CMSC38__: Introduction to Mobile XR

Course Description

We will explore the basics of smartphone-based augmented and virtual reality. The class will focus not only on development of XR apps with Unity, but also on the hardware, mathematics, physics, algorithms, best practices, and principles that make immersive experiences possible. By the end of the course, students will have also gained experience working in a team to develop a real-world XR application of their own choosing.

Course Details

- **Course**: CMSC38__
- **Prerequisites**: Minimum grade of C- in CMSC250 and CMSC216
- **Credits**: 1
- **Seats**: TBD
- **Lecture Time**: TBD
- **Location**: TBD
- **Semester**: Fall 2019
- **Textbook**: None
- **Course Facilitator(s)**: Sahil Mayenkar, Joseph Feldmann
- **Faculty Advisor**: Dr. Roger Eastman

Topics Covered*

Syllabus may be subject to minor changes, but drastic revisions will require input of students/facilitators, and those involved will be notified immediately

- Unity
    - Basics
        - Unity Editor Interface
        - C# Programming
        - GameObjects and Components
        - Assets
        - Debugging

        - Unity API Documentation
    - Mathematics
        - Coordinate Systems
        - Vectors, Scalars, Matrices
            - Basic properties & operations
        - Projections
        - Transformations
        - Orientations
        - Quaternions, Euler Angles
    - Physics
        - Kinematics
        - Projectiles
        - Gravity
        - Forces
        - Collisions
- Virtual Reality
    - Device Tracking
    - Lenses
    - Spatial Audio
    - Cullings
    - Locomotion
    - Interactivity
    - Performance Optimization
    - Minimizing Motion Sickness
    - Google VR SDK (for Cardboard & Daydream)
    - Design Considerations
    - Best Practices
- Augmented Reality
    - Device Tracking
    - Environment Mapping & Recognition
        - SLAM
        - Feature & Plane Detection
    - Lighting Estimation
    - Real-World Occlusion
    - Unity AR Foundations (for ARKit and ARCore)
    - Design Considerations
    - Best Practices

*The topics covered section should break down the content of the course into concrete sections. This not only makes it clearer what exactly your course will cover, but also serves to force you as a facilitator to think about the organization of your course. Note that we only included 3 units and a few subtopics for each, but you have flexibility in the way you structure your own course, provided it can still fit in a 15-week schedule.

Schedule

Week	Topic(s)	Assignment(s)
1 (8/30)	Course Overview & Intro to Unity	Assigned: HW 0
2 (9/6)	Mathematical Foundations	Assigned: HW 1
3 (9/13)	Physics and Motion	Assigned: HW 2
4 (9/20)	Intro to Mobile VR	**Quiz 1 - Unity** Assigned: HW 3
5 (9/27)	Spatial Sound & Cullings	Assigned: HW 4
6 (10/4)	Locomotion & Interactions	Assigned: HW 5
7 (10/11)	Intro to Mobile AR	**Quiz 2 - Virtual Reality** Assigned: HW 6

8 (10/18)	Environment Mapping and Understanding	Assigned: HW 7
9 (10/25)	Mapping cont. & Light Estimation	Assigned: HW 8
10 (11/1)	Real-World Occlusion	Assigned: HW 9
11 (11/8)	The Future of XR	**Quiz 3 - Augmented Reality** Assigned: Final Project
12 (11/15)	Possible guest lecture by MAVRIC OR Work on Final Project	
13 (11/22)	Work on Final Project	Due: Progress Report
14 (11/29)	NO CLASS - THANKSGIVING	
15 (12/6)	Final Presentations + Demos	Due: Final Project

*Note that this is a tentative schedule, and you have flexibility as an instructor to modify when assignments are assigned and due, as well as (limited) leeway on when the midterm will happen. The dates on this schedule also assume class is held on a Friday, so be sure to modify the dates to reflect which day your STIC will actually be held on. All finals/final assignments **must** happen/be due during the last class so as to avoid hosting a final during finals week.

Grading

Grades will be maintained on ELMS. You will be responsible for all material discussed in lecture as well as other standard means of communication (Piazza, email announcements, etc.), including but not limited to deadlines, policies, assignment changes, etc.

Any request for reconsideration of any grading on coursework must be submitted within one week of when it is returned. No requests will be considered afterwards.

Your final course grade will be determined according to the following percentages:

Percentage	Title	Description
10%	Participation	The grade for this category will be based upon attendance and in-class participation. Students with an excused absence will not be penalized for missing that class.
20%	Homework	Homeworks will typically be coding assignments that will complement the material taught in class from a practical standpoint. Unless otherwise stated, a homework assignment will be due on the Thursday following the lecture that it was assigned and should be submitted on ELMs by 11:59 PM.
30%	Quizzes	There will be a quiz after each unit, for a total of 3 quizzes that are equally weighted (10% each). Students will be given 15 minutes at the start of class to complete the quiz.
40%	Final Project	The final project will consist of students getting into teams of up to 3 people to develop a real-world project of their own choosing. Teams will also deliver a presentation and demo of their project during the final class.

Communicating with course staff

Interaction beyond the classroom will occur primarily through office hours and email, as shown in the table below. Additional office hours can be held if necessary by appointment.

