Devices for Virtual and Aaugmented Reality

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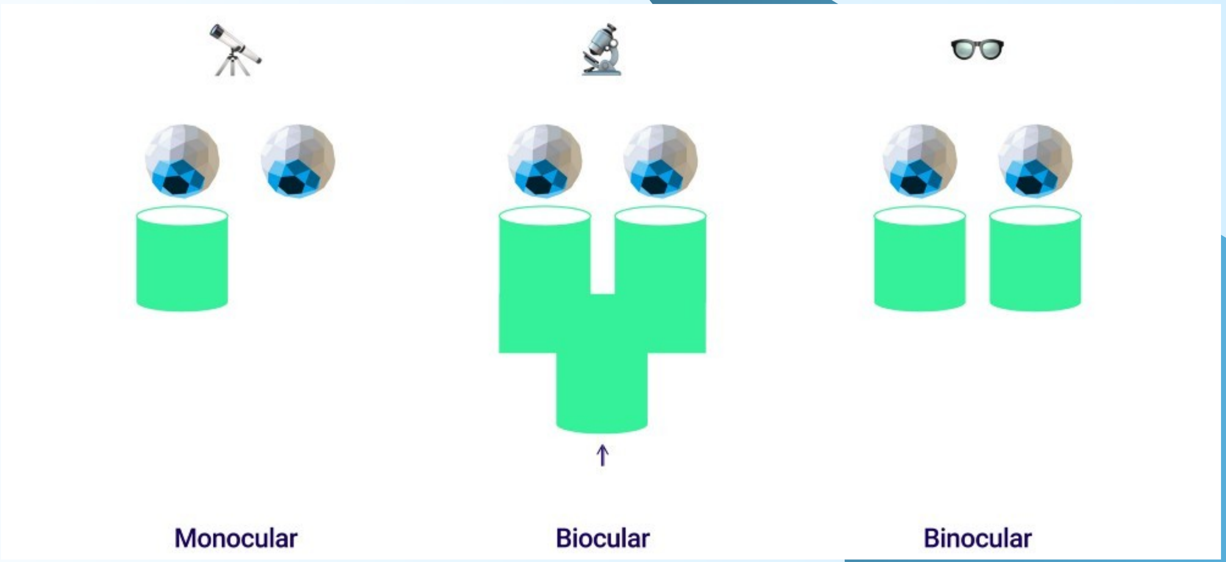
History

- 1940 - head-up display in the aircraft
- 1957 -1962, Morton Heilig built VR machine called “Sensorama”
- 1968, Ivan Sutherland constructed VR system “Sword of Damocles”
- mid-70s, Myron Krueger created artificial reality lab called “Videoplace”
- 1992, Caudell & Mizell simplified the work of aircraft workers by using HMD
- 1994, Julie Martin composed the first AR theatre performance “Dancing in Cyberspace”
- 1999, NASA during a test flight displayed computer-generated map
- 2013, Google introduced its Google Glass

Technologies of Displays

- HMD uses LCD or OLED fully immersive display technology.
- OHWD uses LCoS or DLP projectors with optical see through technology.
- HWD uses only binocular stereoscopic view.
- OHWD uses binocular or monocular displays.
- Displays are small but have great resolution (3840×2160)

