Fundamentals of XR technologies

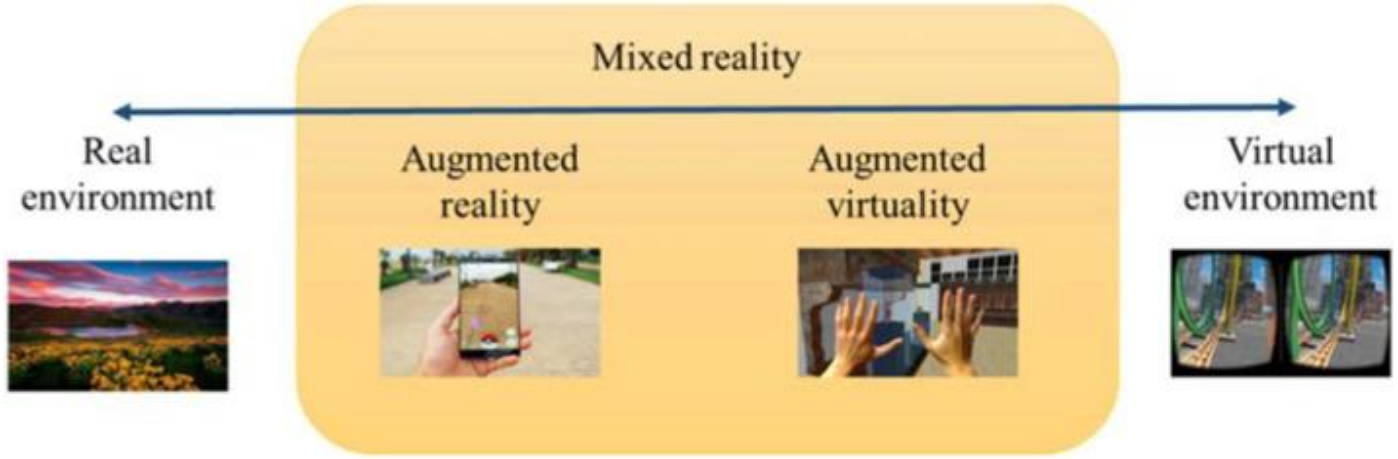
And their applications in robotics

Key concepts

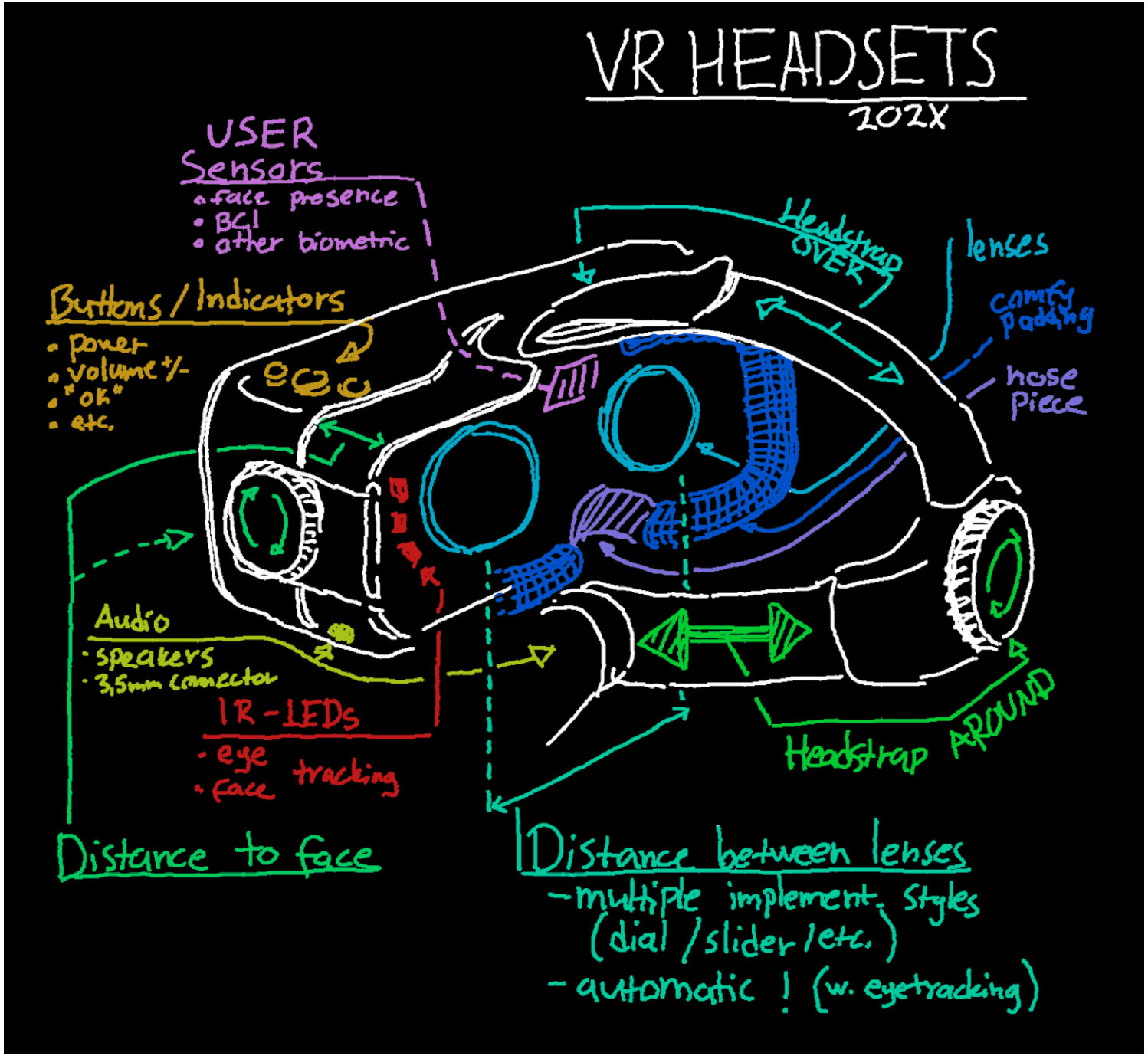
- Basic concepts
- HMD, Head Mounted Display
- Location tracking
- Game engines as development environments
  - Unity
  - Unreal Engine
- Robotics & XR

Basic concept

- XR => VR, AR, MR
  - VR: closed environment immersing the user into a virtualised space
  - AR: adding digital elements to a live view (Pokémon GO)
  - MR (Augmented virtuality): Real-world view mixed with digital elements in a headset (~ VR + AR); Microsoft Hololens



C. Flavián, S. Ibáñez-Sánchez, C. Orús. The impact of virtual, augmented and mixed reality technologies on the customer experience J. Bus. Res., 100 (2019), pp. 547-560, 10.1016/j.jbusres.2018.10.050


VR HEADSETS
202X
USER
Sensors
• face presence
• BCI
• other biometric
Buttons / Indicators
• power
• volume +/-
• "ok"
• etc.
Headstrap OVER
lenses
comfy padding
nose piece
Audio
• speakers
• 3,5mm connector
IR-LEDs
• eye
• face
tracking
Headstrap AROUND
Distance to face
Distance between lenses
- multiple implement. styles
(dial / slider / etc.)
- automatic ! (w. eyetracking)

