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

Extended Reality (XR)

Virtual Reality (VR)  Augmented Reality (AR)  Mixed Reality (MR)
Virtual Reality creates a digital environment that replaces the physical environment.
Virtual Reality (VR)
Virtual Reality (VR)

flight simulator
Virtual Reality (VR)

virtual field trip
Virtual Reality (VR)

visualisation, 3D modeling, and design
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

Processing

Interaction on a 3D display

3D scene understanding and reconstruction
XR Pipeline

Content creation

Scene representation

Processing

3D scene understanding and reconstruction

Autonomous vehicles

Robotics

Digital fabrication

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

- Stereo rendering
- Foveated rendering
- Advanced 3D display rendering
XR @ Rainbow Lab

Cambridge autostereo display project
XR @ Rainbow Lab

Driving simulator, eye tracking, motion tracking
XR @ Rainbow Lab

Real? Virtual?

Visual Turing Test Project
XR @ Rainbow Lab

HDR multi-focal stereo display
- Real-scene box
- Virtual scene
- Capture data from real-scene box
XR @ Rainbow Lab

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
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 Kit | 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 APP / EXPERIENCE
- XR APP / EXPERIENCE
- XR APP / EXPERIENCE
- GAME ENGINE
- WebXR

- STEAMVR
- Windows Mixed Reality
- Hololens 2
- Oculus
- VIVE
- Magic Leap
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

- XR APP / EXPERIENCE
- GAME ENGINE
- WEBXR

OpenXR™ APPLICATION INTERFACE

- acer
- VIVE
- STEAM VR
- oculus
- Monado
- Windows Mixed Reality
- Hololens 2
- Qualcomm Snapdragon spaces
- Magic Leap
- And more!
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