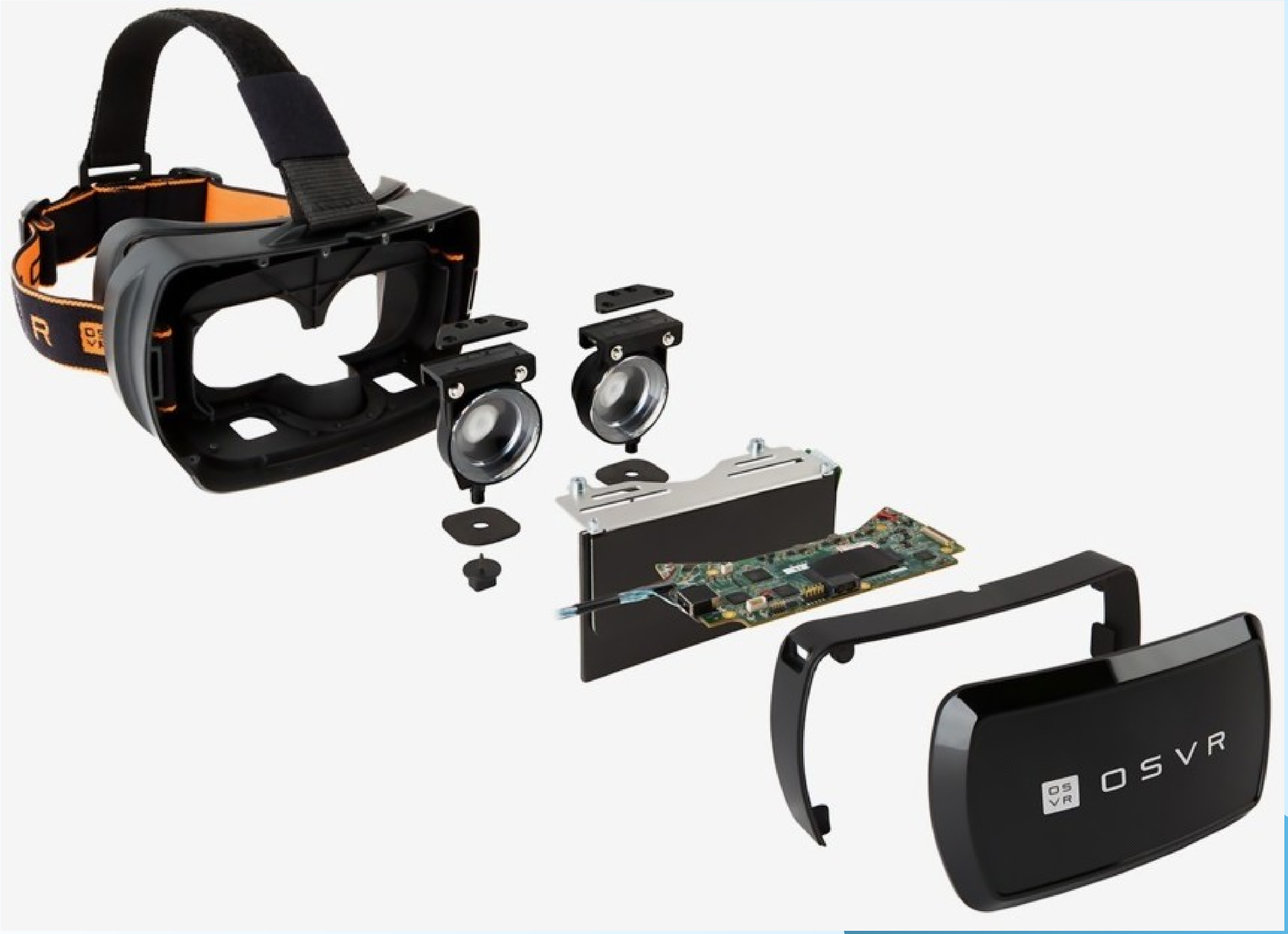


Head-Mounted Displays

Devices with an opaque optical system worn by the user on the head.

- Use miniature LCD or OLED and optics which is needed to prevent the eye from focusing on the screen that is just a few centimetres away from the eye.
- They have also head-motion trackers, stereo headphones and some of them can also have small cameras (for creating AR experiences) and eye-motion trackers.

Head-Mounted Displays



Otical Head-Worn Displays

Devices with an optical see through system worn by the user on the head like glasses.

