



CSCI 538 Augmented, Virtual & Mixed Reality

Units: 4-1

Term—Day—Time: Fall & Spring - Thursdays 10:00am to 1:20pm, Lab 1:20-2:20pm

Location: SCI-108 - School of Cinematic Arts

Instructor: Vangelis Lympouridis, PhD & Michael Zyda

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IT Help: GamePipe Laboratory Manager

Hours of Service:

Contact Info:

Course Description

This course covers the technical and experiential design foundation required for the implementation of immersive environments in current and future virtual, augmented and mixed reality platforms. The curriculum covers a wide range of literature and practice starting from the original Computer Science and HCI concepts following the evolution of all supporting technologies including visual displays for VR, AR and MR, motion tracking, interactive 3D graphics, multimodal sensory integration, immersive audio, user interfaces, IoT, games and experience design.

Learning Objectives

The objective of the course is to establish and cultivate a broad and comprehensive understanding of this rapidly evolving and commercially viable field of Computer Science and prepare the student for participating in the production of highly integrative immersive applications, immersive social platforms, cross disciplinary academic research projects and leading developments in Medical, Industrial and Manufacturing R&D.

During the duration of the course students are expected to work in collaborative group projects and develop working prototypes, demo experiences, immersive platforms, unique controllers and new innovative technologies that can be used in the development and production of immersive environments in the fields of entertainment, education, training, medical and industrial innovation.

Topics include:

- Historical Overview, Current Trends and Future applications of Immersive Technologies
- Best practices in VR,AR and MR including design, prototyping and an ethical code of conduct
- Overview of human physiology, psychology and usability factors
- A critical framework for evaluating current and emerging immersive reality technologies and applications
- Design and Technological foundations for Immersive Experiences
- Input devices – controllers, motion trackers and motion capture technologies for tracking, navigation and gestural control.
- Output devices – Head Mounted VR Displays, Augmented and Mixed reality glasses
- 3D interactive and procedural graphics
- Immersive surround sound
- Haptic and vibrotactile devices
- Systems architecture and integrative immersive media platforms
- Rapid prototyping and physical computing
- VR programming

Prerequisite(s): an introduction to computer graphics or permission of instructor.

Co-Requisite (s):

Concurrent Enrollment:

Recommended Preparation: It is assumed that the student is a strong programmer.

Required Readings and Supplementary Materials

Primary:

- Kelly S. Hale (Editor), Kay M. Stanney (Editor). 2014. Handbook of Virtual Environments: Design, Implementation, and Applications, Second Edition (Human Factors and Ergonomics) ISBN-13: 978-1466511842. [Amazon](#)

Other Resources:

- Michael Madary and Thomas K. Metzinger. 2016. Real Virtuality: A Code of Ethical Conduct. Recommendations for Good Scientific Practice and the Consumers of VR-Technology. *Frontiers in Robotics and AI* 3, February: 1–23. <http://doi.org/10.3389/frobt.2016.00003>
- Jason Jerald. 2015. *The VR Book: Human-Centered Design for Virtual Reality*. Association for Computing Machinery and Morgan & Claypool Publishers. <http://doi.org/10.1145/2792790>
- Tony Parisi. 2015. Learning Virtual Reality ISBN: 9781491922828
- Alva Noe. 2004. Action in Perception. ISBN: 9780262640633
- Paul Dourish. 2001. Where the Action Is. ISBN: 9780262254151
- Philippe Fuchs - Appropriate use of VR headsets <http://worldvrforum.com/product/appropriate-use-virtual-reality-head/>
- Michael Heim. 1994. The Metaphysics of Virtual Reality. <http://doi.org/10.1093/acprof:oso/9780195092585.001.0001>
- Char Davies. 1998. OSMOSE: Notes on being in Immersive virtual space. *Digital Creativity* 9, 2: 65–74. <http://doi.org/10.1080/14626269808567111>
- Philip Brey. 1999. The ethics of representation and action in virtual reality. *Ethics and Information Technology* 1, 1: 5–14. <http://doi.org/10.1023/A:1010069907461>
- Luca Turchet. 2015. Designing presence for real locomotion in immersive virtual environments: An affordance-based experiential approach. *Virtual Reality* 19, 3–4: 277–290. <http://doi.org/10.1007/s10055-015-0267-3>
- Corey J. Bohil, Bradly Alicea, and Frank A. Biocca. 2011. Virtual reality in neuroscience research and therapy. *Nature Reviews Neuroscience* 12, 12: 752–62. <http://doi.org/10.1038/nrn3122>
- George Lakoff and Mark Johnson. 2003. Metaphors We Live By <http://doi.org/10.7208/chicago/9780226470993.001.0001>
- Anton Nijholt. 2014. Playful User Interfaces. <https://doi.org/10.1007/978-981-4560-96-2>
- Florian Mueller and Katherine Isbister. 2014. Movement-based game guidelines. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*: 2191–2200. <http://doi.org/10.1145/2556288.2557163>