HMD, Head Mounted Display

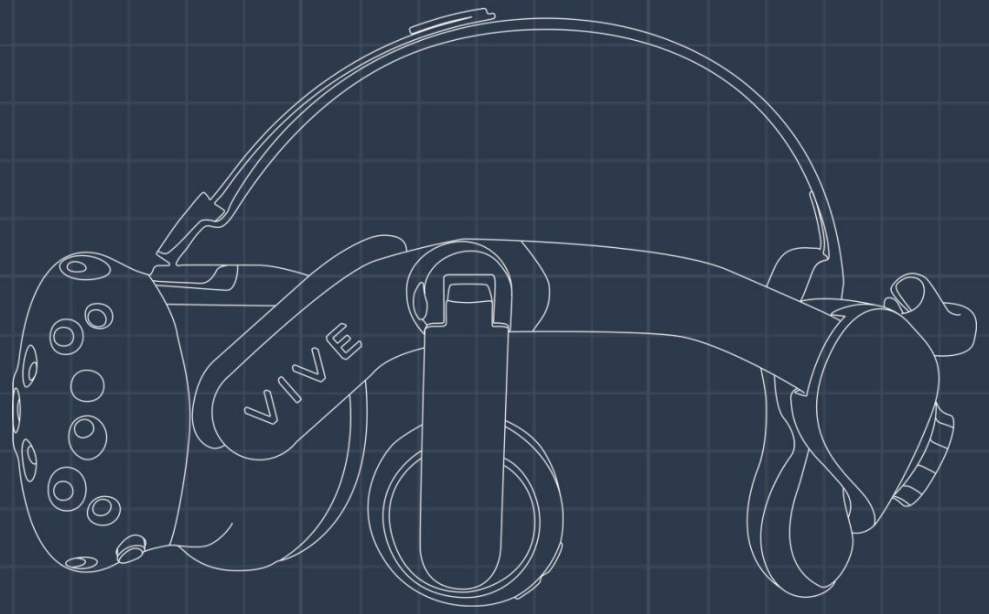
- Different types of HMDs exist
- Various manufacturers
  - HTC Vive (in the picture)
  - Oculus (Meta)
  - Varjo
  - Valve Index
  - Sony
- Differences in screen and tracking technology, as well as on the software stack

VIVE PRO SPECS

- Unprecedented presence with Hi-Res and 3D spatial audio
- Stay comfortably immersed with: high display resolution, colour accuracy and contrast; easy-to-use headset & cable design and improved ergonomics
- Chaperone technology
- Free to move around wirelessly with VIVE Wireless Adapter*
- *VIVE Wireless Adapter sold separately.

Headset Specs

Screen:	Dual AMOLED 3.5" diagonal
Resolution:	1440 x 1600 pixels per eye (2880 x 1600 pixels combined)
Refresh rate:	90 Hz
Field of view:	110 degrees
Audio:	Hi-Res certificate headset Hi-Res certificate headphones (removable) High impedance headphones support
Input:	Integrated microphones
Connections:	Bluetooth, USB-C port for peripherals
Sensors:	SteamVR Tracking, G-sensor, gyroscope, proximity, Eye Comfort Setting (IPD)
Ergonomics:	Eye relief with lens distance adjustment Adjustable Eye Comfort Setting (IPD) Adjustable headphones Adjustable headstrap



Minimum Computer Specs

- **Processor:** Intel® Core™ i5-4590 or AMD FX™ 8350, equivalent or better.
- **Graphics:** NVIDIA® GeForce® GTX 970 or AMD Radeon ™ R9 290, equivalent or better. View the complete list >
- **Memory:** 4 GB RAM or more
- **Video out:** DisplayPort 1.2 or newer
- **USB ports:** 1x USB 3.0 or newer port
- **Operating system:** Windows® 7, Windows® 8.1 or later, Windows® 10
  Upgrade to Windows® 10 for the best results with the dual front facing cameras
  * Driver is required to be downloaded and installed before using VIVE Pro's dual cameras on Windows® 7.

Recommended graphics for the best experience is NVIDIA® GeForce® GTX 1070/Quadro P5000 or above, or AMD Radeon™ Vega 56 or above.