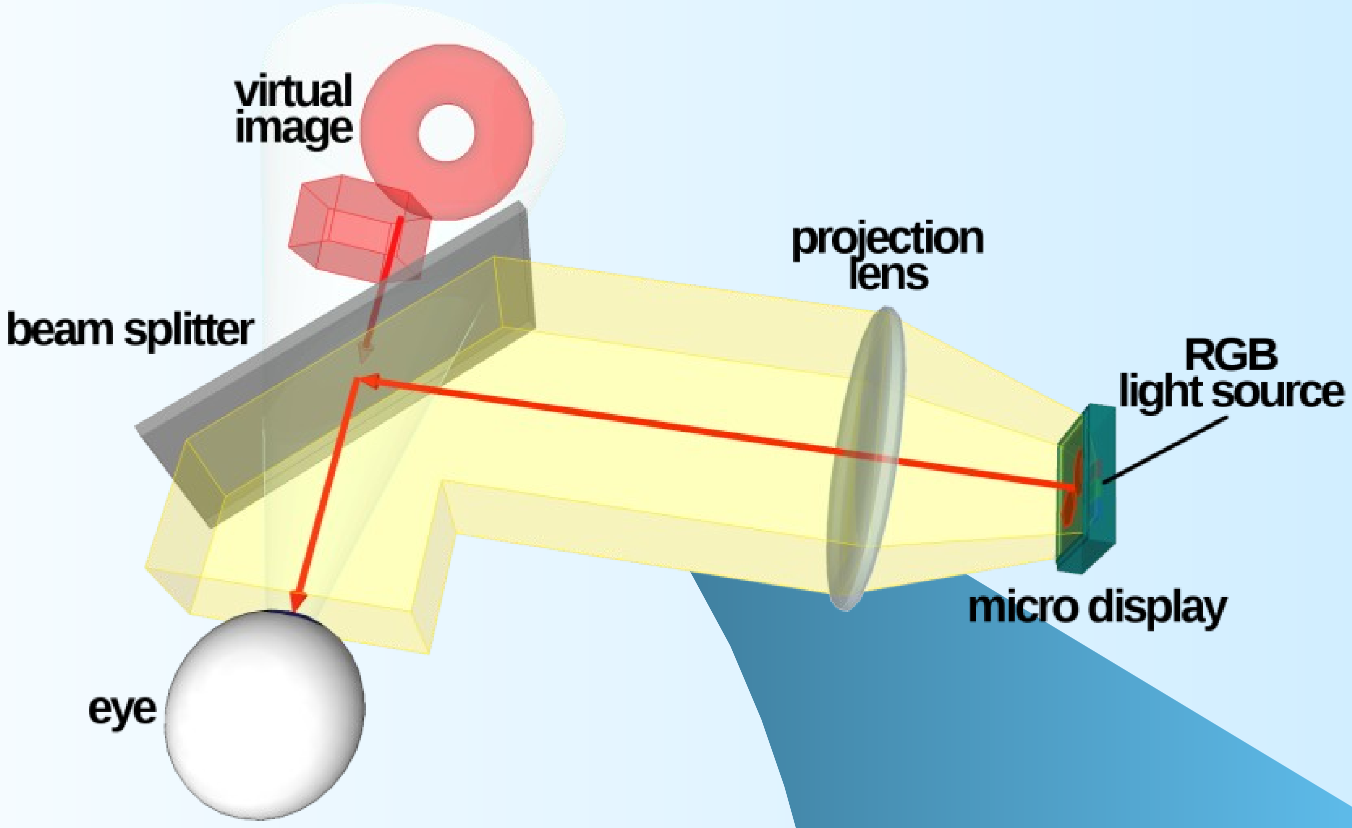
- It is possible to see real-world images together with virtual images through transparent optics.
- Display an image for only one eye or a stereoscopic image for both eyes.
- The basic element of these displays is an optical combiner that combines virtual and real images into one.
- Do not offer sufficient image resolution along with a large field of view (more than 90°).

Otical Head-Worn Displays

The image is created by a small display, which is located outside of the field of view and the full color image is often created by displaying three images sequentially in rapid succession.

