# Extended Reality

Dr Fangcheng Zhong

# Course Logistics

- 12 + 4 hours
  - guest lectures from industry experts
- One practical exercise (20%)
- One course project (80%)
  - a video-based AR application
  - in groups of 2 or 3 persons
- More information and Q&A on Moodle

# Contributors

- Lecturer
  - Dr. Fangcheng Zhong
- Principal lecturer
  - Prof. Cengiz Oztireli
- Teaching assistants
  - Zhilin Guo (zg296)
  - Kyle Fogarty (ktf25)

# Prerequisite

- Intro + further graphics
- No prior knowledge about computer vision or 3D displays is needed

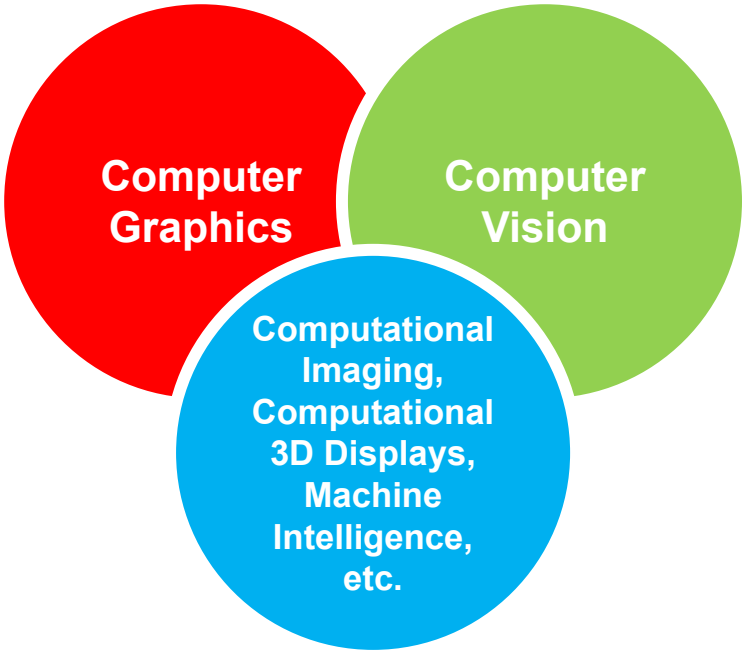
# Prerequisite

- Review MVP matrices from IA Graphics before next lecture!

# Outline

- Course logistics
- What is XR?
  - definition, applications, XR@CL
- XR pipeline
- XR frameworks

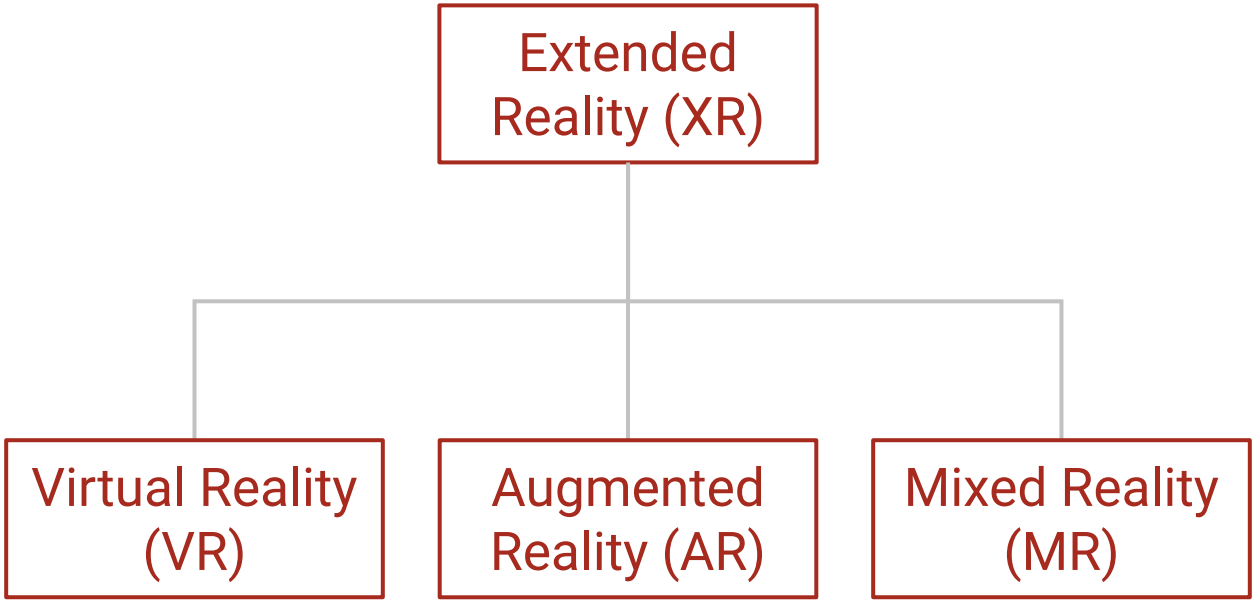
# Extended Reality (XR)




## Goal

**Immersive**, **realistic**, **interactive,** and **intelligent** digital experiences blending the physical and digital worlds

