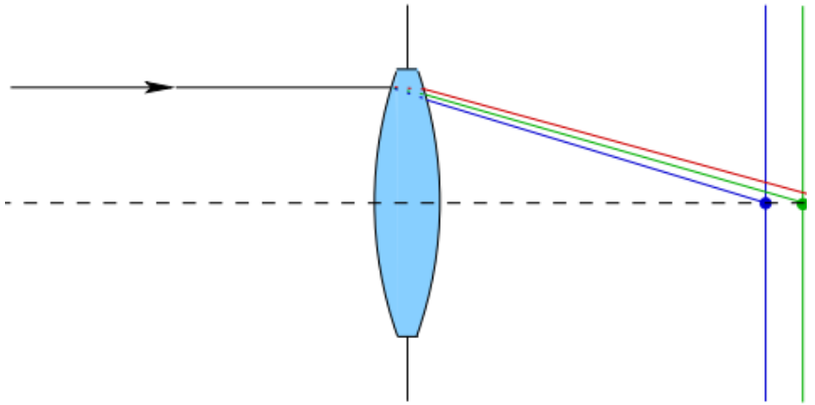
DISTORTION EXAMPLE





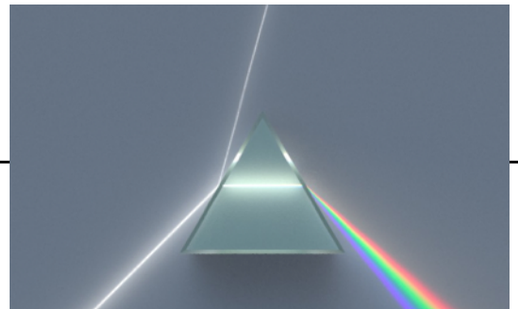
DISTORTION RESULT

CHROMATIC ABERRATION



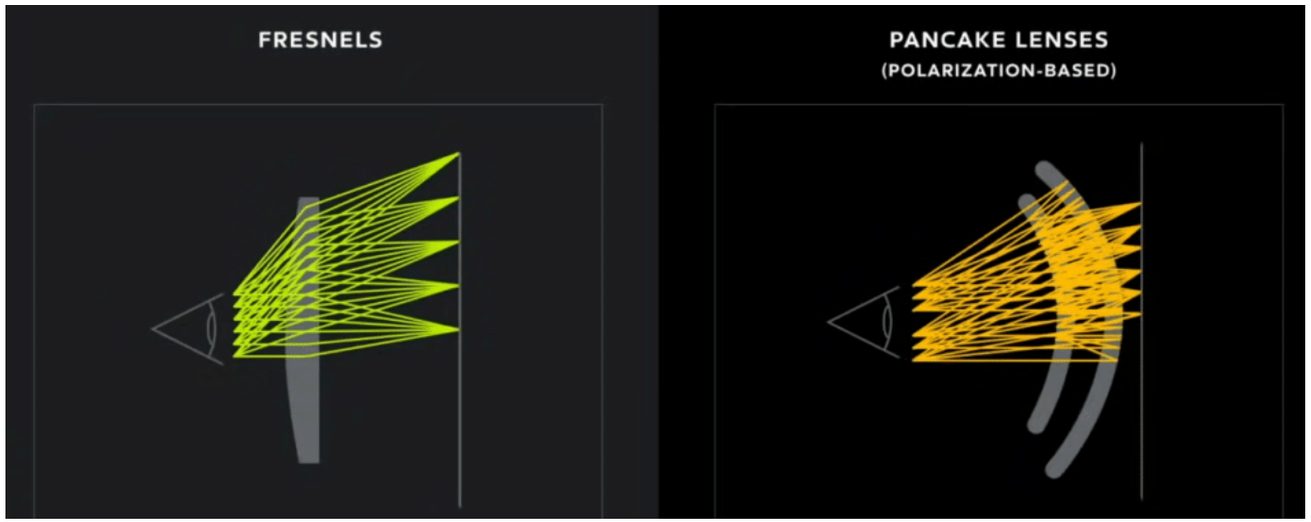
- Light is electromagnetic radiation
- Visible light has wavelengths between 400-700 nm (nanometer)
- Longer wavelengths travel faster through the lens
- Different focal plane for each wavelength

- Handled by most VR SDKs by shifting the rendering Color Space
  - Each color is corrected radially by a different amount based on the wavelength



LENSES

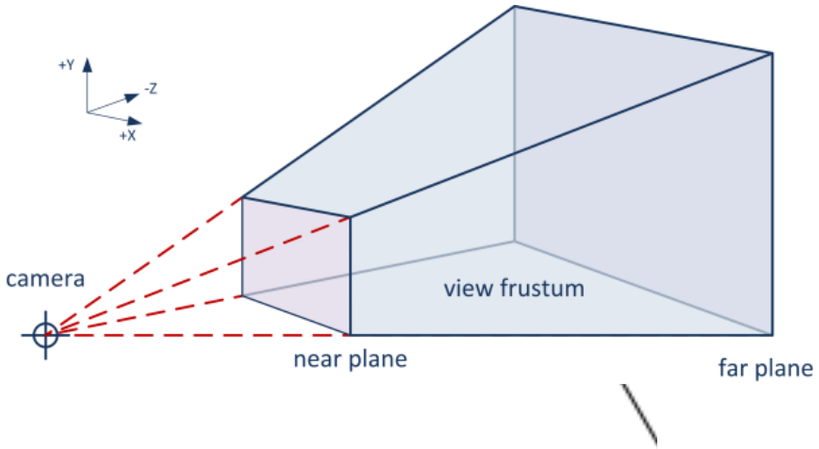
- lenses and display are currently limiting factors in HMD size
- most used are **Fresnel lenses**
- one approach are **Pancake lenses**
  - e.g Quest Pro, HTC Vive Flow
  - allow for thinner headsets
- Fresnel Lenses: bigger FOV

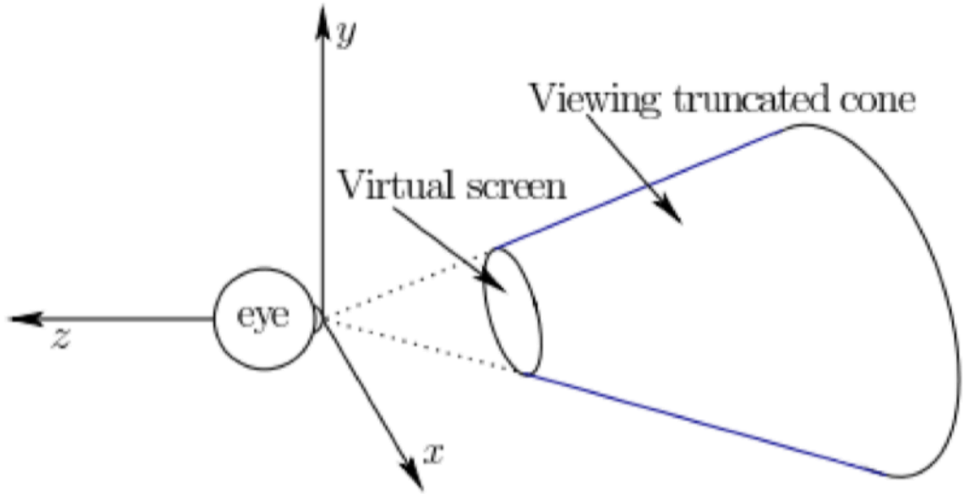


RENDERING OPTIMIZATIONS

- compared to desktop PC upfront demand is higher

- Rendering is doubled compared to traditional screens (2 images)
- High performance is required (~90 FPS+)
- High resolution is required