Description and Assessment of Assignments

Each student is expected to contribute code for a group developed immersive environment or application. The project runs continuously all semester, the code testing the student's knowledge of the in-class lectures and reading material. The student's immersive environment will be presented in class during the last week. The student's grade will be based on the final demonstration of the group project and on the student's participation in that project and in class. Each student will maintain a personal web page detailing his or her part of the group developed immersive environment. Each group will maintain a group web page plus schedule of weekly progress. Each developed immersive environment must be fully 3D, utilize a 3D input device, display on the variety of available laboratory displays, include real-time collision detection, and behavior modeling for the autonomous characters/objects in the developed immersive world.

Grading Breakdown

How will students be graded overall, including the assignments detailed above. Participation should be no more than 15%, unless justified for a higher amount. All must total 100%.

Assignment	Points	% of Grade
Class participation	100	10
Personal Web page	200	20
Team Web page	200	20
Final Demonstration	500	50
TOTAL	1000	100

Assignment Submission Policy

Describe how, and when, assignments are to be submitted.

Additional Policies

Add any additional policies that students should be aware of: late assignments, missed classes, attendance expectations, use of technology in the classroom, etc.

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
Week 1	<p>Content:</p> <p>1. Introduction to Immersive Technologies</p> <p>1.1 A Brief History of Virtual Reality</p> <p>1.2 The five Classic Components of a VR System</p> <p>1.3 Early Commercial VR Technology</p> <p>1.4 VR Becomes an Industry</p> <p>1.5 Reality, Virtuality and Immersion</p> <p>1.6 VR, AR, MR, xR: similarities and differences</p> <p>1.7 Current trends and state of the art in immersive technologies, developing platforms and consumer devices</p> <p>1.7 The future of human experience</p> <p>1.8 Conclusion</p> <p>1.9 Review Questions</p>	<p>Reading Assignment:</p> <p><u>VR Handbook</u>: Chapter 1</p> <p><u>Metaphysics of VR</u>: Chapter 8</p> <p>Writing assignment: Choose an existing VR application and write a summary (500 words) including a personal critical reflection on its look and feel especially in relation to immersion, presence, agency and interactivity.</p>	
Week 2	<p>Content:</p> <p>2. Motion tracking, navigation and controllers</p> <p>2.1 Position and Motion Trackers</p> <p>2.1.1 Inside Out/Outside In</p> <p>2.1.2 Tracker Performance Parameters</p> <p>2.1.3 Optical - Active and Passive Trackers</p> <p>2.1.4 Inertial and Hybrid Trackers - HMD Trackers</p> <p>2.1.5 Magnetic Trackers</p> <p>2.1.6 Mechanical Trackers</p> <p>2.1.7 Ultrasonic Trackers</p> <p>2.2 Navigation and Manipulation Interfaces</p> <p>2.2.1 Tracker-Based Navigation/Manipulation Interfaces</p> <p>2.2.3 Three-Dimensional Probes and Controllers</p> <p>2.2.3 Data Gloves and Gesture Interfaces</p> <p>2.4 Conclusion</p> <p>2.5 Review Questions</p>	<p>Reading Assignment:</p> <p><u>VR Handbook</u>: Chapter 2</p> <p><u>Learning Virtual Reality</u>: Chapter 3</p> <p>Project Assignment:</p> <p>Design an immersive environment in Unity-3D or Unreal that you will develop and enhance all semester. Work in groups. Start by building a simple 3D world that an interactive player can move around in.</p> <p>Connect the controllers and create a simple interaction loop. Measure velocity, acceleration, distances, and other motion and spatial parameters of the user and the controllers.</p>	
Week 3	<p>Content:</p> <p>3. The Human behind the lenses</p> <p>3.1. Human Perception and Cognition</p> <p>3.1.2 The Human Visual System</p> <p>3.1.3 The Human Auditory System</p> <p>3.1.4 The Human Vestibular System</p> <p>3.2 Physiology, Psychology and the Human Experience</p> <p>3.2.1. Adaptation and Artefacts</p>	<p>Reading Assignment:</p> <p><u>VR Handbook</u>: Chapters 7, 23, 26</p> <p><u>Paper</u>: Real Virtuality: A Code of Ethical Conduct.</p> <p>Other Reading:</p> <p><u>Metaphysics of VR</u>: Chapter 8</p> <p><u>Action in Perception</u>: Chapter 1</p>	