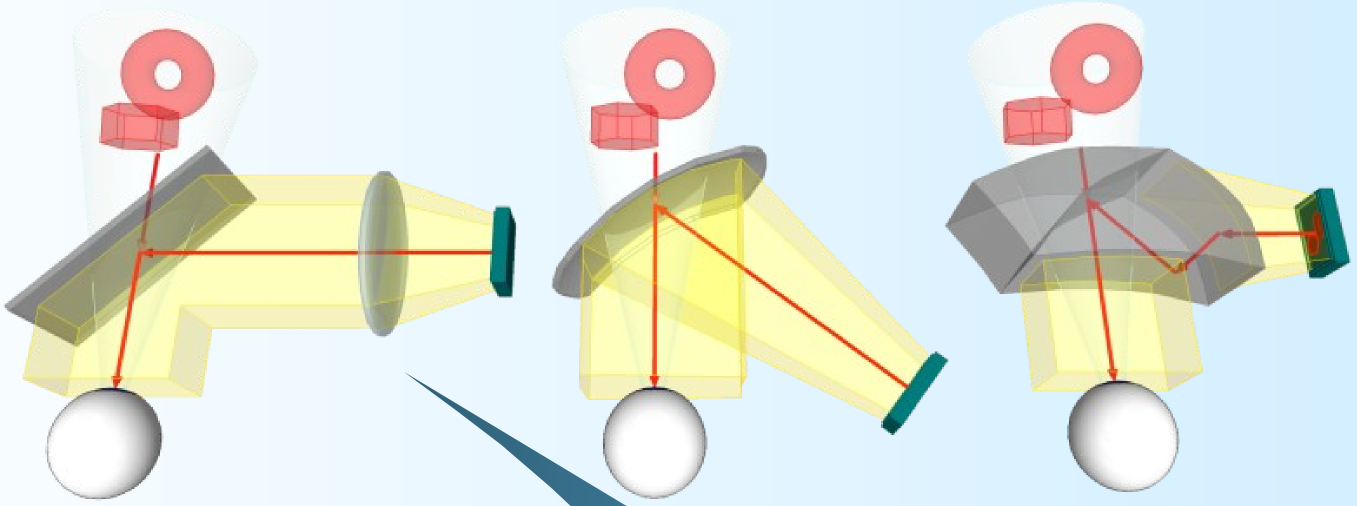
- Optical system redirect the image created outside the field of view to the eye.
- Virtual image is displayed at a greater distance from the eye.
- Small picture from the micro-display is enlarged to the desired size.
- Contains also one or more cameras, a microphone, head-movement sensors, speakers, GPS and even a small touchpad.

Optical Head-Worn Displays

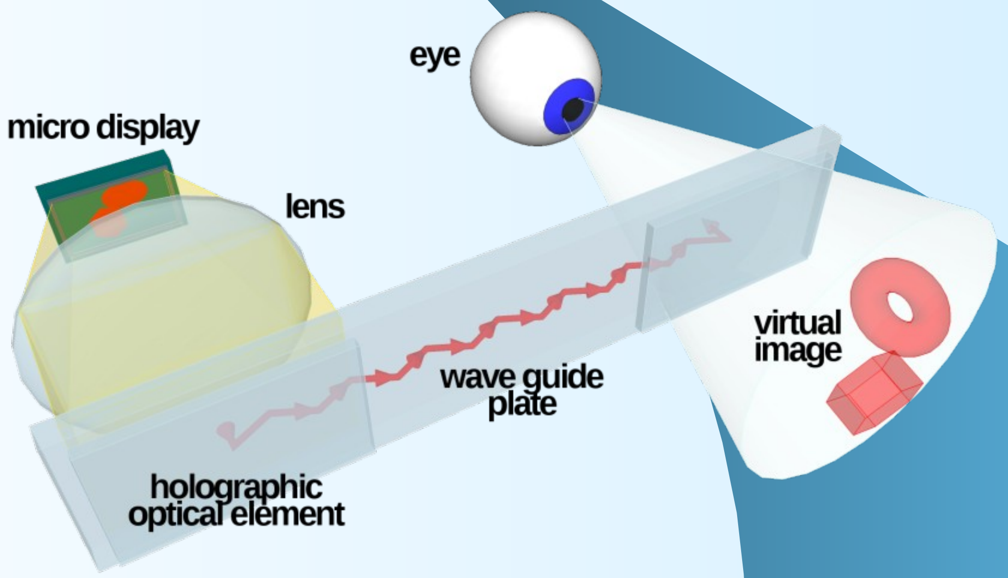


Optical head-worn display scheme

Otical Head-Worn Displays



Planar, spherical and free-form optical combiner



Combiner with holographic optical elements and waveguide plate

Otical Head-Worn Displays

Google Glass

Microsoft Hololens

Input Devices

- Built-in camera(s)
- Microphone
- Position and motion sensors: GPS, ToF position sensor, *accelerometer*, *gyroscope*, *magnetometer* (compass)
- Infrared 3D scanner or stereo camera (depth)
- Touch panel
- Light sensor
- Proximity sensor

Position and motion sensors

- In the outdoor environment, GPS is used to determine the position.
- In the indoor, sensors based on structured pattern, ToF or other technology are used.
- An accelerometer and a gyroscope are used to determine the position change (motion).
- The magnetometer (compass) is also used to improve positioning determination.
- 3 accelerometers and 3 gyroscopes are needed, one for each coordinate axis.
- 6 degree of freedom (DOF) = 3 for position + 3 for orientation.
- Cheaper devices use only 3 DOF for orientation (movement).