Stencil buffer pattern

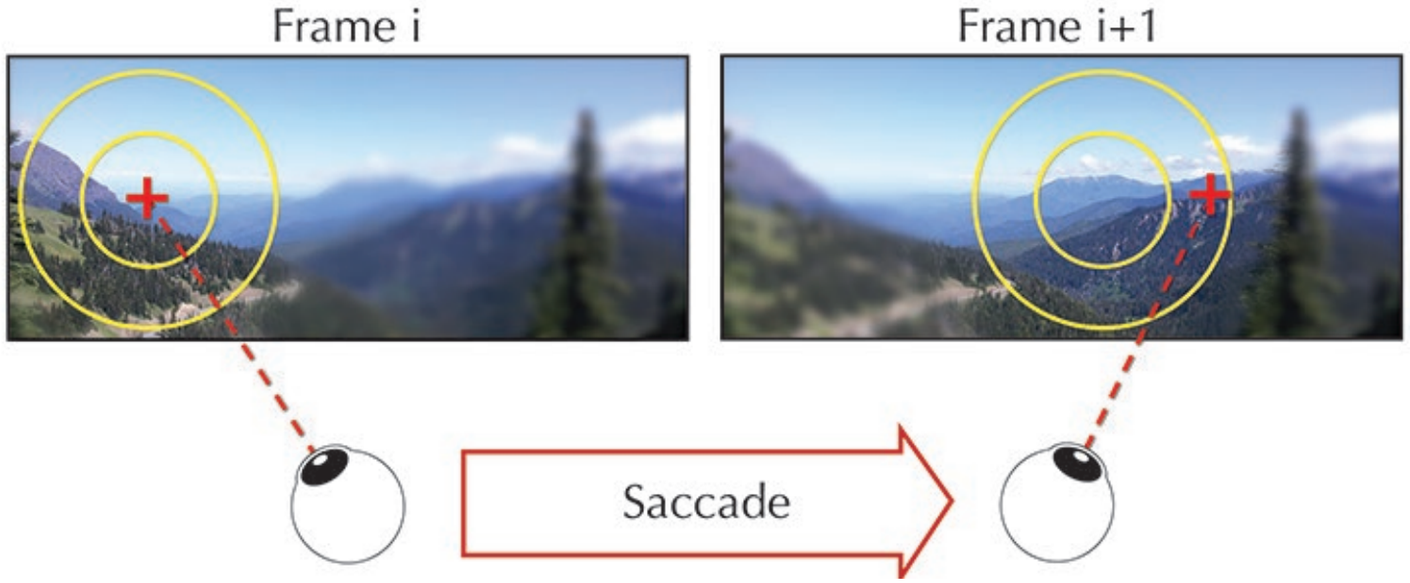
CULLING FOR VR VIEW FRUSTUM

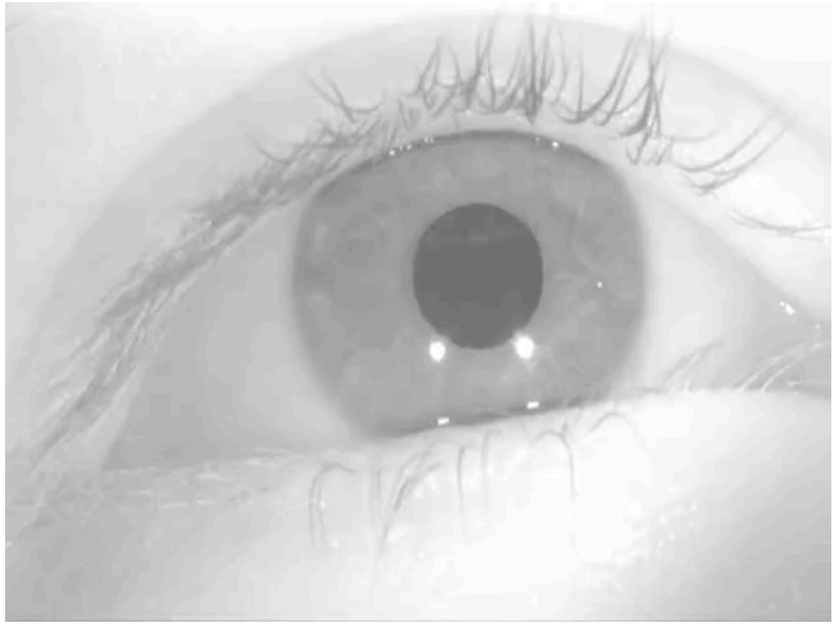
- Resulting image for each eye does not need to be square or rectangular
- Culling geometry before it gets rendered reduces performance overhead

EYE TRACKING

- HMDs with Eye Tracker allow foveated rendering
- Eye Tracking Data can be additional input
  - Rendering
  - Interactions
  - To guide users focus
  - Seen as the next big step
- Common SDK: Tobii Eye-Tracking SDK
  - Data: position pupil, diameter, view direction, combined eyes and single eye data
- Eye Tracker can be added manually
- HMD with integrated eye tracker:
  - Vive Pro Eye
  - HP Reverb G2 Omnicept
  - Pico Neo 3 Pro Eye
  - Pico Neo 2 Eye
  - Quest Pro
  - PSVR2

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

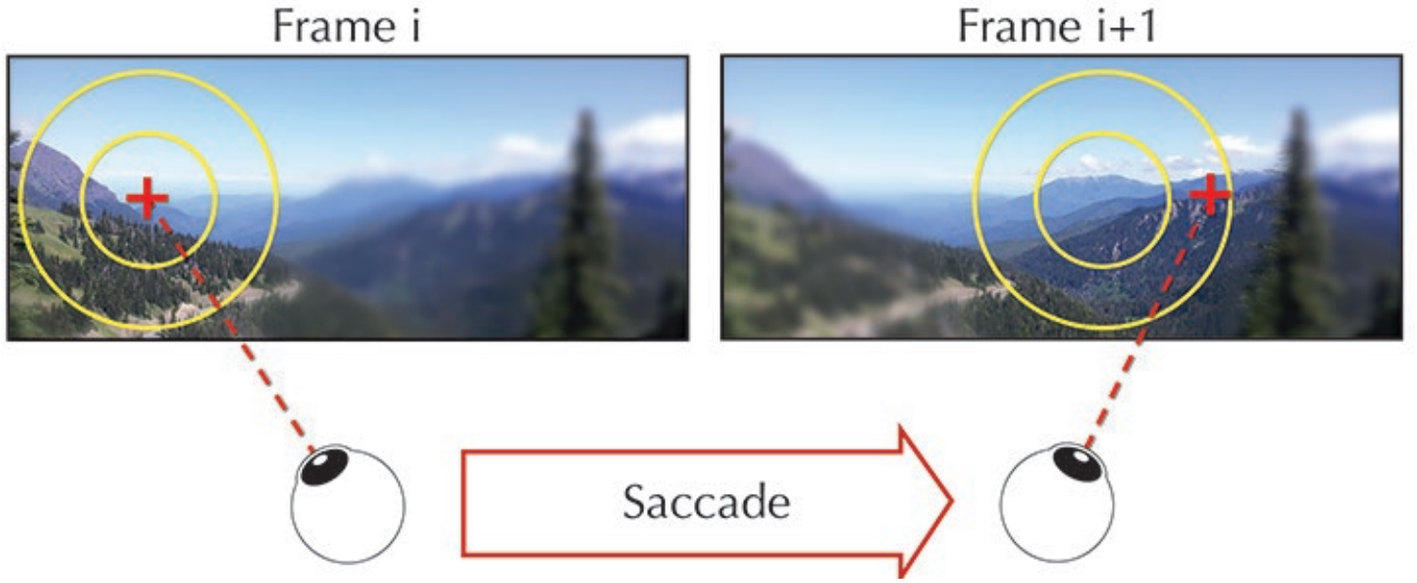


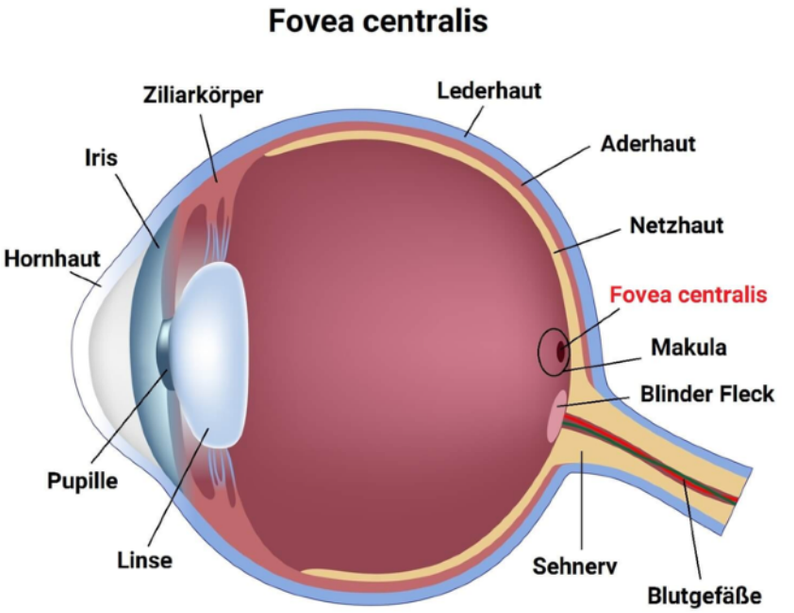


FOVEATED RENDERING

- Render technique with eye tracking for VR Headsets
- Reduce rendering workload in peripheral vision by reducing the quality
- Fixed foveated rendering assumes a fixed focal point without eye tracking
- *Trivia: Fovea is a part of the eye*