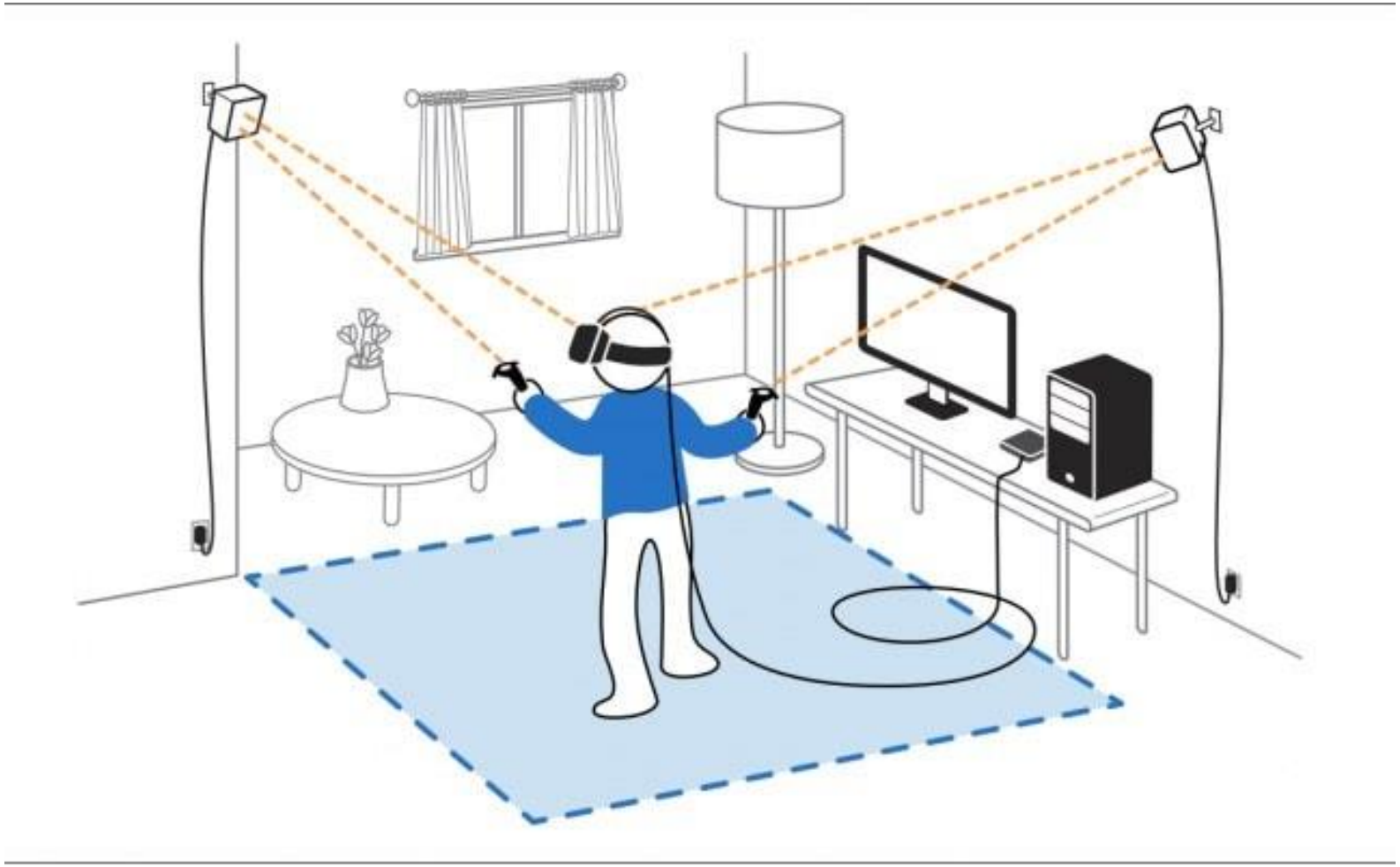
Example: Oculus Quest 2

- Standalone XR headset
- Snapdragon XR2 SoC
- 6 GB RAM
- 120 Hz single LCD panel, per-eye resolution 1832x1920
- Horizon OS (Android-based operating system)
- Maybe be connected to a computer with WLAN or USB tethering link