Position sensors - GPS

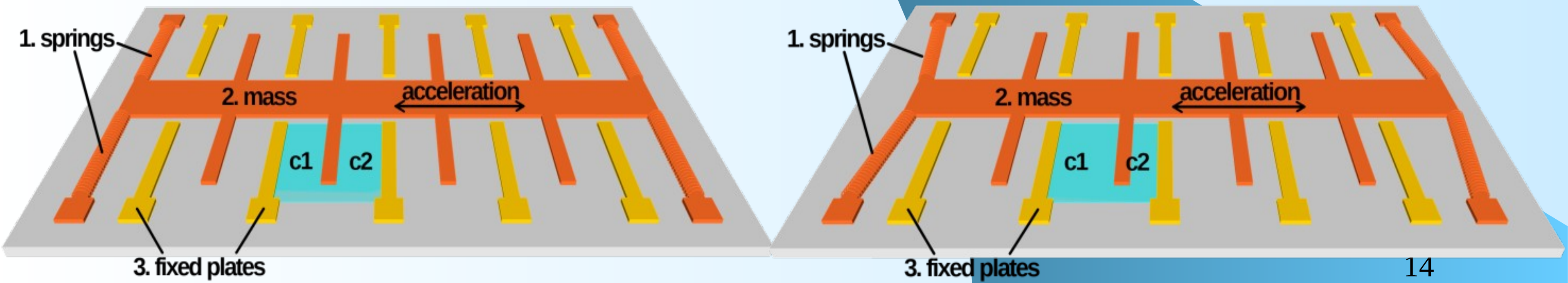
GPS receiver use a signal from four or more satellites.

- Signal propagates with the speed of light and contains highly accurate information about the current time and position of the satellites.
- Based on the time of transmission and reception of each satellite signal, the receiver calculates the distance to each satellite.
- At first, a sphere is created for each satellite. Each sphere is centered in the position of the satellite and has radius equal to the distance of the satellite to the GPS receiver.
- Since the receiver is located at the point of intersection of all the spheres, its position can be calculated by the center of this intersection.

Motion sensors - accelerometer

Accelerometer is a device for measuring acceleration in a given direction.

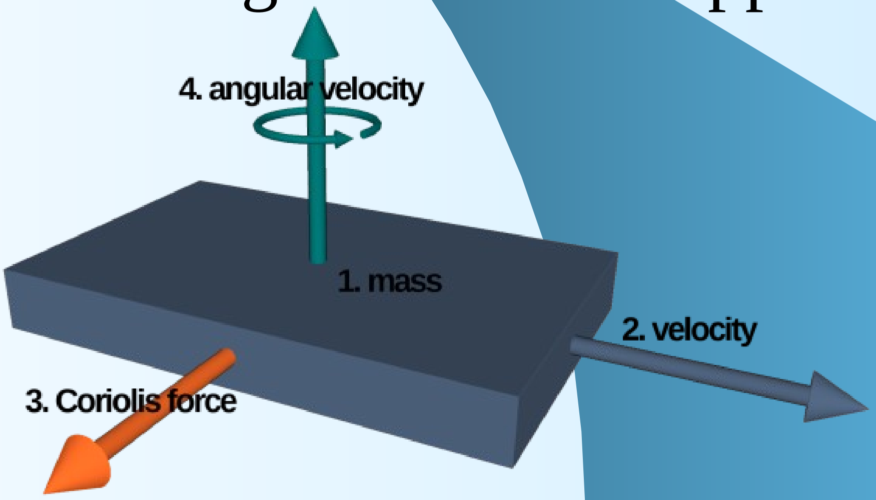
- Change in capacity on miniature capacitors is used.
- When accelerating, the movable part (2) moves in the opposite direction to the direction of acceleration and the capacity $c1$ and $c2$ between the fixed and movable plates changes.
- Three accelerometers are needed, one for each coordinate axis.