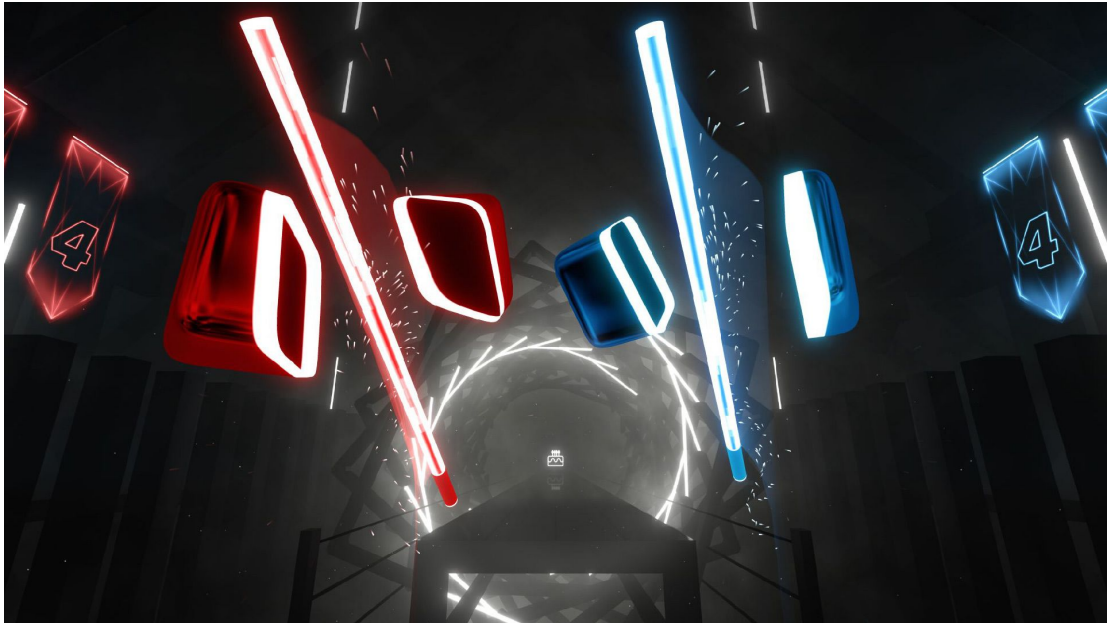
# XR Terminologies



**Virtual Reality** creates a digital environment that replaces the physical environment


Ready Player One

# Virtual Reality (VR)




**gaming**

# Virtual Reality (VR)


flight simulator

# Virtual Reality (VR)

**virtual field trip**

# Virtual Reality (VR)

**visualisation, 3D modeling, and design**

# Virtual Reality (VR)


HTC VIVE

Meta Quest

Sony Playstation

Valve Index

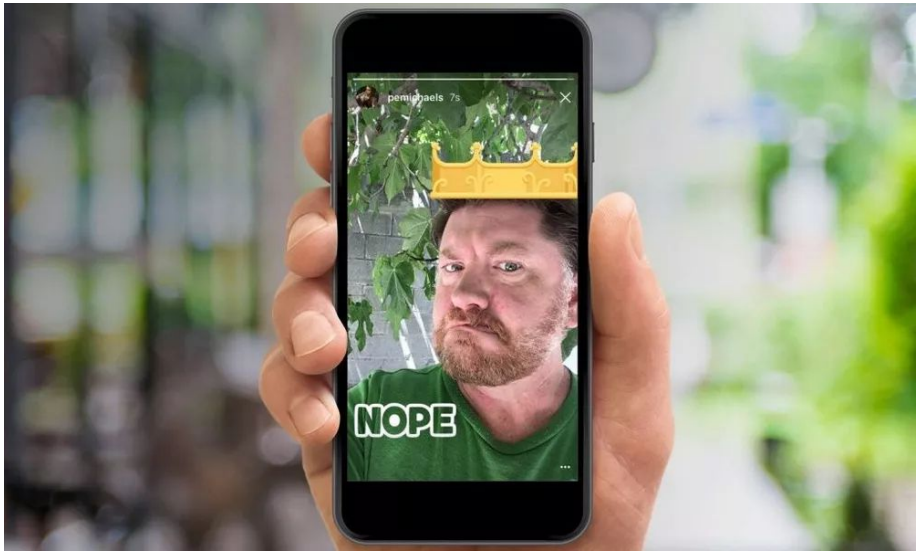

**Augmented Reality** overlays digitally created content into the physical environment

# Augmented Reality (AR)


**Pokemon Go**

# Augmented Reality (AR)


Snapchat