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





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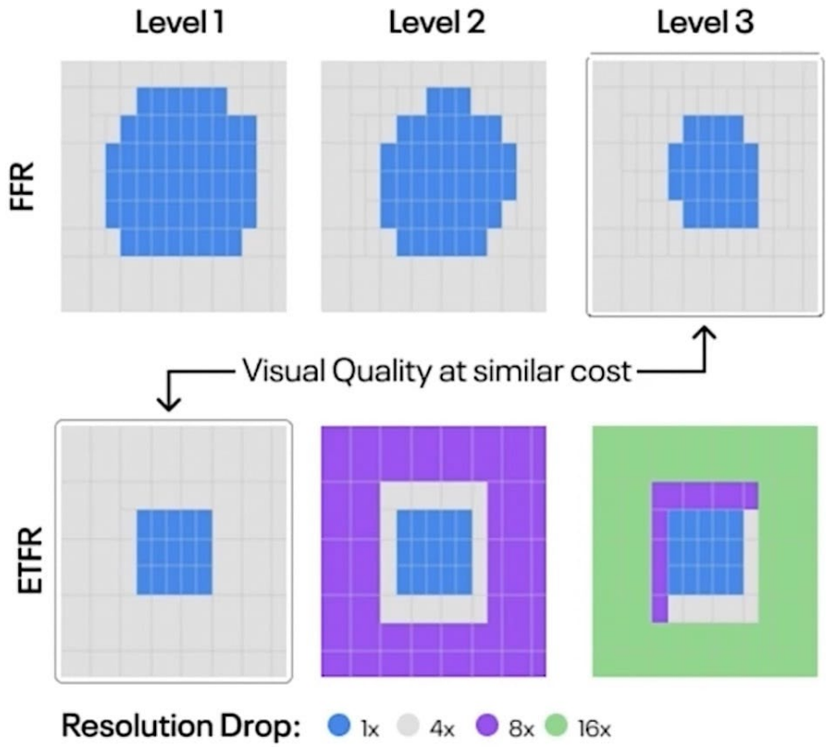
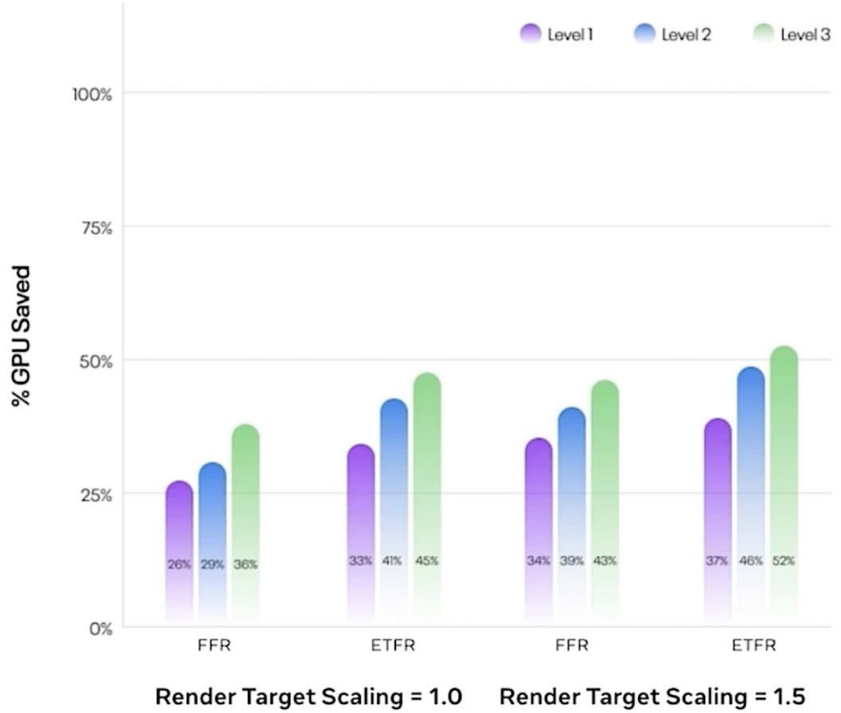
- *Trivia: Fovea is a part of the eye*
  - peripheral vision = outside of the zone gazed by the fovea



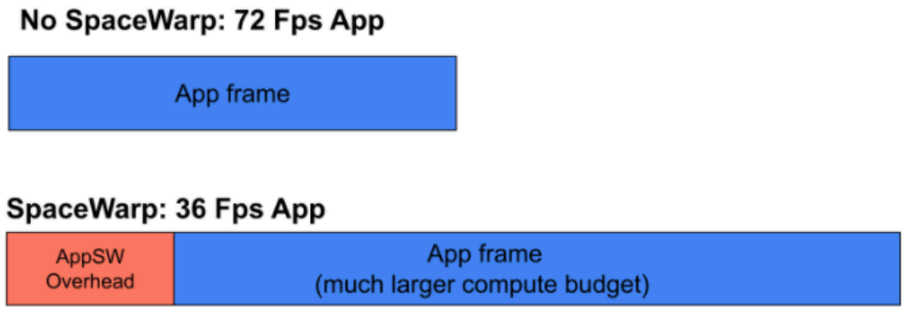


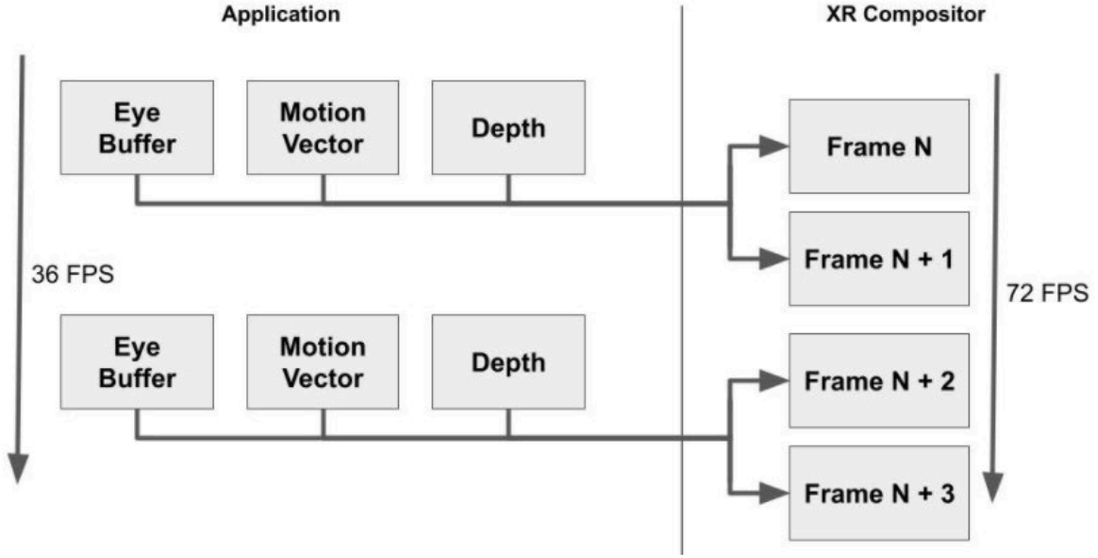
(Perf Data from ETFR UE4 Test App with MSAA2 / Symmetric FoV Enabled)

FOVEATED RENDERING EXAMPLE

- Example Meta Quest Pro Foveated Rendering
  - Eye Tracked Foveated Rendering (ETFR)
  - Fixed Foveated Rendering (FFR)

https://www.tobii.com/blog/what-is-foveated-rendering





APPLICATION SPACE WARP

- Optimization tech to unlock more computation power (up to 70%)
- generating additional frames that are not required to be fully rendered
- https://developer.oculus.com/blog/introducing-application-spacewarp/