Name	Role	Email Address	Office Hours
Sahil Mayenkar	Course Facilitator	sahil.mayenkar@gmail.com	TBD
Joseph Feldmann	Course Facilitator	josfeldmann@gmail.com	TBD
Dr. Roger	Faculty Advisor	reastman@umd.edu	TBD

Eastman			

Excused Absence and Academic Accommodations

See the section titled "Attendance, Absences, or Missed Assignments" available at Course Related Policies.

Disability Support Accommodations

See the section titled "Accessibility" available at Course Related Policies.

Academic Integrity

Note that academic dishonesty includes not only cheating, fabrication, and plagiarism, but also includes helping other students commit acts of academic dishonesty by allowing them to obtain copies of your work. In short, all submitted work must be your own. Cases of academic dishonesty will be pursued to the fullest extent possible as stipulated by the Office of Student Conduct. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.shc.umd.edu.

Course Evaluations

If you have a suggestion for improving this class, don't hesitate to tell the instructor or TAs during the semester. At the end of the semester, please don't forget to provide your feedback using the campus-wide CourseEvalUM system. Your comments will help make this class better.

Thanks to the CS professors at the University of Maryland, College Park for the basic syllabus outline.

Appendix A: References

General Unity (Math + Physics):

- CMSC 425 Materials: https://www.cs.umd.edu/class/spring2019/cmsc425/lectures.shtml
- http://vr.cs.uiuc.edu/vrch3.pdf
- http://vr.cs.uiuc.edu/vrch8.pdf
- https://www.cs.trinity.edu/~jhowland/class.files.cs357.html/blender/blender-stuff/m3d.pdf

Lenses (VR)

- http://vr.cs.uiuc.edu/vrch4.pdf
- http://vr.cs.uiuc.edu/vrch7.pdf
- http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/aberrcon.html
- http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/aber3.html
- http://marcodiiga.github.io/radial-lens-undistortion-filtering
- http://olympus.magnet.fsu.edu/primer/java/aberrations/distortion/index.html
- http://sprg.massey.ac.nz/pdfs/2003_IVCNZ_408.pdf

Device Tracking (Poses, IMUs) (VR & AR)

- https://www.eecs.umich.edu/courses/eecs373/Lec/StudentF18/373%20IMU%20Presentation.pdf
- http://stanford.edu/class/ee267/notes/ee267_notes_imu.pdf
- http://vr.cs.uiuc.edu/vrch9.pdf

Locomotion (VR)

- http://vr.cs.uiuc.edu/vrch10.pdf
- https://vr.berkeley.edu/decal/lecture/2
- http://stanford.edu/class/ee267/Spring2016/report_mago_karaouni.pdf
- https://www.blog.google/products/daydream/daydream-labs-locomotion-vr/

Cullings (VR)

- https://webpages.uncc.edu/krs/courses/5010/ged/lectures/cull_lod2.pdf
- http://www.cse.ohio-state.edu/~hwshen/788/sp01/Culling.ppt
- https://www.youtube.com/playlist?list=PLEETnX-uPtBVszVeAIDl5jp5j9YT9EFae
- http://www.gamasutra.com/view/feature/131801/occlusion_culling_algorithms.php
- https://computergraphics.stackexchange.com/questions/1736/vr-and-frustum-culling

Spatial Sound (aka 3D sound or positional audio) (HRTF) (VR)

- http://www.3dsoundlabs.com/hrtf-definition-introduction/
- https://www.ece.ucdavis.edu/cipic/spatial-sound/tutorial/hrtf/
- https://www.ece.ucdavis.edu/cipic/spatial-sound/tutorial/hrtfsys/
- http://users.umiacs.umd.edu/~ramani/cmsc828d_audio/HRTF_INTRO.pdf
- https://www.frontiersin.org/articles/10.3389/fnins.2018.00021/full

Environment Mapping & Understanding (SLAM, point clouds, plane detection) (AR)

- https://www.andreasjakl.com/basics-of-ar-slam-simultaneous-localization-and-mapping/
- https://blog.griddynamics.com/how-arkit-and-arcore-recognize-vertical-planes/
- https://www.andreasjakl.com/basics-of-ar-anchors-keypoints-feature-detection/
- https://web.mit.edu/2.166/www/handouts/davison_etal_pami2007.pdf
- http://www.cs.princeton.edu/~funk/iccv09.pdf
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.438.4189&rep=rep1&type=pdf
- https://scss.tcd.ie/publications/theses/diss/2018/TCD-SCSS-DISSERTATION-2018-035.pdf

Environment Light Estimation (AR)

- https://cs.brown.edu/courses/csci2951-i/week8/IlluminationEstimationPDF.pdf
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.88.4153&rep=rep1&type=pdf
- https://www.andreasjakl.com/real-time-light-estimation-with-google-arcore/

Environmental Occlusion (AR)

- https://hackernoon.com/why-is-occlusion-in-augmented-reality-so-hard-7bc8041607f9
- http://ltu.diva-portal.org/smash/get/diva2:1263215/FULLTEXT01.pdf
- http://blog.guidigo.com/blog/how-to-work-around-occlusion-issues-in-augmented-reality/
- https://homes.cs.washington.edu/~holynski/publications/occlusion_sa2018.pdf