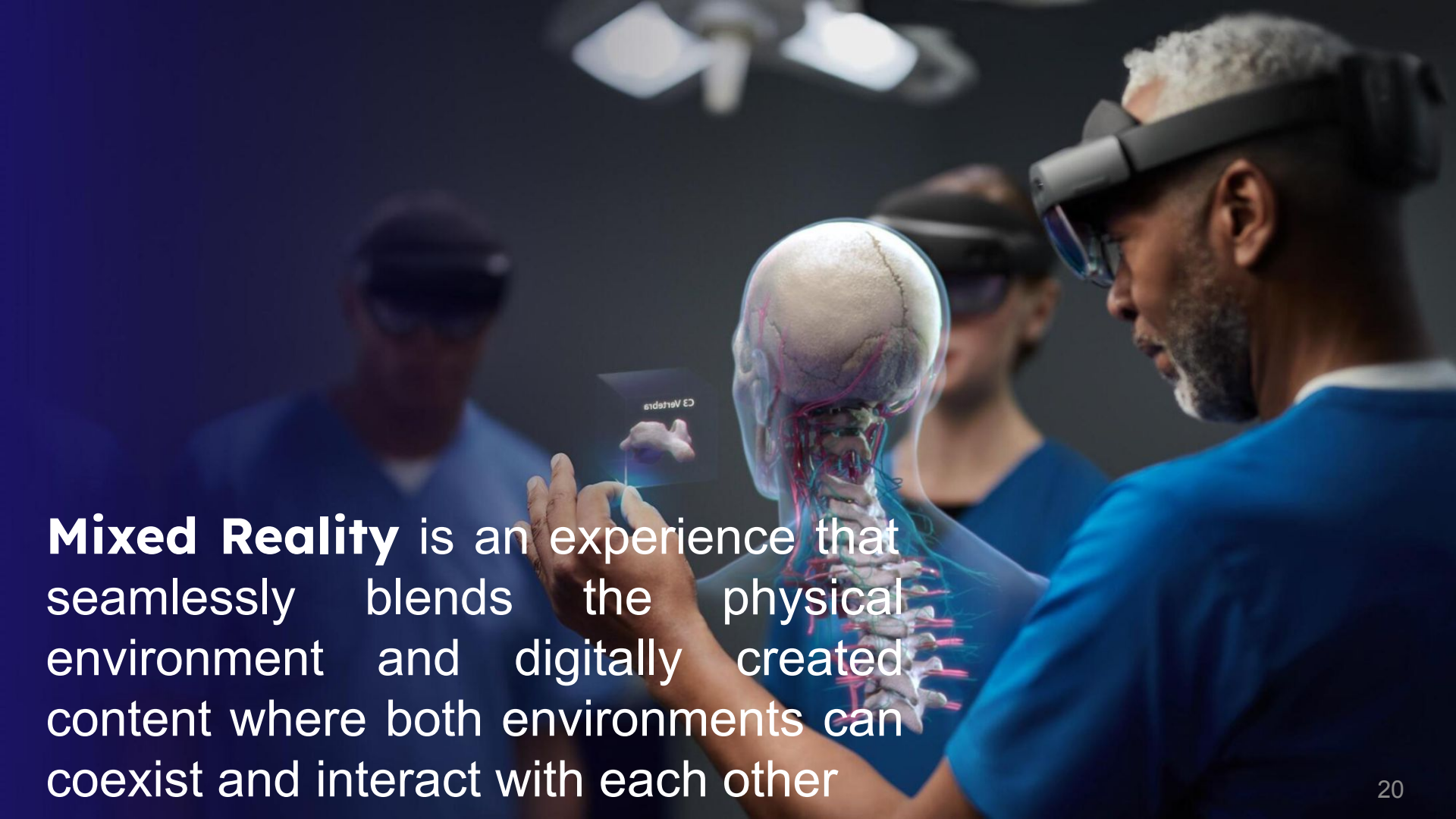



Instagram

# Augmented Reality (AR)

IKEA Place


Google Translate



**Mixed Reality** is an experience that seamlessly blends the physical environment and digitally created content where both environments can coexist and interact with each other

# Mixed Reality (MR)

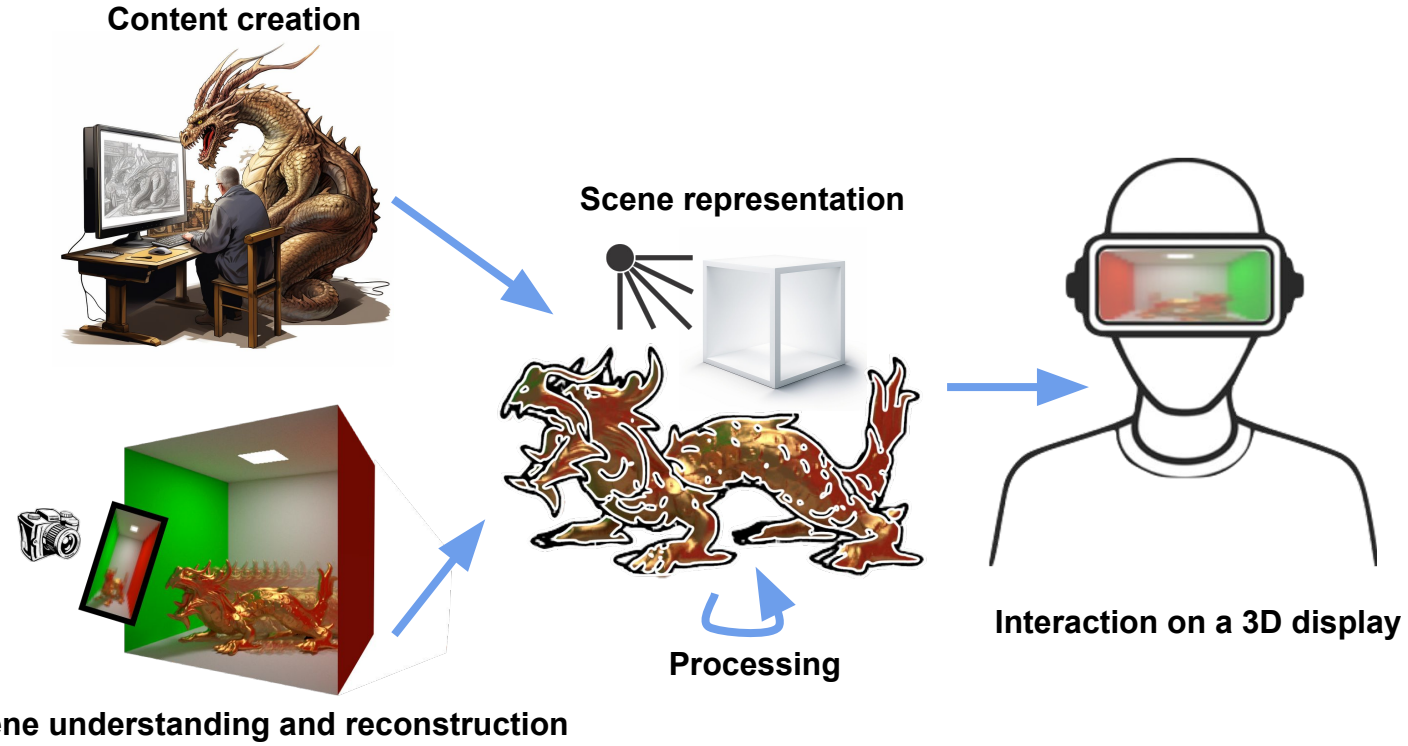
HoloLens


Magic Leap

# Mixed Reality (MR)

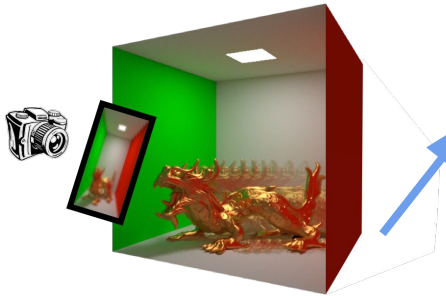
Vision Pro

# XR Pipeline


Content creation
Scene representation
Interaction on a 3D display
Processing
3D scene understanding and reconstruction