Working principle

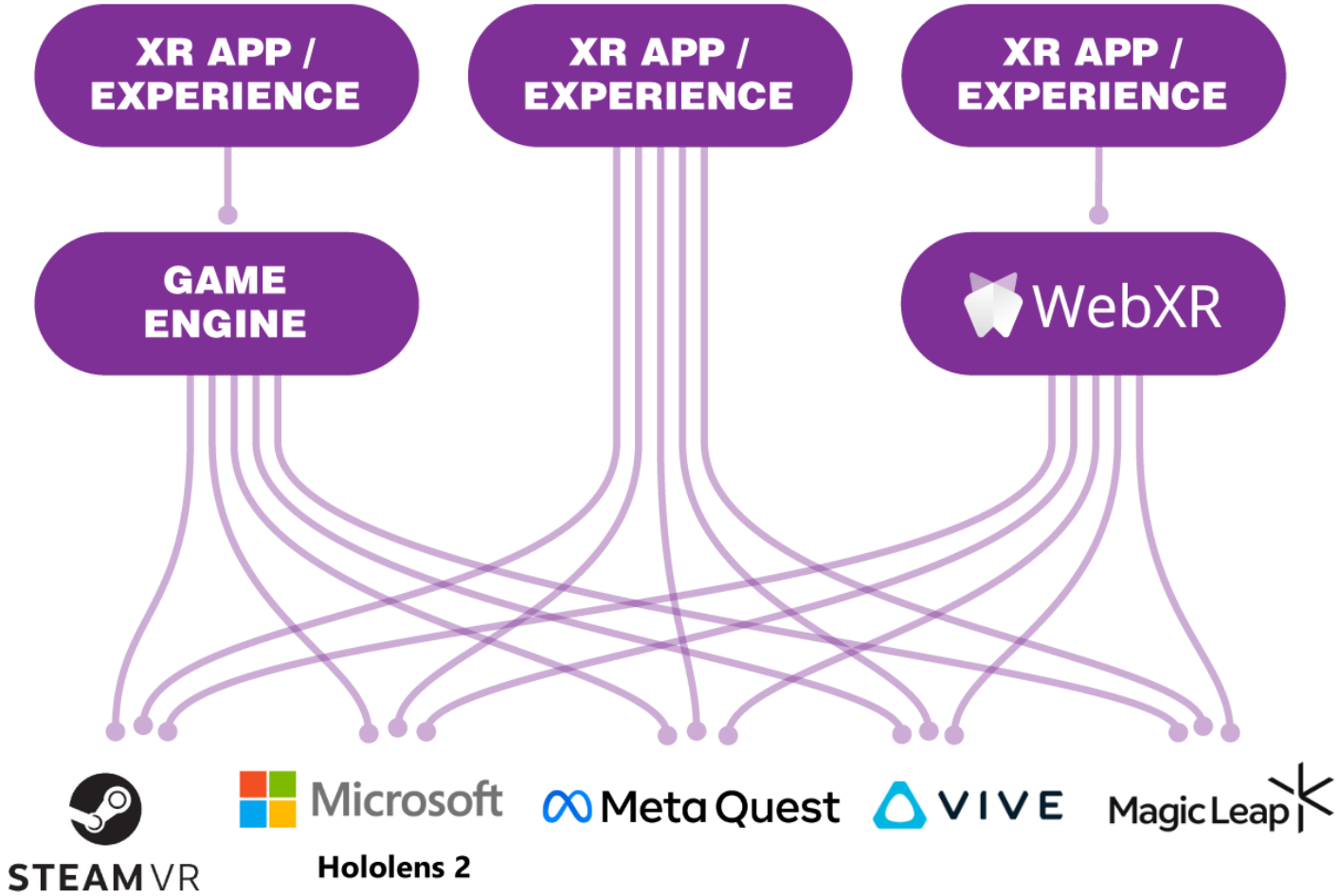
- HMDs utilize (and may be considered) as a (dual) display, running either
  - Standalone
  - Attached to the computer with HDMI or Display Port
- Camera (inside-out SLAM) or infrared / laser tracking (”Valve ecosystem”) to detect the position in 3D space
- IMUs (Inertial Measurement Unit) to detect the movements in space @ 1000Hz + external sensor / camera sync @ 60-200 Hz (sensor fusion!)
- Controlling the application with physical controllers or with hand gestures or eye movements
- Audio and haptic feedback for added immersion

Beacon tracking system (”Valve tracking”)