Motion sensors - gyroscope

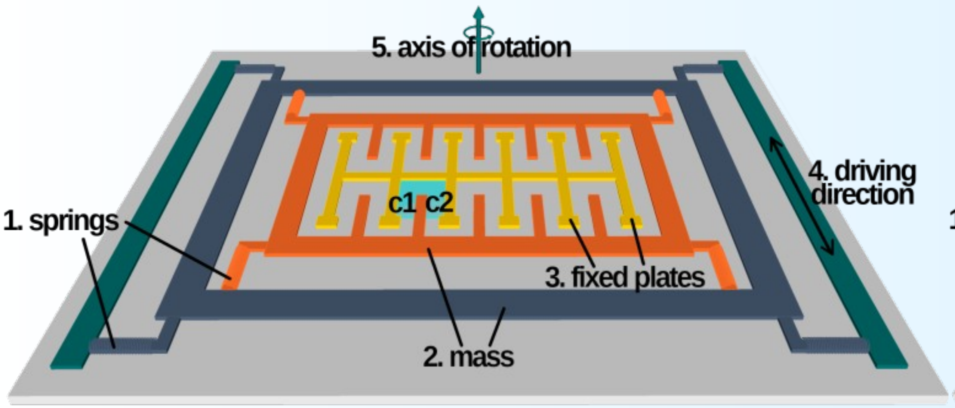
Using the gyroscope, it is possible to measure the magnitude of the change in rotation around one of the coordinate axes.

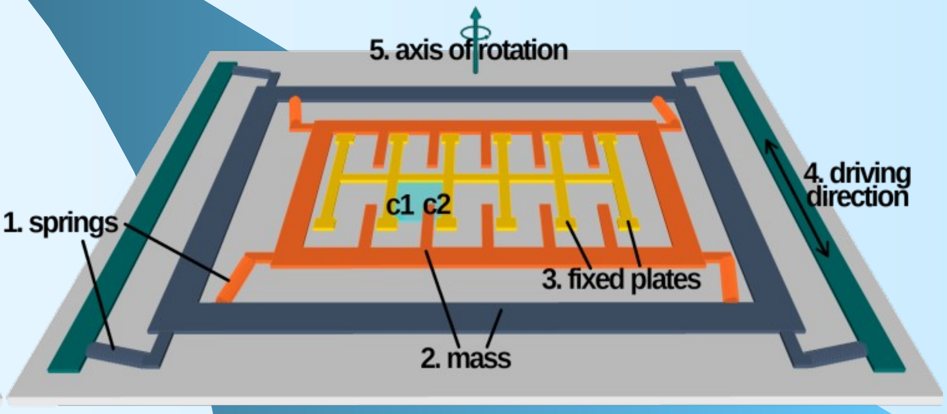
- Gyroscope uses the Coriolis force to measure angular velocity.
- Angular velocity causes the object to deviate from the original direction.
- Movement causes a change in capacity that is proportional to the magnitude of the applied angular velocity.



Motion sensors - gyroscope

- Movable part (2) vibrates very quickly in direction (4).
- If the gyroscope starts to rotate around axis (5), the vibrating part begins to deviate in a direction perpendicular to the direction of vibration, resulting in a change of capacity $c1$ and $c2$.
- Three gyroscopes are needed, one for each coordinate axis.





Motion sensors – magnetometer (compass)

The compass uses Hall effect that causes a potential difference between the electrodes of the semiconductor plate.

- Current passes through the semiconductor plate and the electrons pass from the cathode to the anode.
- If the plate is affected by the magnetic field of the Earth, their direct flow is disturbed, and the electrons begin to deflect to one side of the plate.
- The voltage between the opposite sides of the plate depends on the strength of the magnetic field and its direction.