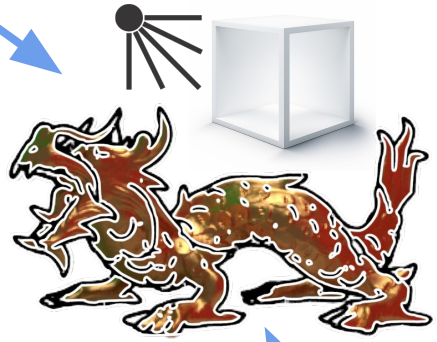
# XR Pipeline

Content creation

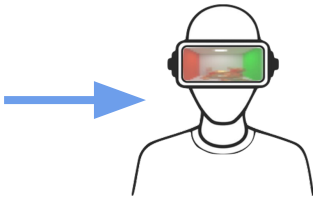


3D scene understanding and reconstruction

Scene representation



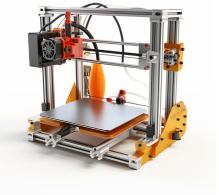
Processing



Autonomous vehicles

Robotics

Digital fabrication



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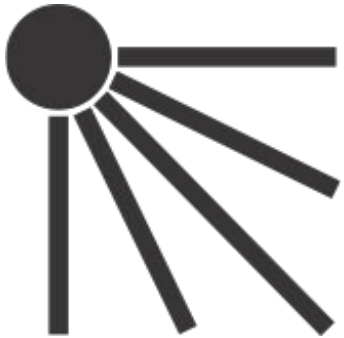
# XR Pipeline

- Same pipeline for VR, AR, and MR
- Only differs in capture and display devices!

# Scene representations

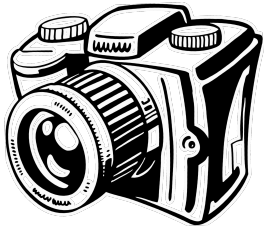
Geometry



Lighting

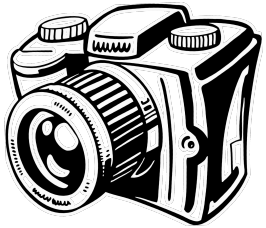
Materials

# Machine Perception

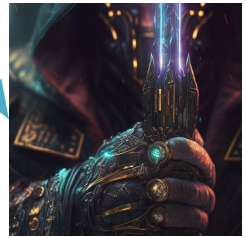


- **RGB camera**
- **Depth camera** (LiDAR, light-field camera, time-of-flight camera, structured-light camera)
- **Other sensor types**

# Machine Perception

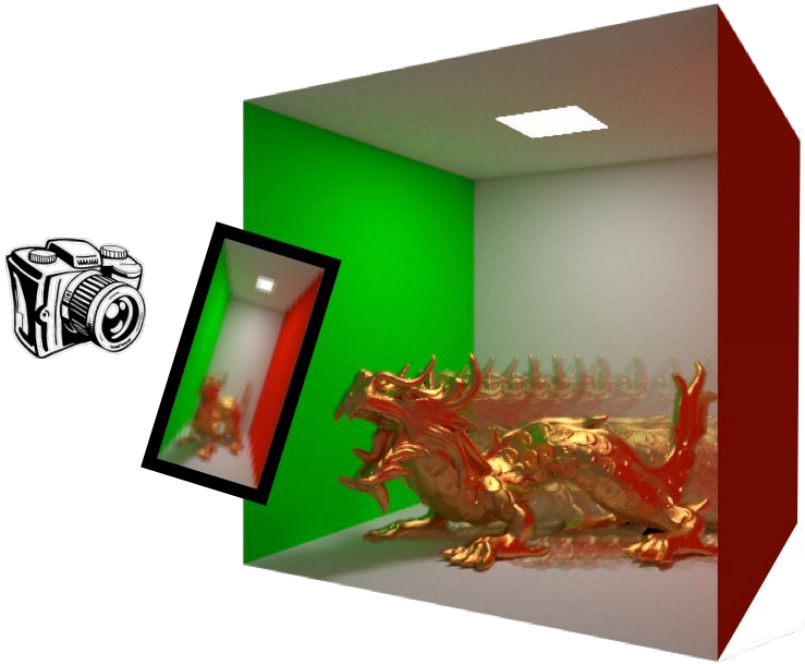


Head pose



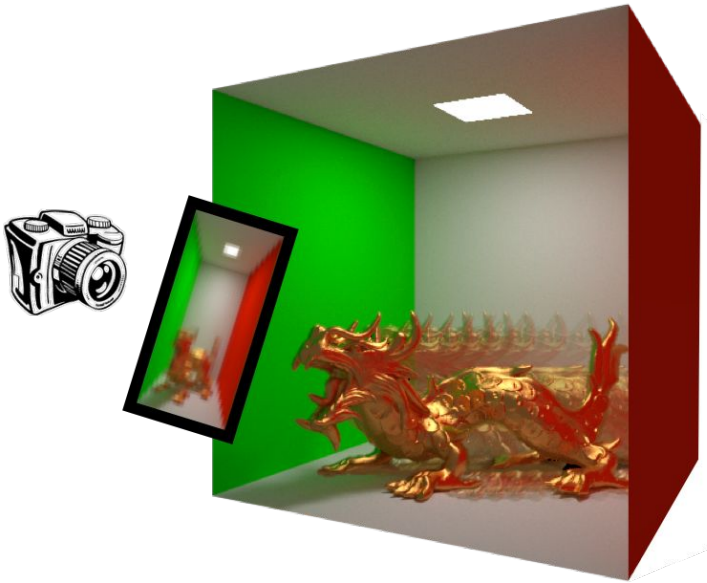
Hand pose

# Processing



- Interaction
- Physics
- Animation
- Relighting
- etc.