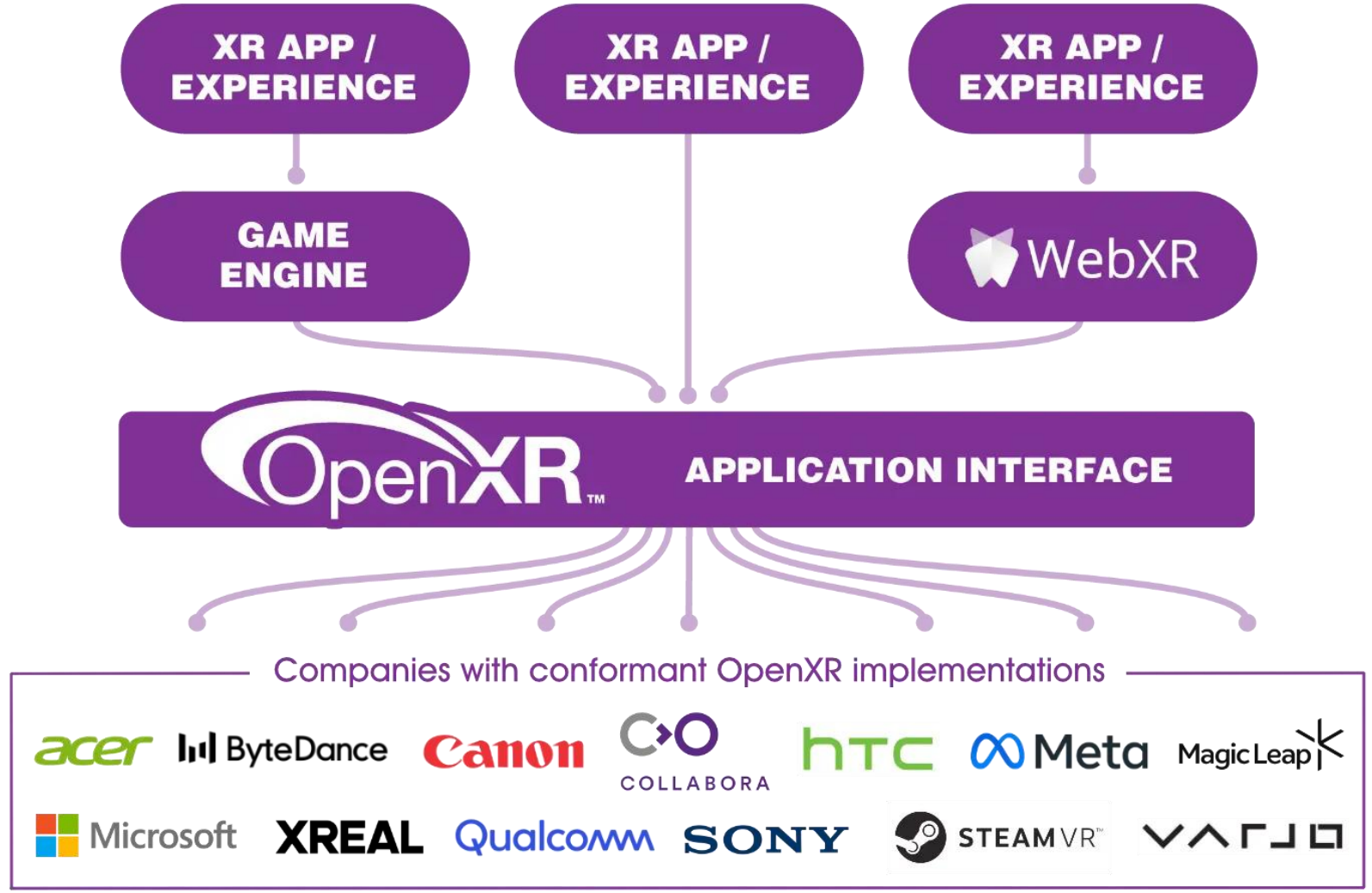
More about VR environments

- Controllers to interact with the props in virtual environment
- 3D modelled environment, movement in the space
  - Cables may restrict the movement
  - Wireless communication, WLAN or dedicated protocol
- Game engines for developing the environment (Unity, Unreal Engine, NVIDIA Omniverse, Blender, Godot, etc)
- Platform specific SDKs
  - Apple ARKit, Google ARCore, Microsoft HoloLens, Windows Mixed Reality, Oculus, OpenXR, Unity OpenXR: Meta, PlayStation VR, Apple visionOS XR



Before OpenXR: Applications and engines needed separate proprietary code for each device on the market.