	<p>3.2.2 Ergonomics 3.2.3 Ethics 3.2.4 Scientific Concerns 3.3 VR Health and Safety Issues 3.3.1 Effects of VR Simulations on Users 3.3.2 Cybersickness, before and now 3.3.3 Guidelines for Proper VR Usage 3.4 User Centered Design, User Experience and an Ethical Code of Conduct 3.5 Conclusion 3.6 Review Questions</p>	<p>Writing assignment: Find an existing immersive commercial application that you think it violates best practices and induces nausea by design. Identify what doesn't work and propose a solution (500 Words) Project Assignment : Create a well-rounded multisensory action that is meaningful, safe and accommodates all senses, visual, auditory and tactile.</p>	
Week 4	<p>Content: 4. The present and the future of xR 4.1 Areas and industries for immersive reality applications. 4.1.1 Entertainment 4.1.2 Education 4.1.3 Training 4.1.4 Medical 4.1.5 Industrial 4.1.6 Military 4.2 Use-cases, applications and production pipelines 4.2.1 From Sensing to Rendering 4.2.2 Mobile, Standalone and high- end immersive computing platforms 4.3 VR, Immersive Tech and the Society 4.3.1 Impact on Professional Life 4.3.2 Impact on Private Life 4.3.3 Impact on Public Life 4.4 Conclusion 4.5 Review Questions</p>	<p>Reading assignment: VR <u>Handbook</u>: Chapter 36 Other Reading: <u>Handbook</u>: Chapter 4 <u>Metaphysics of VR</u>: Chapter 9 Project Assignment: Define the area of application of your Virtual Reality project. Choose your immersive computing platform and define an interactive scenario that involves combination of visual, auditory and rich controller integration within the context of your application area. Write and submit a proposal of your idea, a description of your prototype and a flow chart for its design and use.</p>	
Week 5	<p>Content: 5. Camera tracking and 3D Rendering for Immersive Environments 5.1 Inside-Out Camera tracking 5.1.1 Depth Sensing 5.1.2 Microsoft HoloLens 5.1.3 Vrvana Totem 5.1.4 Low cost AR and MR systems 5.1.5 Mobile Platforms 5.2 Full-Body tracking 5.2.1 Inverse & Forward Kinematics 5.2.2 Kinect 5.2.3 Intel Realsense 5.2.4 Full body inertial tracking 5.2.6 Ikinema 5.2.7 Holographic Video 5.3 Rendering Architecture 5.3.1 Graphics Accelerators</p>	<p>Reading Assignment: <u>Handbook</u>: Chapter 5, 14 Other Reading: Learning Virtual Reality: Chapters 4, 6 Project Assignment: Add full body tracking to your VR project using the HTC Vive trackers and the Ikinema framework. Add moving objects into your immersive environment with behavior and collision detection. OR Recognize Track and Classify objects and markers in HoloLens or a Low- End AR, MR device and</p>	