URP Application Spacewarp

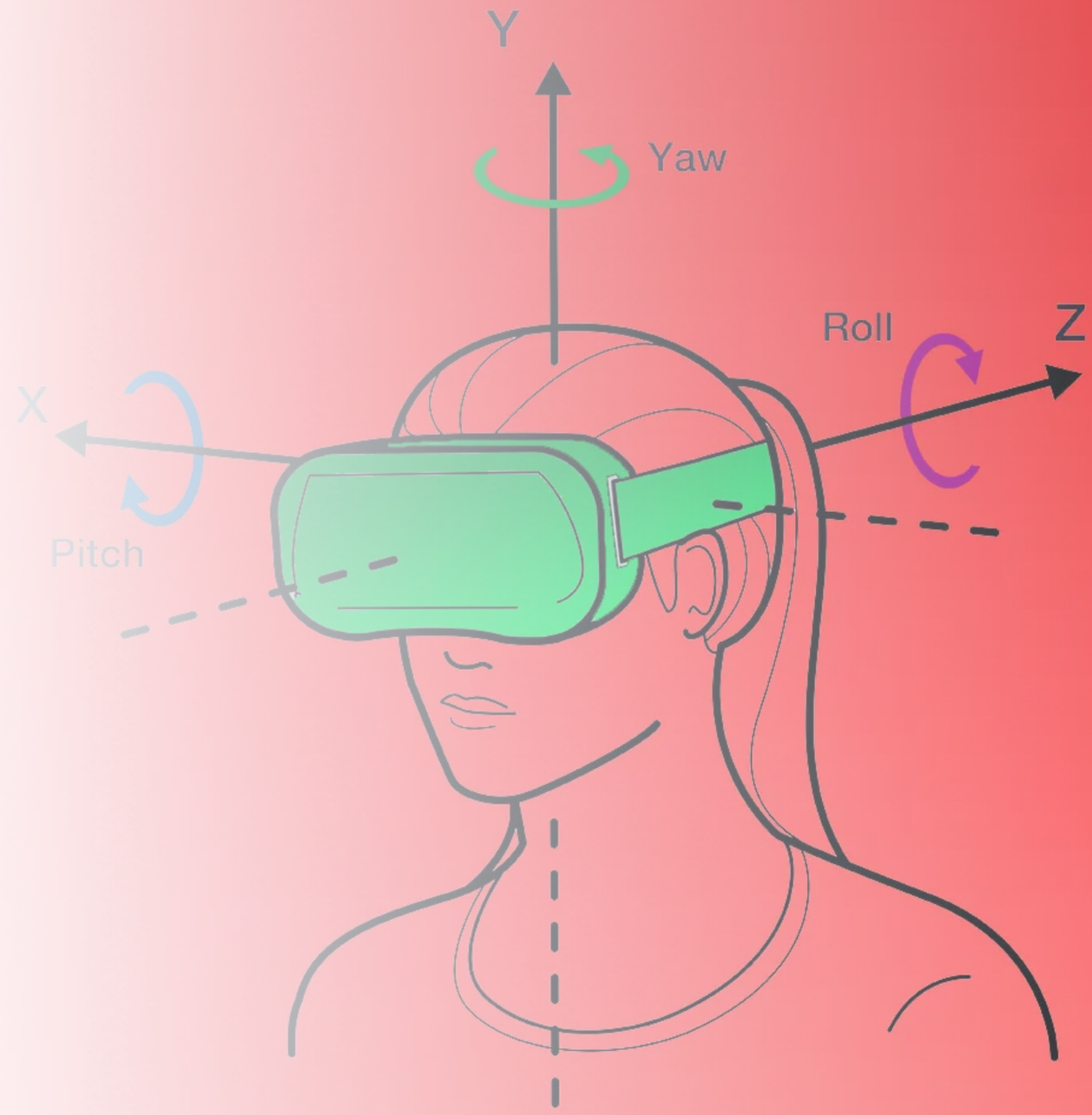
URP Application Spacewarp is an optimization for OpenXR that helps applications maintain a high frame rate. Spacewarp synthesizes every other frame, which can reduce computational power and energy use considerably. The technique uses reprojection when synthesizing frames to reduce latency between the user's movements and display updates.

DONE!

Examples and discussion

Meta Prototyping https://www.youtube.com/watch?v=IMpWH6vDZ8E
PSVR2 Ad https://youtu.be/u5L9Mvh7tAk
Meta Horizon Worlds https://www.youtube.com/watch?v=R9qacN6vyKg
Red Matter 2 https://www.youtube.com/watch?v=7xHXtPeVSTg
Half Life Alyx https://www.youtube.com/watch?v=O2W0N3uKXmo

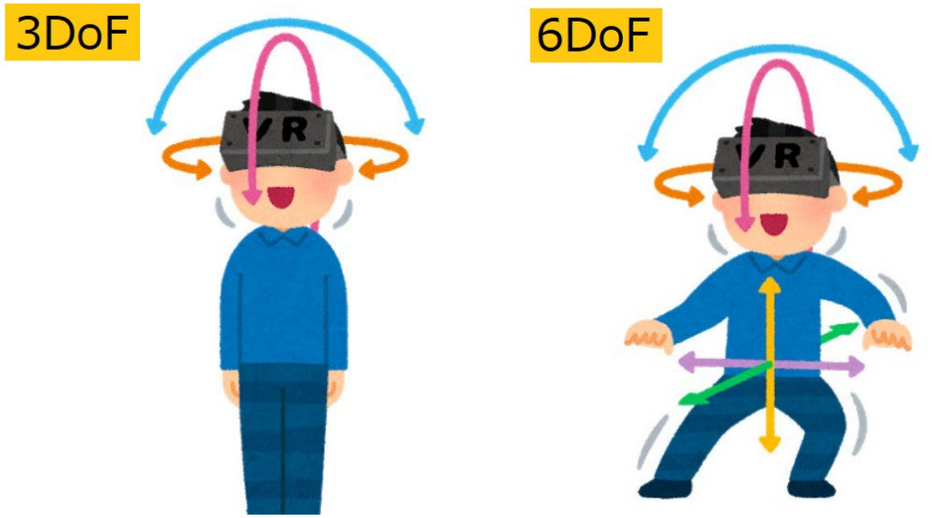
VR Tracking



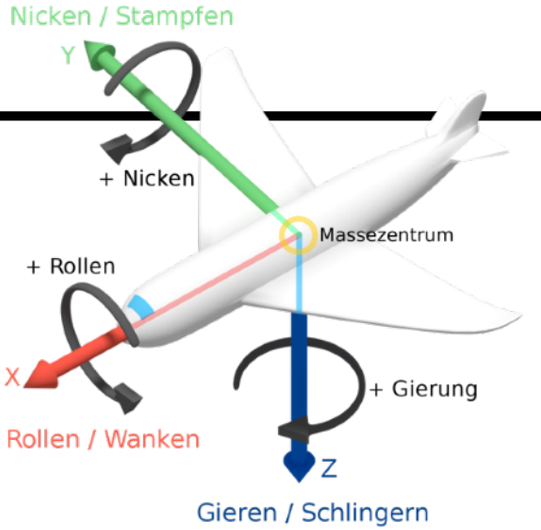
TRACKING TECHNOLOGY

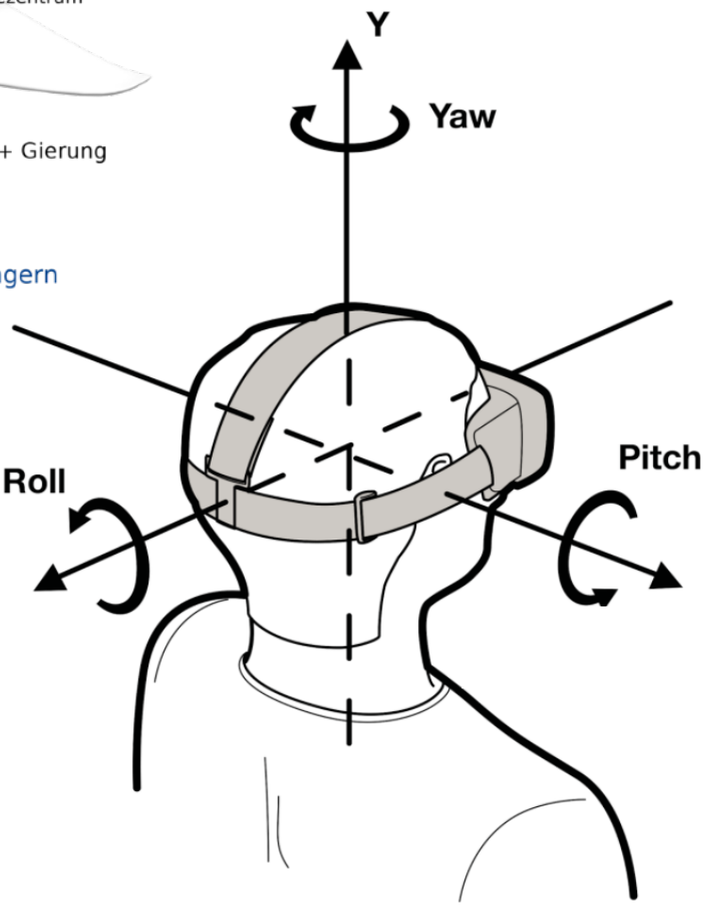
- Tracking different aspects of user's position and movement is essential to enhance the immersion in virtual worlds