Image source: https://www.khronos.org/openxr/

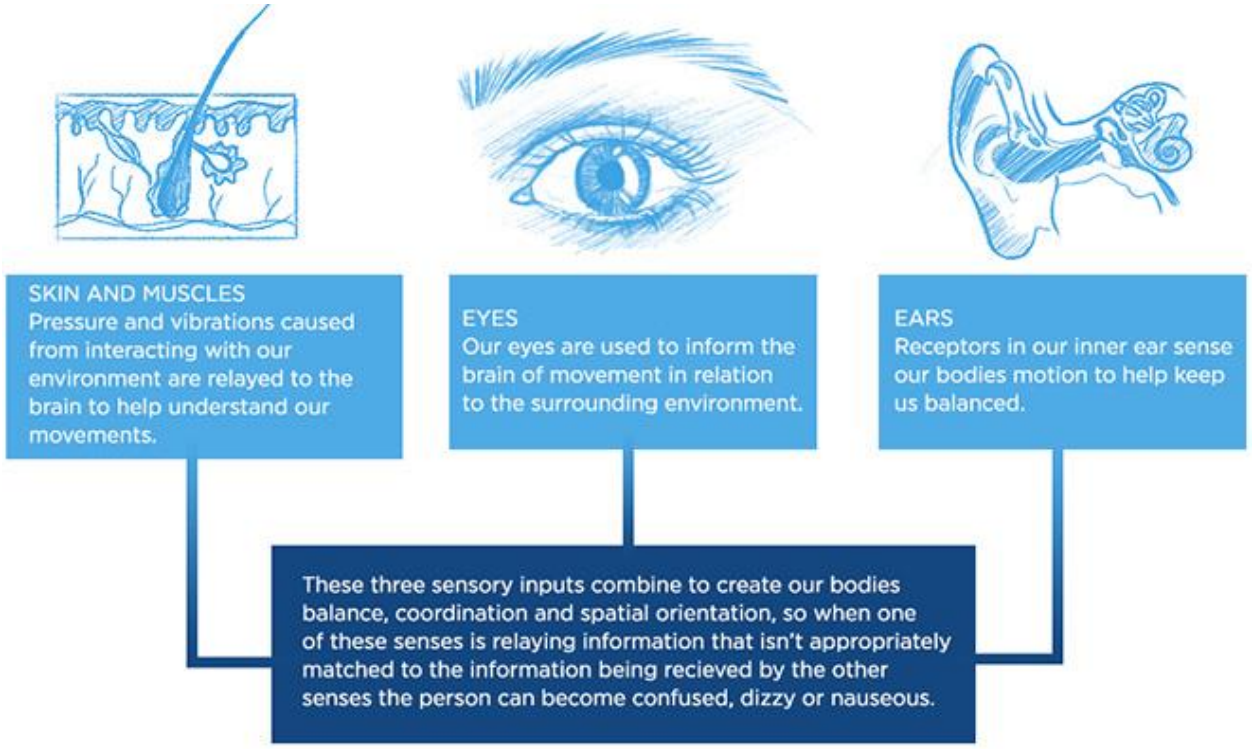


OpenXR provides a single cross-platform, high-performance API between applications and all conformant devices.

Image source: https://www.khronos.org/openxr/

User perception in XR environments

- Possibility to combine physical and virtual worlds
- Users may feel differently being and interacting in and with VR / XR environments
- Balance: 60% eyes, 30% ears, 10% muscles
- Motion sickness
- Eye-ear coordination
- Sense of being “here” or “there”



Some application areas of XR in robotics

- Operations of medical robots (for example surgery, rehabilitation)
- Logistics and construction
- Industrial robotics
- Telepresence robots
- Robot exploration and path planning, rescue operations
- Military robotics

Further reading:

Makhataeva, Z.; Varol, H.A. *Augmented Reality for Robotics: A Review*. Robotics 2020, 9, 21. https://doi.org/10.3390/robotics9020021

XR development and ROS 2

- ROS-TCP-Connector in Unity: https://unity.com/blog/engine-platform/advance-your-robot-autonomy-with-ros-2-and-unity
- ROS2 For Unity: https://github.com/RobotecAI/ros2-for-unity
- rclUE for Unreal Engine: https://github.com/rapyuta-robotics/rclUE

Some examples of VR projects from the RXR course

- VR Robot Kart with Hand Tracking
- https://youtu.be/HzojQ0dXamQ

Some examples of VR projects from the RXR course

- Novel Human-Robot Interfaces using XR
- https://youtu.be/I6QHjA7SUR8?si=57dr7L8Ilj8kaGPK