# Rendering + 3D Display



- **Stereo rendering**
- **Foveated rendering**
- **Advanced 3D display rendering**

- **Stereo displays** (multi-focal display, vari-focal display)
- **Volumetric displays** (holographic display, light-field display, voxel-based display)

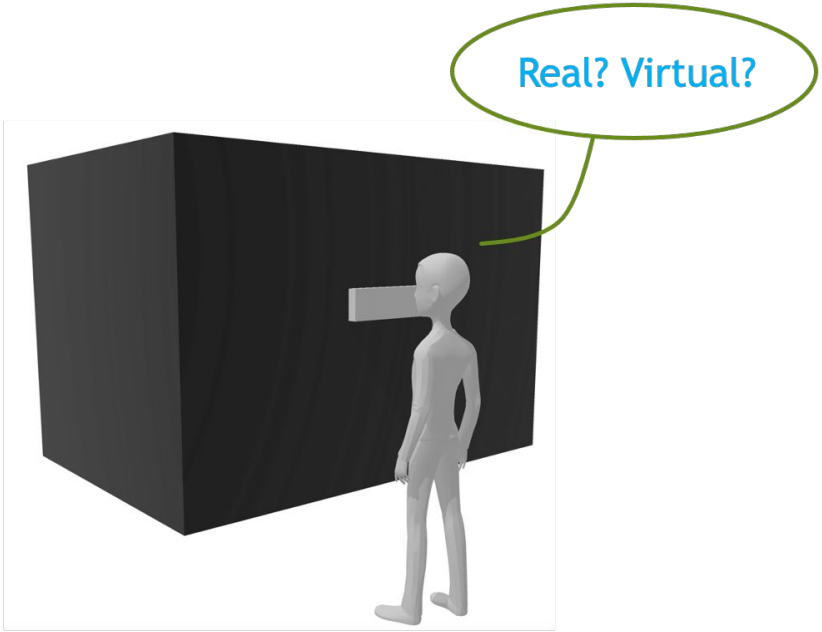
# XR @ Rainbow Lab

**Cambridge autostereo display project**

# XR @ Rainbow Lab

**Driving simulator, eye tracking, motion tracking**

# XR @ Rainbow Lab

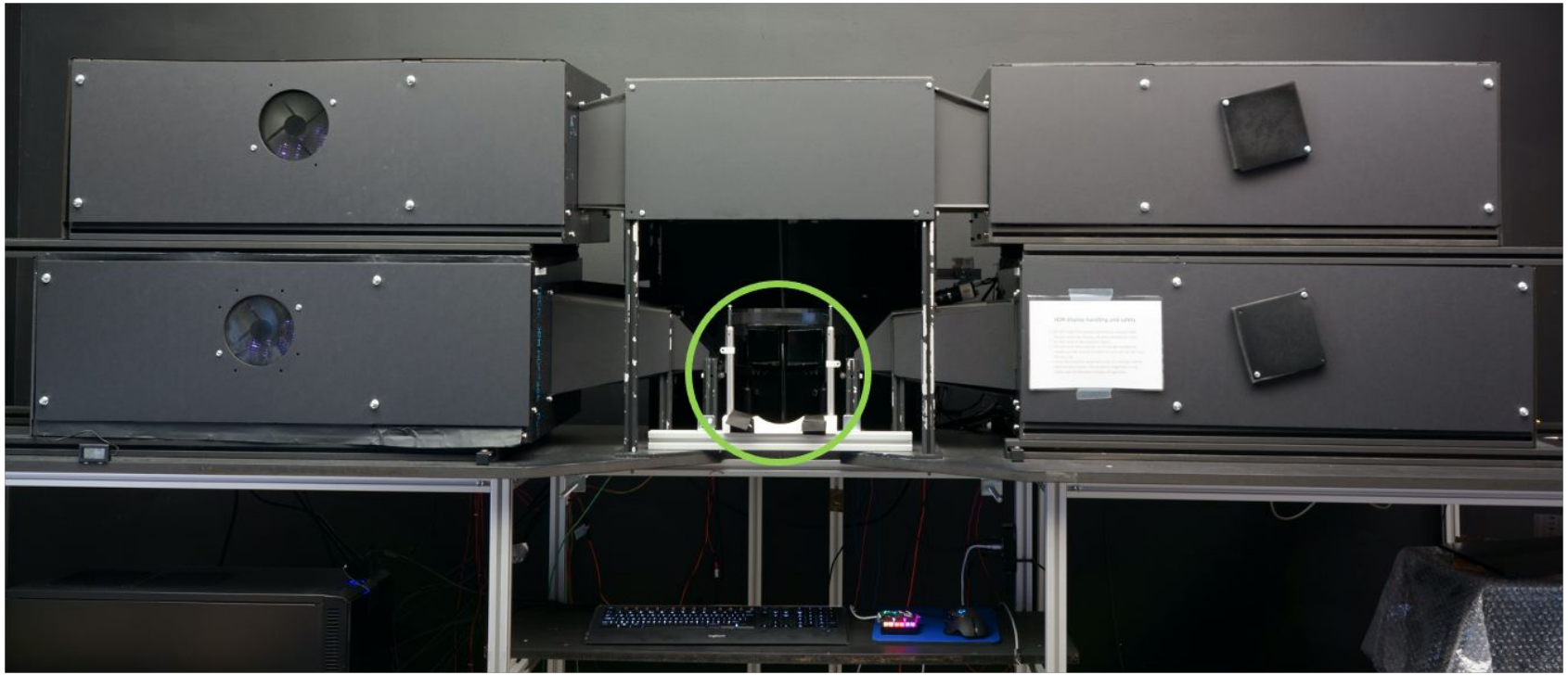


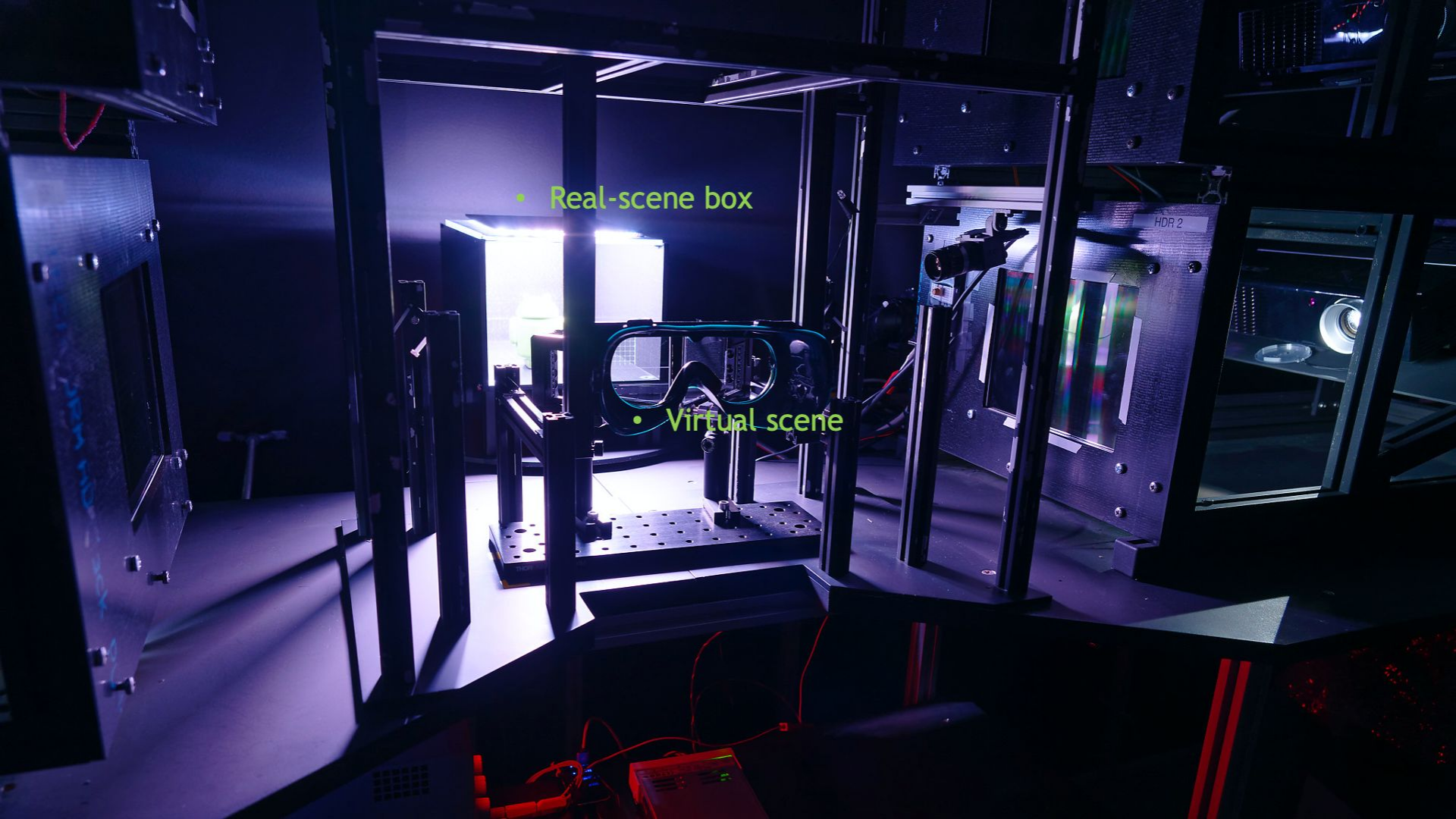