- DoF – Degrees of Freedom – independent changing parameter
  - 3DoF – mostly describes Rotation on all axis
  - 6DoF – rotations and position an all axis



ROTATION AXIS





- 3DoF
- Special Euler angle to describe orientation of vehicles and devices
- Axis of the rotations are often referred to as
  - Yaw Gieren
  - Pitch Nicken
  - Roll Rollen

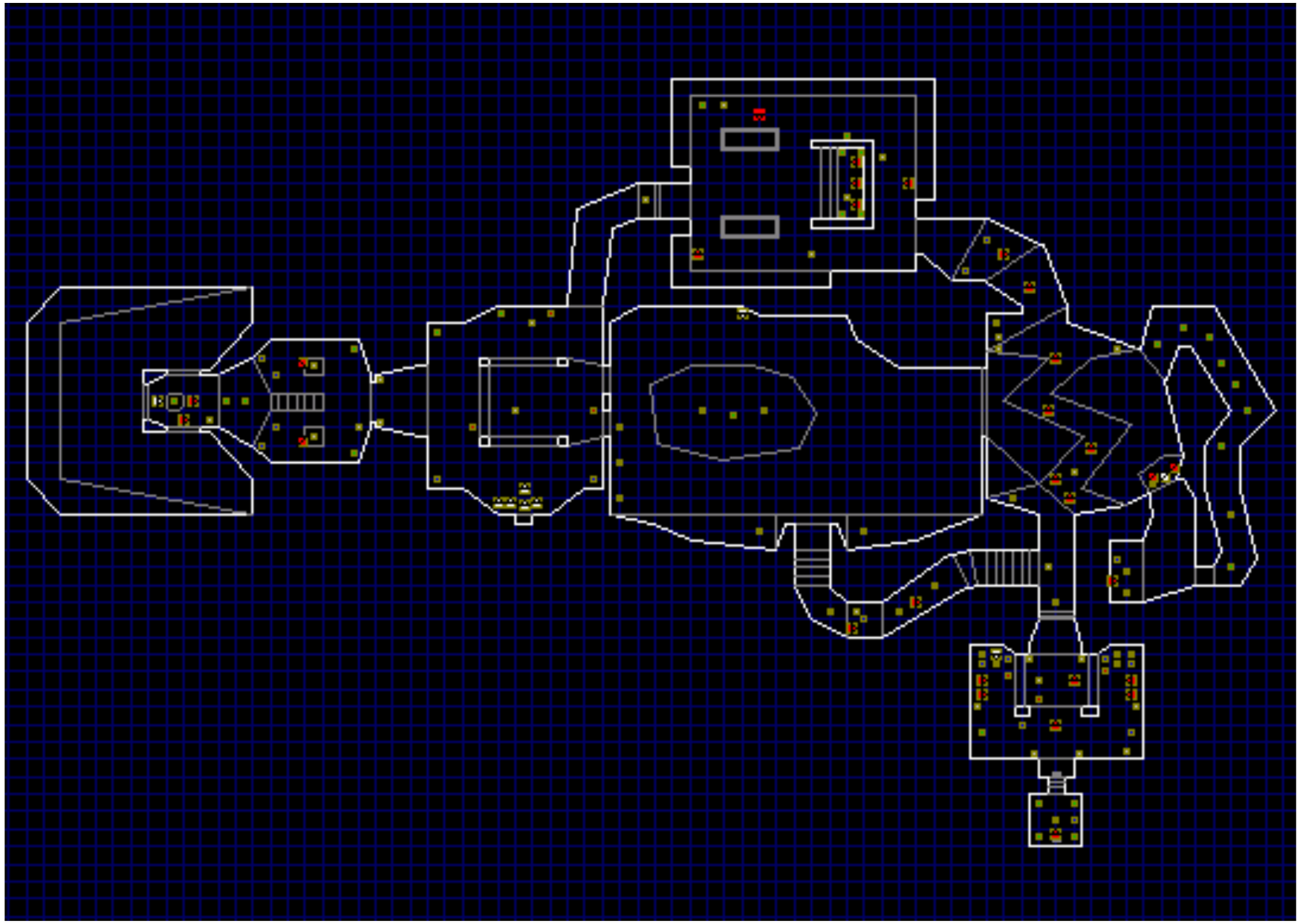
  - Roll-Nick-Gier-Winkel

Wieviel DoF hat das originale DOOM?

Wieviel DoF hat das original DOOM?

3 DoF!

- move x- & y-axis
- rotate z-axis
- rest is fake 3D

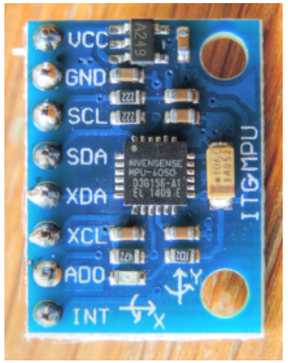


IMU TRACKING

- IMU – inertia measuring unit
- Sensor providing time-series data

- Contains:
  - Accelerometer – measures acceleration
  - Gyroscope – measures orientation - angular velocity
  - Magnetometer – measures magnetic field

IMU TRACKING



Gyroscope data + Accelerometer data + Magnetometer data → Motion Tracking Algorithm → Movement and Rotation of Device

- Ideally if we know the angular velocity of our device from the gyroscope and the acceleration from the accelerometer, we should know all movements of our device
- All sensors have a calibration error based on the device (the cheaper the device, the higher the error)

ORIENTATION DRIFT ERROR

- Measured angular velocity $\hat{\omega} = a + b\omega.$
- Discrepancy between $\hat{\omega}$ and ω is the calibration error

$$\hat{\omega} - \omega = a + b\omega - \omega = a + \omega(b - 1).$$

- Drift error is the aberration over time $d(t) = \theta(t) - \hat{\theta}(t).$
  - Causes wrong tracking over time
- The calibration error could be reduced or either eliminated by the perfect calibration

CALIBRATION OF ORIENTATION DATA

- Start orientation can be set by the application or “reset” by the user
- Drift error can be partly compensated by the accelerometer and the magnetometer
  - Accelerometer can give information about orientation of the “up”-Vector
  - Gravity = 9,81 m/s2

  - Magnetometer measures a 3D magnetic field vector
  - Data is calibrated and allows to reduce the drift error
  - Error increases if there are materials influencing the magnetometer
- Reduction of drift error is good enough to provide a stable orientation
- Used in almost all VR headsets (especially mobile device VR)

POSITION TRACKING

- Accelerometer measures acceleration due to gravity
- With the gravity substracted ideally the true acceleration on all axis should give us the needed information of movement
- Unfortunatly the drift error rate is much larger than in a gyroskope
- Other parts if the IMU can‘t compensate

POSITIONS TRACKER

- HMD: Oculus DK 1, DK 2, Oculus Rift
- One or more cameras
- Sensor in camera sends out infrared light
- Devices reflect light
- Camera detects reflected light and calculates positions