Haptic devices

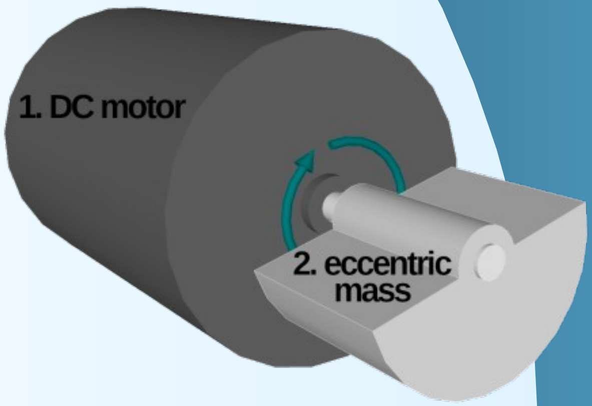
Haptic devices (HDs) allow manipulation of virtual objects by touch.

- They are usually divided into *tactile*, *kinesthetic* and *hybrid*.
- Using *tactile* haptic devices, we can feel the texture of the surface of a virtual object, its roughness or smoothness, temperature, surface tension and others.
- *Kinesthetic* HD serve for interaction with the object as such, allowing us to perceive not only its overall shape and weight, but also the force it exerts on us.
- *Hybrid* haptic devices are a combination of tactile and kinesthetic and combine the capabilities of both types.
- Feedback (vibration or mechanical force) is often used when manipulating virtual objects.

Haptic devices - tactile

There are many technologies to create a feeling of touching a virtual object.

- *Vibration*, as response to touch, can be made using a miniature motor with an eccentric rotating mass or using a linear resonant actuator.
- *Active surfaces* can be also used to create an illusion of touching an object. *Pin arrays* technology simulates the surface and shape of the object by ejecting a large number of small pins.
- *Mid-air* technology use a field of small ultrasonic speakers.



Haptic devices - kinesthetic

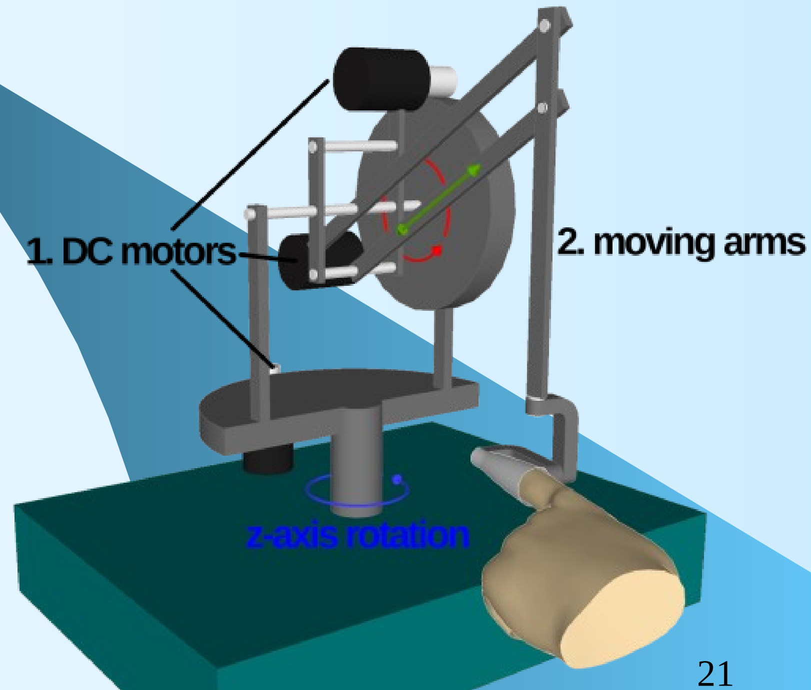
In kinetic HDs, the muscles of the hand and its movement are used to interact with a virtual object.

- Feedback is generated by mechanical forces that create variable resistance to hand movement.
- Forces are most often generated by electromechanical, pneumatic or hydraulic technology.
- We can divide the kinetic HDs into *manipulanda*, *grasp devices*, and *exoskeletons*.
- Can contain motion sensors so that the software can identify the position of some elements (e.g. fingers).
- They can be useful not only for playing games, but also for teaching medicine.

Haptic devices - manipulandum

- Manipulanda use a set of arms and electric motors.
- Force is transmitted by the arms to the rotors of the electric motors.
- Electric motor produce the necessary braking power depending on the resistance that a virtual object creates.

Novint Falcon



Haptic devices – grasp & exoskeletons

These devices put variable pressure on individual fingers to simulate contact with the virtual object.