	<p>5.3.2 3D Rendering API's, OpenGL, DirectX, Vulkan, Metal</p> <p>5.3.3 Best practices and Optimization techniques</p> <p>5.4 Distributed VR Architectures</p> <p>5.4.1 Multi-pipeline Synchronization</p> <p>5.4.2 Co-located Rendering Pipelines</p> <p>5.4.3 Distributed Virtual Environments</p> <p>5.5 Conclusion</p> <p>5.6 Review Questions</p>	<p>render Immersive 3D graphics.</p> <p>OR</p> <p>Create a Dual MR/VR prototype scenario for using a Video Pass Through device such as Vrvana Totem.</p>	
Week 6	<p>6. Modeling the Physical world</p> <p>6.1 Geometric Modeling</p> <p>6.1.1 Virtual Architecture</p> <p>6.1.2 Virtual Object Shape</p> <p>6.1.3 Virtual Object Appearance</p> <p>6.1.4 Procedural Textures</p> <p>6.1.5 Advanced Material Properties</p> <p>6.1.6 Procedural Objects</p> <p>6.1.7 Photogrammetry</p> <p>6.2 Kinematics Modeling</p> <p>6.2.1 Homogeneous Transformation Matrices</p> <p>6.2.2 Object Position</p> <p>6.2.3 Transformation Invariants</p> <p>6.2.4 Object Hierarchies</p> <p>6.2.5 Scale, Perspective and Perception</p> <p>6.3 Physical Modeling</p> <p>6.3.1 Collision Detection</p> <p>6.3.2 Surface Deformation</p> <p>6.3.3 Force computation</p> <p>6.3.4 Force Smoothing and Mapping</p> <p>6.3.5 Haptic Texturing</p> <p>6.4 Behavior Modeling</p> <p>6.5 Model Management</p> <p>6.5.1 Level-d-Detail Management</p> <p>6.5.2 Cell Management</p> <p>6.6 Conclusion</p> <p>6.7 Review Questions</p>	<p>Reading Assignment: <u>Handbook:</u> Chapter 11</p> <p>Other Reading: <u>Action in Perception:</u> Chapter 5</p> <p>Project Assignment: Populate your immersive application with objects that have behavior or transformative properties.</p> <p>OR</p> <p>Experiment with Photogrammetry and improve the visual look and feel of your environment.</p> <p>After that make sure that the whole project is based on optimized code, following best practices and is professionally organized.</p>	
Week 7	<p>7. Presence, Agency and Interactivity</p> <p>7.1 Augmenting the sense of Presence</p> <p>7.1.1 Space and Architecture</p> <p>7.1.2 The Uncanny Valley</p> <p>7.1.3 Dissolving the Medium</p> <p>7.2 Identity in Immersive Environments</p> <p>7.2.1 Change of Identity</p> <p>7.2.2 Transforming the senses</p> <p>7.2.3 Extending the senses</p> <p>7.3 Agency and Interactivity</p> <p>7.3.1 Cybernetics, Causality and meaning making</p> <p>7.3.2 Interactivity within Physical</p>	<p>Reading Assignment: <u>Handbook:</u> Chapter 17, 27</p> <p>Other Reading: <u>Luca Turchet</u> : Designing presence for real locomotion in immersive virtual environments</p> <p>Project Assignment: Introduce autonomous characters or objects into your 3D world. Extend or Transform the senses and create a sense of super power for the user.</p>	