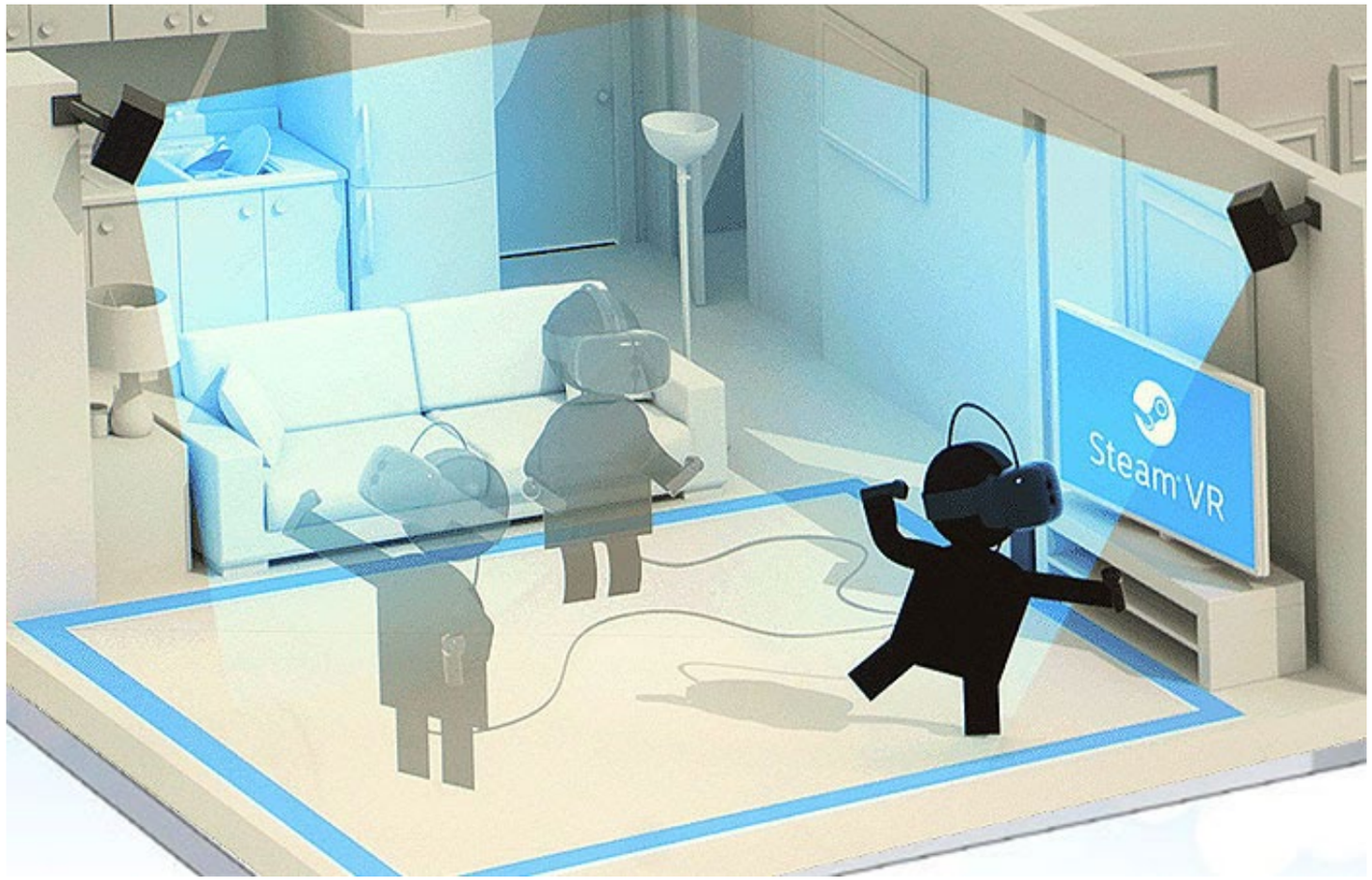
LIGHT TRACKING

- HMD: PSVR

- Single camera tracking oft light (Outside-In Tracking)
- PS move controller and headset with different Colors
- Size and shape is used for evaluation
- Camera can only see in cone-shape FOV → restricted interaction direction

LIGHTHOUSE TRACKING

- HMD: HTC Vive, Valve Index, Pimax
- 5x5m tracking with 2 base stations (extendable to 4 base stations)
- Base station with laser and infrared LEDs
- Vulnerable to occlusion – line of sight
- Can have a problem with other sources of Synchronization flashes and infrared LED light
- Easy extendable

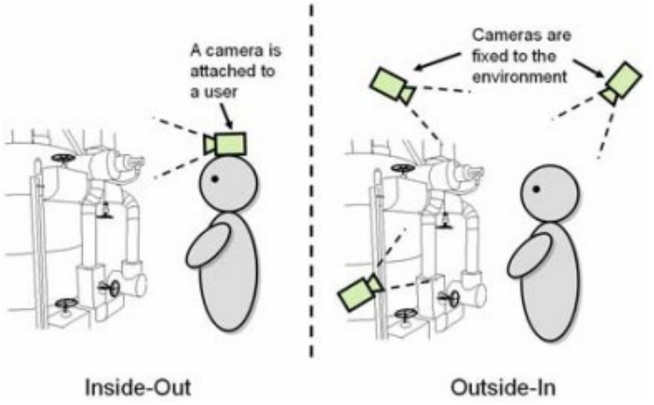


LIGHTHOUSE TRACKING - DETAILED

- Sync Blinker emit synchronization pulse
- 2 laser sin rapidly in the base station
- 1 of the 2 lasers sweep a beam across the room
- Receptors on devices (HMD, controller, other compatible devices) intercepts light
- After the synchronization pulse is detected, the time is counted till laser hits
- Based on the elapsed time and position of the receptor, the device position can be calculated

INSIDE-OUT TRACKING

- HMD: Meta Quest
- Commonly referred to HMDs and other tracker, that can detect their position in the room themselves
- Cameras and Sensors in the device register changes in relation to the environment
- system's algorithms identify specific images or shapes and uses them to calculate the device's position in space
- Based on device there could be additional sensor data like IMU



INSIDE-OUT TRACKING

- Simultaneous localization and mapping (SLAM)
- Computational problem of constructing and updating a map of an unknown environment
  - Computational Geometry
  - Computer vision

- Mostly individual implementations by the company (and most likely secret)
- Controller are tracked by IMUs and the cameras
  - Controller can be tracking for little bit outside of the field of view of the cameras because of an algorithm of predicted motion

CONTROLLER

- Most controller offer different sets of buttons, trackpad or stick, trigger etc.
- for example, Oculus and Index offer proximity sensors for different hand poses
- Index allows holding the controllers without gripping

HTC
Vive Pro

Valve Index

Meta Quest

CONTROLLER TRACKING

Viele Realisierungen

- Internal IMU
- Tracked by Lighthouse-System
- Tracked by HMD
- Tracking itself (Inside-Out-Tracking)
  - e.g. Quest Pro
    decreases computation load on headset
- Sometimes with finger-detection on buttons

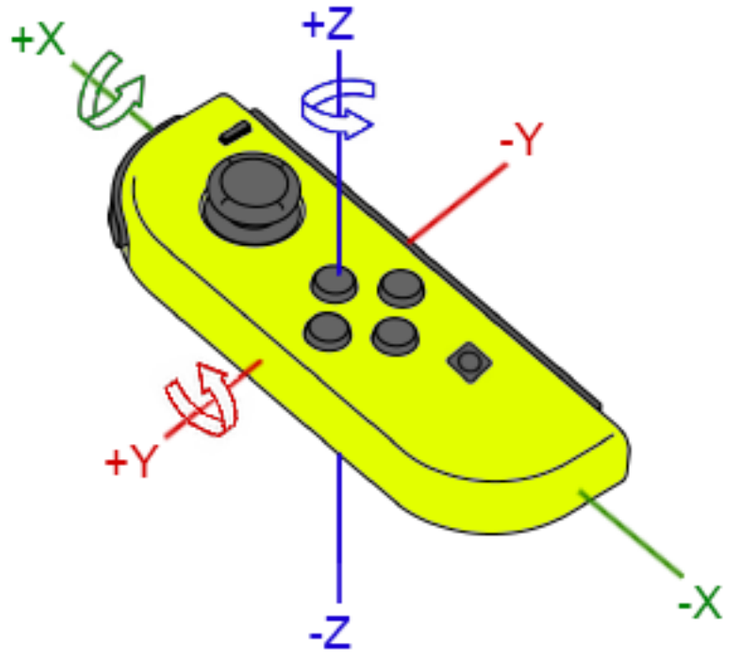
HTC
Vive Pro

Valve Index

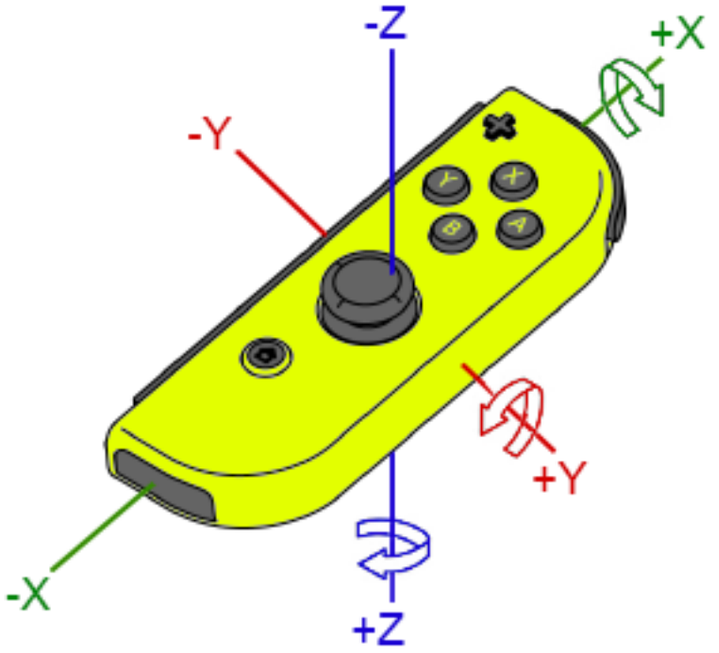
Meta Quest Pro

Nintendo Switch

Left Joy-Con



Right Joy-Con



https://github.com/dekuNukem/Nintendo_Switch_Reverse_Engineering/blob/master/imu_sensor_notes.md