- Finger movement is transmitted using a system of wires to the electric motors which produce the necessary mechanical force that reverses the movement of the wires.

HaptX – hybrid HD

Overview of Commercially Available VR/AR

Head-Mounted Displays for PC

Oculus Rift

HTC Vive

Pimax 8k

Head-Mounted Displays for PC

Name	Technology	Resolution	FOV	DOF
Oculus Rift	OLED	1080×1200	110°	6
HTC Vive	OLED	1440×1600	110°	6
Pimax 4k	LCD	1920×2160	110°	6
Pimax 8k	LCD	3840×2160	200°	6

HMD for Smartphones

Samsung Gear VR

HMD for Smartphones

Name	Technology	Resolution	FOV	DOF
Galaxy Note9, S9	AMOLED	2960×1440*	101°	6**
Galaxy Note8, S8	AMOLED	2960×1440*	101°	3
Galaxy Note5	AMOLED	2560×1440*	101°	3
Galaxy S7, S6	AMOLED	2560×1440*	101°	3

* Resolutions are both eyes
** Not available yet

Standalone HMD

Oculus Go

Lenovo Mirage Solo

Standalone HMD

Name	Technology	Resolution	FOV	DOF
Oculus Go	LCD	1280×1440	110°	3
Lenovo Mirage Solo	LCD	1280×1440	110°	3

Video Game Console HMD

Sony Playstation VR

Video Game Console HMD

Name	Technology	Resolution	FOV	DOF
Sony Playstation VR	OLED	960×1080	100°	6

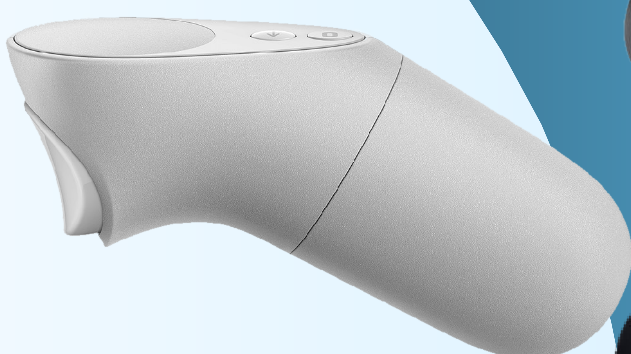
HMD Controllers

Oculus Rift Touch

HTC Vive controller/tracker

Pimax controller

Samsung Gear controller



Oculus Go controller

Playstation Move

HMD position tracking technology

- Oculus Rift uses many IR LEDs on HMD which are sensed by two IR cameras (Oculus constellation). The exact shape and size of the LED pattern is known, so by analyzing the camera frames the software can deduce the position and rotation of the headset in space.
- HTC Vive uses pair of “lighthouses“ with two IR laser diodes on rotated drum. Pair of light waves are sensed by photodiodes on HMD.
- Pimax uses exactly same position tracking technology like HTC Vive.
- PlayStation camera has two cameras for stereo depth perception. Camera tracks LED lights on the headset that are arranged in a pattern that covers all sides of the HMD. LEDs are shaped in such a way that their orientation can be determined by the camera, and the stereo depth perception can work out their position.

HTC Vive position tracking

- The base stations contains single rotation cylinder which is able to create two IR light waves (laser beams) with encoded data (current time of transmission + current angle of rotation).
- When the two waves successively hit the sensor in the controller, the chip inside the controller decodes the encoded information in the light waves.
- From two angles and ToF principle "brain" of the Vive tracking system calculates exact position in sub millimeter precision.

HMD Controllers

Name	Analog trigger	Button	Haptic feedback	Touchpad/ trackpad	DOF	Room Scale ≈	Technol.	FOV
Oculus Rift Touch*	2×	2× +menu	vibration	analog joystick	6	12×12ft	IR LED	120×120
HTC Vive controller	1×	2× +2×grip	vibration	trackpad	6	15×15ft	IR Laser	100×70
Pimax controller	1×	2× +grip		trackpad	6	15×15ft	IR Laser	100×70
Samsung Gear VR controller	1×	2× +volume		trackpad	3			
Oculus Go controller	1×	2×		trackpad	3			
Sony Playstation Move	1×	5× + 2× +move	vibration		6		Stereo camera	72×45

* With capacitive touch sensor state