**Visual Turing Test Project**

# XR @ Rainbow Lab

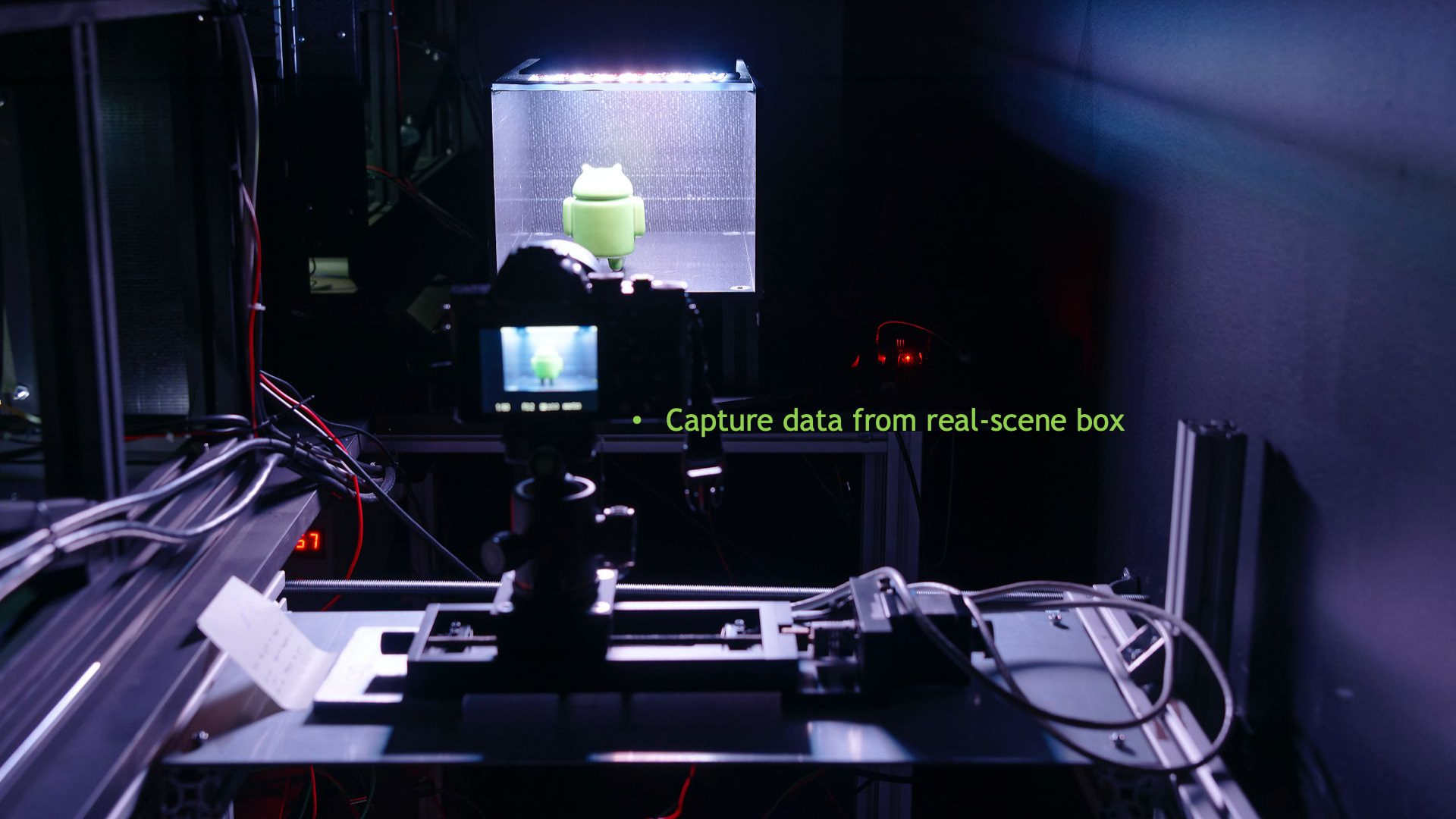
**HDR multi-focal stereo display**

# XR @ Rainbow Lab

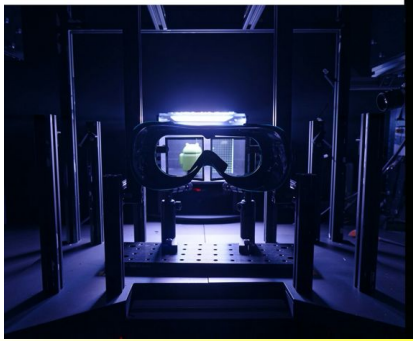


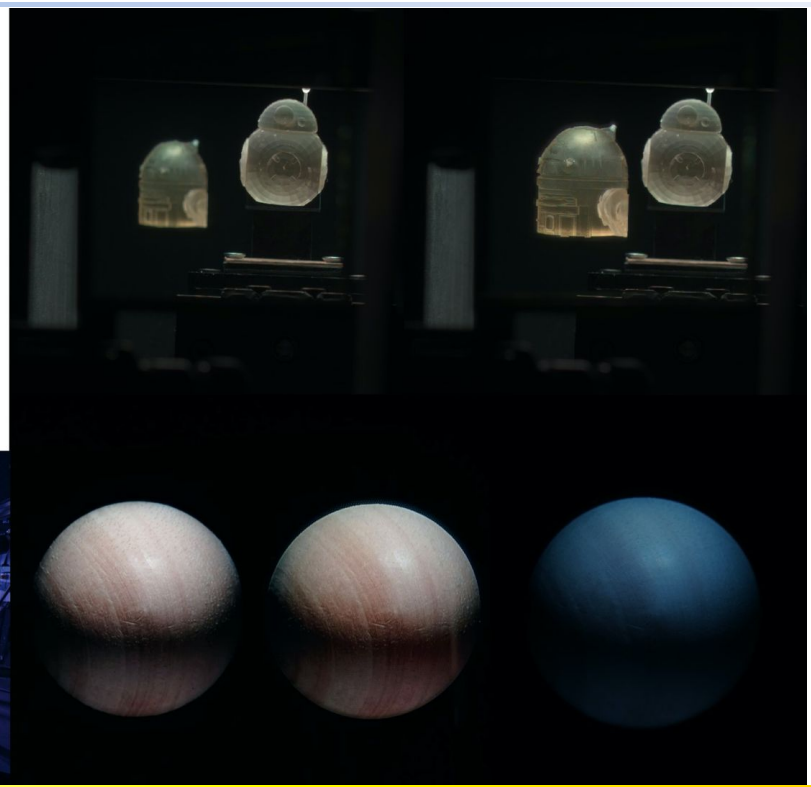



- Real-scene box
- Virtual scene


• Capture data from real-scene box

# XR @ Rainbow Lab



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Fangcheng Zhong, Akshay Jindal, Ali Özgür Yöntem, Param Hanji, Simon J. Watt, and Rafał K. Mantiuk. 2021. Reproducing Reality with a High-Dynamic-Range Multi-Focal Stereo Display. ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH Asia, Journal Track), 2021

# XR Frameworks

## ARCore 


- a software development kit (SDK) developed by Google to build AR applications
- available on Android Studio, Unity, and Unreal engine for application development
- supported by a limited number of Android devices
- uses OpenGL and Vulkan for rendering

# XR Frameworks

## ARKit 


- a software development kit (SDK) developed by Apple to build AR applications
- available on Xcode, Unity, and Unreal engines for application development
- supported by all iOS devices with an A9 or later chip
- uses Metal for rendering