	<p>Dimensions</p> <p>7.3.3 Interactivity beyond Physical restrictions; the Super Hero effect</p> <p>7.4 Physical Computing</p> <p>7.4.1 IoT and sensor networks</p> <p>7.4.2 Rapid Prototyping</p> <p>7.5 User Performance Studies</p> <p>7.5.1 Test-bed Evaluation of Universal VR Tasks</p> <p>7.5.2 Influence of System Responsiveness on User Performance</p> <p>7.5.3 Influence of Feedback</p> <p>7.6 Conclusion</p> <p>7.7 Review Questions</p>	<p>OR</p> <p>Use a physical computing platform to rapidly prototype a custom controller, environmental sensor or biosensor in order to bridge the physical and the virtual worlds</p>	
Week 8	<p>8. Sound in Immersive Environments</p> <p>8.1 Evolution of Sound Systems</p> <p>8.1.1 From mono to stereo to surround</p> <p>8.1.2 Object Based Sound</p> <p>8.1.3 Ambisonics</p> <p>8.1.4 HRTF</p> <p>8.2 Sound Design Basics</p> <p>8.2.1 Sound as Information</p> <p>8.2.2 Earcons</p> <p>8.2.3 Impact of Sound in Objects and Actions</p> <p>8.2.4 Natural vs Real Sound</p>	<p>Reading Assignment: <u>Handbook</u>: Chapter 13</p> <p>Other Reading:</p> <p>Project Assignment: Design and implement 5 distinguish sounds to accommodate an interaction within your prototype environment. How does sound transform the user's experience? Create a unique event in order to direct user's attention to a specific are solely based on sound. Then do the same with visual and tactile feedback but no sound. Bring the two together.</p> <p>Writing Assignment: Write a 500 word report about what you have discovered with the project assignment.</p>	
Week 9	<p>9. Medical Applications of xR</p> <p>9.1 Areas of Application</p> <p>9.1.1 Behavioral Therapy</p> <p>9.1.2 Exposure Therapy and PTSD</p> <p>9.1.3 Training</p> <p>9.1.4 Rehabilitation</p> <p>9.1.5 Virtual and Augmented Surgery</p> <p>9.1.6 Virtual Anatomy</p> <p>9.1.7 Triage and Diagnostics</p> <p>9.2 The role of FDA</p> <p>9.2 Conclusion</p> <p>9.3 Review Questions</p>	<p>Reading Assignment: <u>Handbook</u>: Chapter 45</p> <p>Project Assignment: Add a training component to your existing prototype. Define the mechanics that will progressively improve user's performance to mastery through an interaction loop using the dual concept of challenge / reinforcing.</p> <p>OR</p> <p>Create a rich experience of Augmented or Mixed Reality information that progressively evolves through layers of achievement. How can you assist</p>	

		the user to perform a task with success? What is the UI for improving performance?	
Week 10	10. VR Applications in Manufacturing 10.1 Productivity Enhancement Platforms 10.1.1 Virtual Prototyping spaces 10.1.2 Virtual collaborative working spaces 10.1.3 Augmented and Virtual Assistance 10.1.4 Telepresence 10.2 Applications of VR in Robotics 10.2.1 Robot Programming 10.2.2 Robot Teleoperation 10.3 Information Visualization 10.3.1 Oil Exploration and Well Management 10.3.2 Big Data Visualization 10.3.3 Volumetric Data Visualization 10.4 Product Liability and Social responsibility 10.4.1 Innovation as continuity vs disruption 10.4.2 Entrepreneurial Design for Societal Progress 10.4.3 Legal Responsibilities 10.4 Conclusion 10.5 Review Questions	Reading Assignment: <u>Handbook</u> : Chapter 21 Project Assignment: Complete the project as a Beta Prototype. Polish its edges and make its core functionality accurate and robust. Writing Assignment: Write a short assessment of your immersive application so far. How safe is it for commercial use? What is your target group and how will it improve their intended experience? How can you improve it if you had the resources to bring it to market?	
Week 11	Advanced Topics in VR - Highlights from recent papers on immersive environments.	Project Assignment: continue to enhance your immersive environment.	
Week 12	Advanced Topics in VR - Highlights from recent papers on immersive environments.		
Week 13	Advanced Topics in VR - Highlights from recent papers on immersive environments.	Project Assignment: continue to enhance your immersive environment.	
Week 14	Advanced Topics in VR - Highlights from recent papers on immersive environments.		
Week 15	Advanced Topics in VR - Highlights from recent papers on immersive environments.	Project Assignment: continue to enhance your immersive environment.	
FINAL	Final Presentations	Final Project Demo & Write up - Student critique Instructor feedback	Date: For the date and time of the final for this class, consult the <i>USC Schedule of Classes</i> at www.usc.edu/soc .

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* <https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions>. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* <http://equity.usc.edu> or to the *Department of Public Safety* <http://adminopsnet.usc.edu/department/department-public-safety>. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* <http://www.usc.edu/student-affairs/cwm/> provides 24/7 confidential support, and the sexual assault resource center webpage <http://sarc.usc.edu> describes reporting options and other resources.

Support Systems

A number of USC’s schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* <http://dornsife.usc.edu/ali>, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* <http://emergency.usc.edu> will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.