OTHER VR SYSTEMS

- CAVE Systems
  (image on the left)
  - We have a CAVE with 4 sides @BHT
- Marker-based-tracking
- Stereoscopic rendering – alternate rendering for each eye with synchronisation

VR Devices

OVERVIEW

- What devices are currently relevant
- What are their properties
- What can be expected in the future

GOOGLE CARDBOARD

- 2014 by Google
- poor tracking
- poor visuals
- requires smartphone
- Karton, 2 Sammellinsen, Druckschalter ≈10€

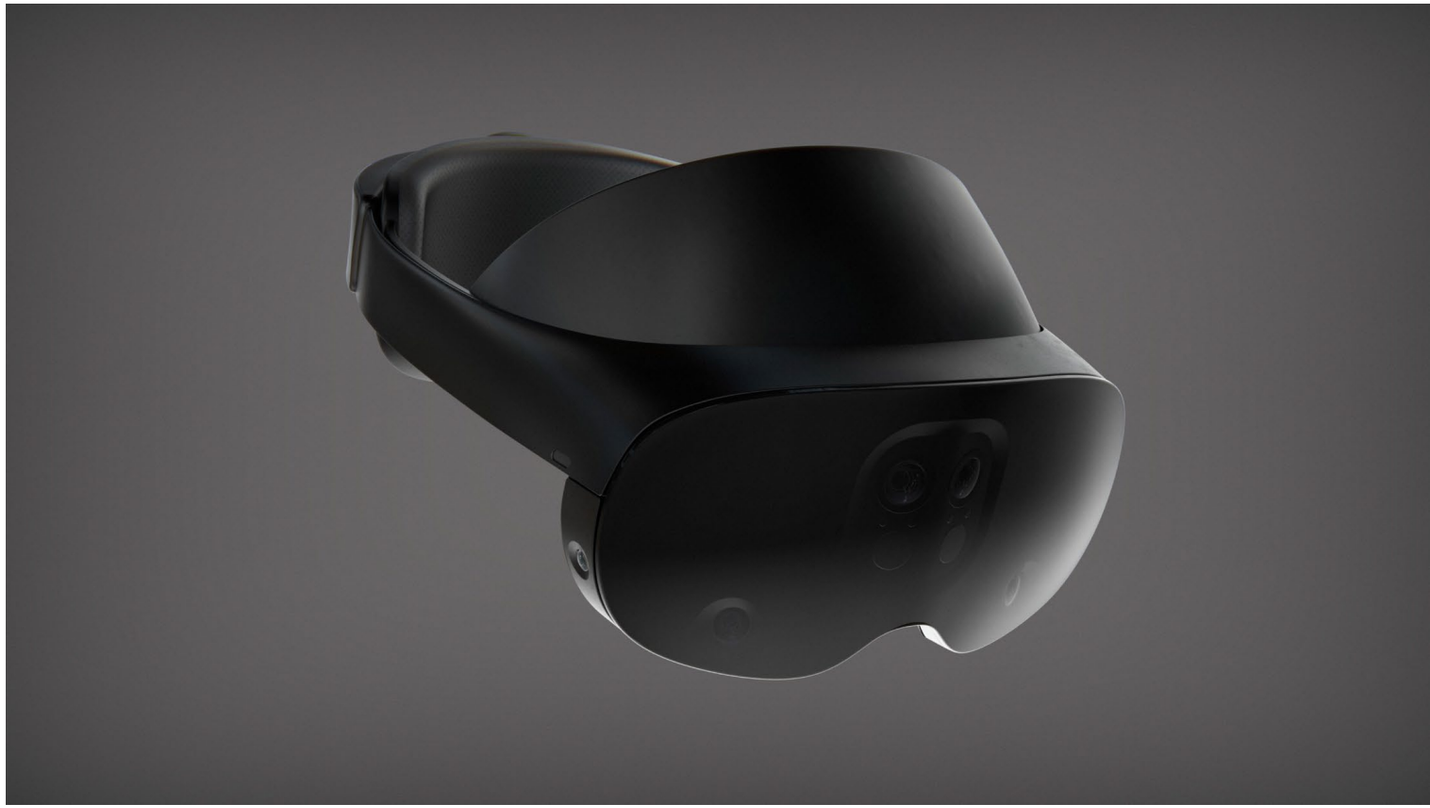
https://arvr.google.com/cardboard/

META QUEST 2

- 2020 by Meta
- Autonomous (but can be connected to PC optionally)
- Inside-Out-Tracking
- Most sold/used headset
- Strongly subsidized by Meta
- Successor of Oculus/Meta Quest
- Meta Quest 3 neu released

META QUEST PRO

- Oct 2022 by Meta
- Autonomous (but can be connected to PC optionally)
- Inside-Out-Tracking
- Additional features to Quest 2
  - Eye tracking
  - Colored see-through
  - improved performance



credit: Bradley Lynch, Project Cambria Rendering

HTC VIVE

- 2016 by HTC x Valve
- Lighthouse tracking
- Cable-bound, requires PC
- Very accurate tracking, high performance (dependent on PC)

https://www.flickr.com/photos/92587836@N04/24177102722/

VALVE INDEX

- 2019 by Valve
- Lighthouse tracking
- Cable-bound, requires PC

https://www.valvesoftware.com/de/index

- Very accurate tracking, high performance (dependent on PC)

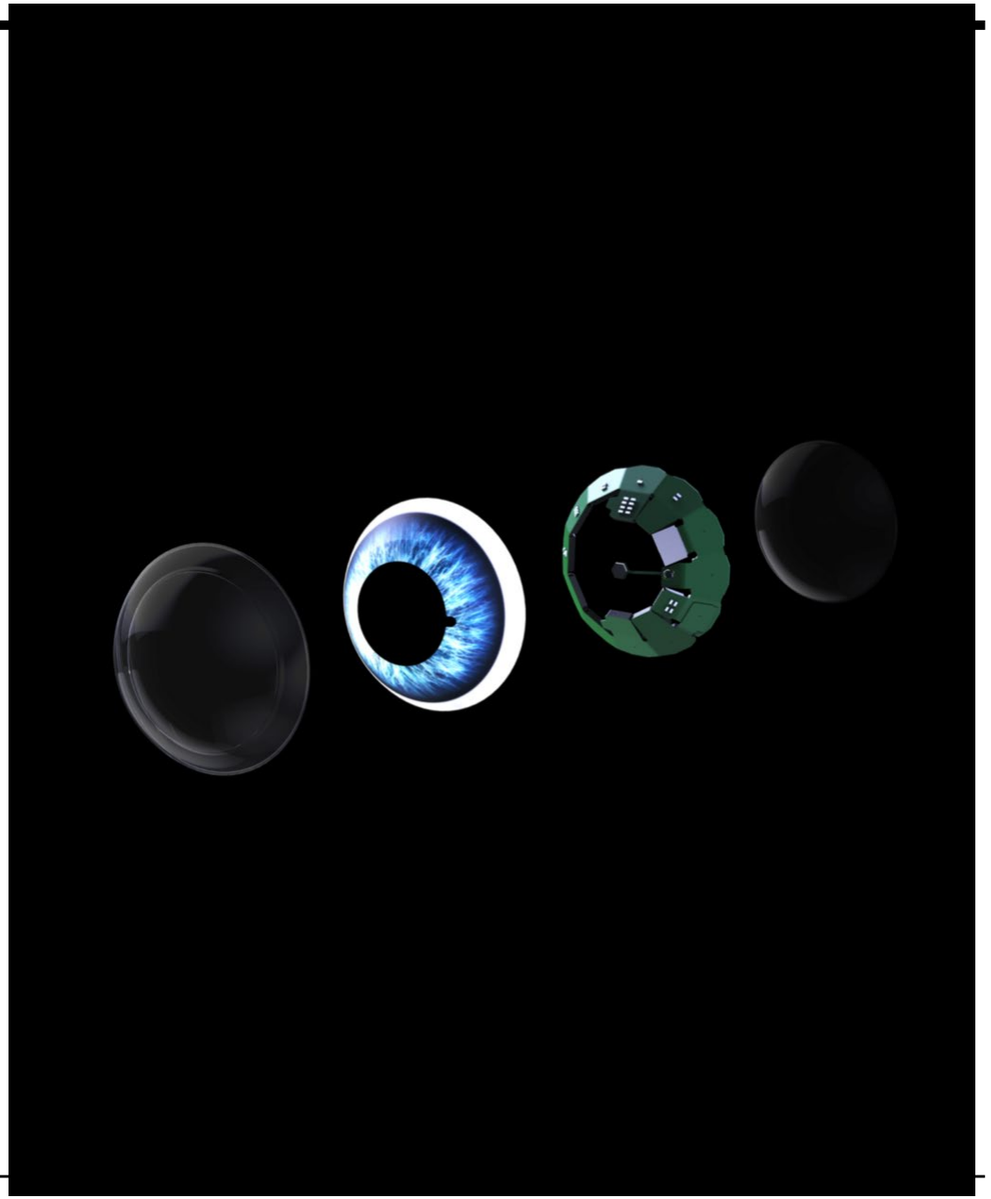
PS VR
(& PS VR2)