# XR Frameworks

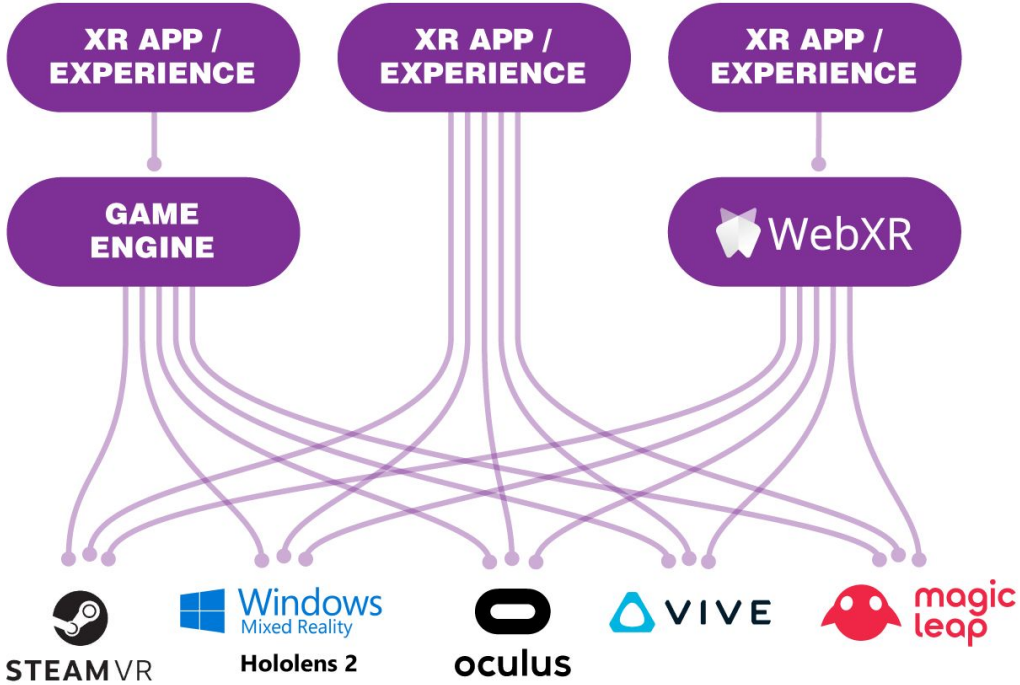
## AR Foundation

- a set of Unity packages that provide a common foundation for building AR applications for both Android and iOS devices
- support for the ARCore and ARKit SDKs, and allows developers to build AR applications that can run on either platform using a single codebase
- includes core features from ARKit, ARCore, Magic Leap, and HoloLens

# XR Frameworks

| Device | Framework | Development Environment |
|---|---|---|
| HTC, Valve | steamVR | Visual Studio, Unity, Unreal Engine |
| Oculus, Meta | Oculus Mobile SDK | Visual Studio, Unity, Unreal Engine |
| Sony PlayStation | PlayStation SDK | PlayStation development kit |
| HoloLens | HoloLens 2 Development Edition | HoloLens 2 Development Kit, Visual Studio, Unity, Unreal Engine |
| Magic Leap | Magic Leap SDK | Visual Studio, Unity, Unreal Engine |
| Android | ARCore | Android Studio, Unity, Unreal Engine |
| iOS | ARKit | Xcode, Unity, Unreal Engine |

# XR Frameworks

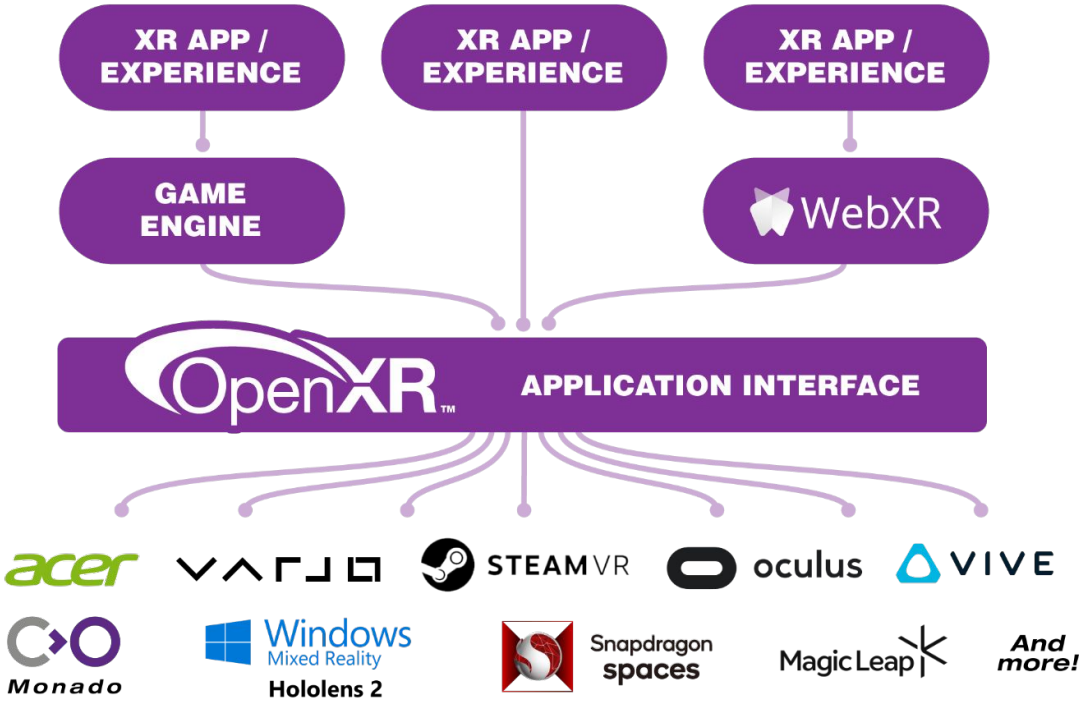


# XR Frameworks

## OpenXR


- open, royalty-free standard for accessing VR and AR systems
- a single, unified API to develop cross-platform applications
- developed by the Khronos Group, an industry consortium that also develops other graphics-related standards such as OpenGL and Vulkan

# XR Frameworks



# Practical Exercise

- Main tasks
  - camera pose estimation
  - AR Foundation device tracking
  - individual work
- Due 23 February 2024, 12:00 PM

# Course Project

- Main tasks
  - a video-based AR application
  - development using Unity AR Foundation
  - group work
- Deliverables
  - project plan
  - implementation
  - project report
  - presentation/demo (check last year)

# Course Project

- Timeline
  - Project proposal due 3 February 2023, 12:00 PM
  - Final report due 14 March 2024, 12:00 PM