Master's Department of Engineering Sciences
MSc in Automation Engineering and Robotics

Name of the unit: Virtual Reality

Lecturer: Benoît Alary (benoit.alary@ircam.fr)
Course code: MU5RBI40-RV
Student workload: 18 h of lectures, 6 h of labs
Credits: 3 ECTS
Specialization tracks: ☐ ROBOT ☒ SI (elective) ☒ MeDH (elective)
Semester offered: ☐ S1 ☐ S2 ☒ S3 ☐ S4
Language of instruction: ☐ French ☒ English
Targeted audience: ☒ Engineering Sciences students ☐ Other (specify):
Localization : ☒ PMC Campus ☐ Other (specify):

Course Overview

This course unit provides students with the fundamentals of designing interactive virtual environments. The theoretical component covers real-world physics (light, acoustics, etc.), perceptual mechanisms (vision and hearing), and how to use this knowledge to produce perceptually credible virtual environments. The practical component introduces the fundamentals of virtual-reality development (scene graphs, interaction management and software architecture), then guides students through a mini-project involving a game or immersive experience.

Keywords: Virtual reality, human-computer interaction, audiovisual perception, physical simulation, immersive-environment design

Prerequisites

Students should have previously acquired the following prerequisites to follow this course:

- Basic programming (preferably in C)
- Fundamental concepts in mathematics (algebra, geometry)
- Fundamentals of computer science (data structures, logic)

Intended Learning Outcomes

By the end of this course, students will be able to:

1. Explain the main mechanisms of visual and auditory perception and their limitations in virtual environments.
2. Describe the physical foundations of light and sound and their impact on visual and audio rendering.
3. Analyze the contributions of sensory modalities (vision, hearing, haptics and the vestibular system) to immersion.
4. Understand the fundamental principles of room acoustics and virtual acoustics.
5. Master the fundamentals of the graphics pipeline and real-time 3D modeling.
6. Implement simple interactions in a virtual environment (logic, events and object manipulation).
7. Structure a VR/AR project according to basic software-architecture principles.
8. Identify perceptual-optimization strategies for real-time interactive applications.
9. Develop a functional mini-project (game or immersive experience) integrating interaction, rendering and perceptual consistency.

10. Present and justify the technical and perceptual choices made in a project.

Indicative Teaching Sequence and Methods

Week	C/TD/TP*	Content	Preparation	Learn. outc.
S1	C4.2: What is VR/AR, Why learn it, How learn it	Understand VR/AR concepts, uses and challenges, together with the tools and methods used to develop them.		6, 7, 10, 11
S2	C1.1: Perceiving the environment: human vision	Understand the mechanisms of human vision (image formation, visual processing and perceptual limitations) and their implications for creating virtual environments.		1, 3
S3	T1: Game Creation 101	Become familiar with Unity, understand the creation workflow (scene, objects and components), and build a simple scene.		5, 6, 7
S4	C3.1: 3D Modelling and Illumination Models: Visual rendering models and graphic pipeline	Understand the fundamentals of 3D modeling and the graphics pipeline (geometry, transformations and rasterization) to produce real-time visual scenes.		5, 6, 7
S5	C3.2: 3D Modelling and Illumination Models: Illumination models and perceptual rendering From geometry to light	Understand local and global illumination models and their relationship to visual perception in order to generate realistic rendering.		2, 5, 9
S6	T2: Game Programming Patterns	Acquire the fundamentals of C programming in Unity and understand the basic design patterns used for interactive logic.		6, 7
S7	C1.2: Perceiving the environment: sound, acoustics, and psychoacoustics	Understand the fundamentals of acoustics and psychoacoustics (sound propagation, auditory cues and spatial perception) to design coherent sound environments.		1, 2, 3
S8	C2.2: Room acoustics	Understand acoustic phenomena in enclosed spaces (reflections, reverberation and absorption) and their impact on sound perception.		2, 4
S9	T3: Interfaces	Understand inter-application interfaces using the OSC protocol and rapidly integrate external components to prototype interactions.		6, 7, 9
S10	C4.1: Virtual acoustics and spatial sound reproduction	Understand the principles of virtual acoustics and sound spatialization (HRTF, binaural audio and sound-field synthesis) to reproduce immersive auditory environments.		4, 9
S11	C2.1: Haptic and vestibular sensations	Understand the mechanisms of haptic and vestibular sensations (touch, proprioception and balance) and their role in immersion and interaction.		3, 9
S12	C5 Pos	Sensory-Motor Interaction	Understand how to	

* C/TD/TP respectively corresponds to lectures, tutorials and lab sessions.

Sequence of the unit:
The course unit is organized into three successive sequences:

Sequence 1: introduction to VR/AR, visual perception and tool familiarization (C4.2, C1.1, T1), with an initial introduction to the graphics pipeline (C3.1)
Sequence 2: advanced visual rendering and fundamentals of interactive programming (C3.2, T2), followed by an introduction to auditory perception, room acoustics (C1.2, C2.2) and interfaces (T3)
Sequence 3: sound spatialization and multimodality (C4.1, C2.1), perceptual optimization and sensorimotor integration (C5), followed by a synthesis mini-project (T4)

Indicative Assessment of Intended Learning Outcomes (1st session)

Week	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
S6	Individual	In-person	Written exam	1-3, 5-7, 10-11	20 %
S13	Individual	In-person	Written exam	1, 2-11	40 %
S13	Group	In-person	Project	9, 10, 11	40 %

2nde session of exam

Session	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %

Bibliographic references

- Unity tutorials : https://brackeys.com/
- Game programming patterns : https://gameprogrammingpatterns.com/
- Pulkki, Ville, and Matti Karjalainen. Communication acoustics: an introduction to speech, audio and psychoacoustics. John Wiley Sons, 2014.
- Vorländer, Michael. Auralization: fundamentals of acoustics, modelling, simulation, algorithms and acoustic virtual reality. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008.
- Jerald, Jason. The VR book: Human-centered design for virtual reality. Morgan Claypool, 2015.

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