- 2016 by Sony
- Connects with Playstation 4 or 5
- Cable-bound
- tracking via single Camera

- PS VR2 for Playstation 5 in development (estimated for 2023)

MOJO LENSES

- 20xx by Mojo
- contact lens
- autonomous
- **not reality yet**, but in active development



PICO

- Wird oft als Nicht-Meta-Alternative für mobile Headsets gesehen
- Passthrough
- Inside-Out-Tracking 6DoF

DONE!

Examples and discussion

- https://www.youtube.com/watch?v=TX9qSaGXFyg (Apple Vision)
- https://www.youtube.com/watch?v=7UvfmvMU3Vc (Meta Quest Pro Commercial)
- https://www.youtube.com/watch?v=lJnFlHZF2jw (Varjo, Racing Sim)
- https://www.youtube.com/watch?v=wlB51dSkqw8 (Varjo, Fighter Jet Sim)
- https://www.youtube.com/watch?v=61QNTWE54QU (Mojo Lense Commercial)

VR Periphery

VR PERIPHERY

- Additional hardware tries to increase VR interaction capabilities
- Types of periphery
  - Detailed tracking of additional positions of the body (feet, finger..)
  - Walking (treadmills, shoes…)
  - Simulation (flying like a bird…)
  - Etc.

- ICAROS https://www.youtube.com/shorts/PuT96f1eh8U

EXTENDED CONTROLLERS

- Dedicated controllers for some applications
  - e.g. Guns, Tools
- Sometimes regular controllers are incorporated

EXTENDED CONTROLLERS

- Dedicated controllers for some applications
  - e.g. Guns, Tools
- Sometimes regular controllers are incorporated

Baomaeyea VR Gunstock für Meta Quest 2 Gun Sto…

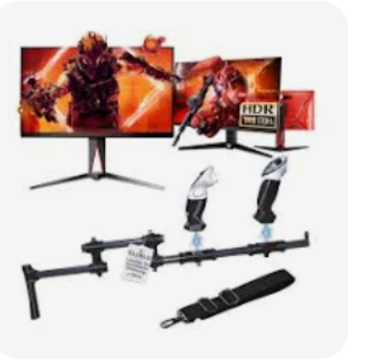
36,99 €

Amazon.… & mehr

Baomaeyea VR Stock Zubehör for Meta Quest…

25,88 € ~~32 €~~

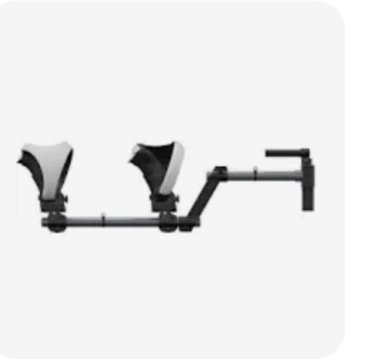
Amazon.de - Am…



VR Stock Zubehör for Meta Quest 3/Quest 3S,VR…

23,98 €

Amazon.de - Am…



CBDYWVR VR Gunstock für PlayStation VR2…

40,99 €

Amazon.… & mehr

Magnetic VR Gun Stock for Quest 2 Rifle Grip VR…

33,99 €

Bigshopper

VRifle Casual Flexx

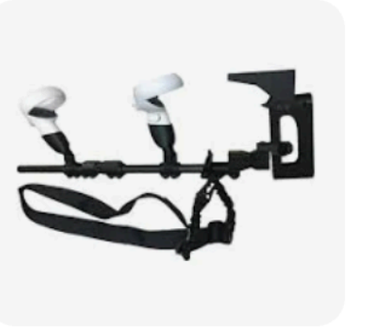
47,50 €

VRifle

Yuiturt VR Stock Zubehör, VR Stock für Meta Quest 3…

26,98 € ~~29 €~~

Amazon.de - Am…



Für Oculus Quest 2/Quest 3 Gun…

48,99 €

AliExpress

1,9 ★★☆☆☆ (10)

EXTENDED CONTROLLERS

Provolver

Vortex VR

- haptic feedback (recoil)
- https://www.knoxlabs.com/products/forcetube-vr-gun-stock

VIVE TRACKER - ADDITIONAL TRACKING

- Allows to extend lighthouse-based systems
- Allows to track additional objects attached or bodyparts
- Simple integration with the same technology

TREADMILL

- Treadmill-like devices to allow more natural walking, without needing extra tracking space
- Omnidirectional treadmill
- Different versions, shapes
- Unfortunately, costly and most likely inconvenient at home

- Omni One
  https://virtuix.com/

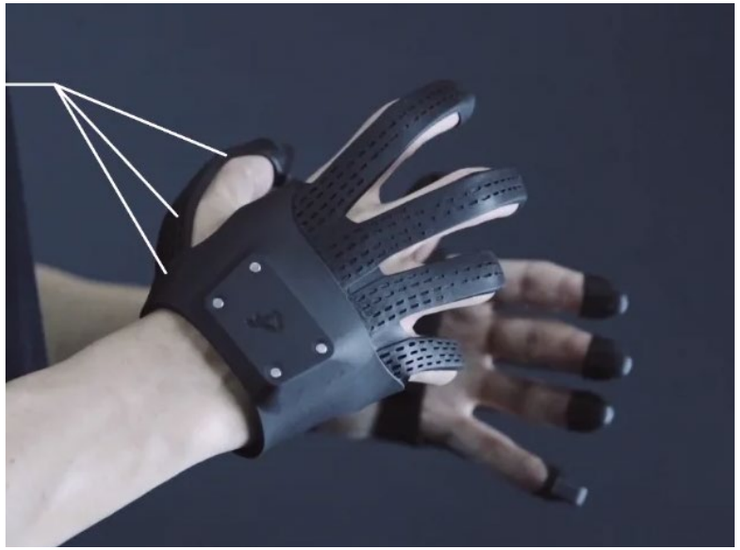
- Omnidirectional treadmill CM1

https://www.youtube.com/watch?v=R-bWKF6ySTo


Strider VR
https://www.youtube.com/watch?v=NK41x5kenO4
pathbender.de

GLOVES

- Mutliple tracking gloves for VR are in development
- Could be very costly
- Not really ready for consumer until now



GLOVES

bHaptics TactGlove DK2 Wireless Haptic Gloves (Pair) - VR Accessory

$ 334.95

SenseGlove Nova 2 Haptic XR / VR Gloves

$ 7,549.50

Sold out

SenseGlove Nova Blue | Haptic Virtual Reality Gloves

$ 4,618.95

StretchSense Studio Glove

$ 834.75

HAND TRACKING

- etee Controller

https://www.youtube.com/watch?v=j7YgK5eNNXk

HAND TRACKING - LEAP MOTION

- Infrared hand tracking sensor
- Can be attached to VR devices
- Cone-shaped FOV

cybershoes.com

SHOES

- Allows locomotion

DONE!