University of Oklahoma
School of Computer Science
CS 5970-003: Visual Navigation for Autonomous Aerial and Ground Vehicles
Fall 2022

Course Format/Meeting Time and Location

Lecture time: T/Th 3-4:15 PM CST
Lecture Location: Sarkeys Energy Center, P0203
online lectures at: https://oklahoma.zoom.us/j/9123772842
Lab sessions: Wednesdays 3-5
Instructor: Golnaz Habibi golnaz@ou.edu
Learning Management System/website: canvas.ou.edu
Course Materials: all the materials will be posted on Canvas
Course Announcement and discussions: canvas

Course Staff:
Golnaz Habibi (Instructor) golnaz@ou.edu
Office hours: TBD, DEH 210-F and zoom: https://oklahoma.zoom.us/j/9123772842

Course Description*:
This graduate-level course covers fundamental mathematics and implementations of state-of-the-art algorithm for visual-based navigation with application for self-driving cars, self-driving delivery robots, and autonomous drones. This course covers topics on visual navigation on single robotics platform which is extended to multi-agent platforms in terms of multi-robot coordination and planning. Students will learn how to implement these algorithms using software packages mainly in ROS.

Course Outcome:
During this course, the students learn broad topics in autonomous navigation system, with focus on vision, such as 3D trajectory planning and optimization, basics on 3D geometric control, 3D object detection and tracking, Visual Inertial Odometry, place recognition and Simultaneous Localization and Mapping, multi-view geometric vision for real-time motion estimation, and calibration, sensor fusion and the extension to multi-agent coordination and navigation. At the end of the course, students are able to integrate three modules of perception, planning and control and implement end-to-end autonomous navigation. The theoretical foundations are complemented with a set of homework assignments which focus on the theory of the course as well as projects based on state-of-the-art race car and drone simulators. The course is concluded by the review of most recent works and the-state-of-the-art algorithms in the field of visual navigation. Student will work on the final project which advances the state-of-the-art and can be presented and submitted in a format of a conference paper.

* This course syllabus is based on the course VNAV, which has been taught at MIT for 4 years with a great success and the instructor of the course 5970 at OU was the co-instructor of VNAV course at MIT. The open-source version of the course is available at:
https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-485-visual-navigation-for-autonomous-vehicles-vnav-fall-2020/

Topics covered in this course:

- 3D Geometry and 3D vision
- 3D trajectory and motion planning and optimization
- Visual Inertial Odometry and state estimation
- Place Recognition
- Visual Simultaneous Localization And Mapping (Visual SLAM)
- 3D object detection and tracking
- 2D multi-view geometric vision for real-time motion estimation
- Beyond vision: multi-sensors fusion (camera, LiDARs and Radars)
- Multi-agent communication and decentralized algorithms
- Multi-agent coordination and navigation
- Collaborative SLAM
- Robustness of Visual navigation
- Reinforcement Learning in autonomous navigation

Course Prerequisites:

- CS 2413 (Data Structure)
- MATH 3333 (Linear Algebra)

Recommended Programming Skill:

Projects are largely based on ROS and OpenCV and all in C++. Previous experience in robotics and programming in ROS is a plus.

C++ refresher: https://youtu.be/F_vIB3yjxaM

Course Material:

There is no required textbook for this course, but following books are recommended:

- Barfoot, Timothy. *State Estimation for Robotics*. Cambridge University Press, 2017. ISBN: 9781107159396.
- Ma, Yi et al. *An Invitation to 3-D Vision: From Images to Geometric Models*. Springer, 2003. ISBN: 9780387008936.
- Howie Choset et al. *Principles of Robot Motion: Theory, Algorithms, and Implementations*, MIT Press, 2005

Course Evaluation:

- Projects and lab assignment: 60%
- Attend in the class discussion both in canvas an in lectures: 5%
- Final Project Report, Demo, Presentation, Proposal: 30%
- Your teammate assessment: 5%

Teaching Philosophy & Inclusion Statement:

My goal is to create a class in which everyone is welcome, included, and able to learn and succeed. Please talk to me if there is something I need to know to facilitate a positive and productive learning experience for you.

Course Tentative Schedule (note that this schedule is subject to change)

Week	Topics	Lab	**Lab schedule**
Week 1	Introduction and overview of visual navigation	Lab 1: Linux,Git,C++	Lab 1 out
Week 2	3D Geometry		
Week 3	3D Geometry	Lab 2: ROS	Lab 2 out, lab 1 due
Week 4	Quadrotor Dynamics	Lab 3: 3D Trajectory following (Geometry controller)	Lab 3 out, lab 2 due
Week 5	Quadrotor Control		
Week 6	3D motion planning and trajectory optimization	Lab 4: Trajectory Optimization	Lab 4 out, lab3 due
4Week 7	2D and 3D computer vision and 2-view Geometry	Lab5: Feature extraction and tracking	Lab 5 out, lab 4 due
Week 8	2D and 3D computer vision and 2-view Geometry – Structure from motion	Lab6: Pose estimation (2-view Geometry)	Lab 6 out, Lab 5 due
Week 9	Visual Inertial Odometry and state estimation		
Week 10	Place Recognition and Bag of Words	Lab7: GTSAM for pose and landmark estimation	Lab 7 out, Lab 6 due
Week 11	3D object Detection and Tracking Overview of Deep Neural Network and its application in Visual Navigation	Lab 8: 3D object detection using Yolo and landmark estimation	Lab 8 out, lab 7 due
Week 12	Beyond vision: multi-sensors fusion (camera, LiDARs and Radars)		lab 8 due
Week 13	SLAM – Pose graph Optimization		Final Project
Week 13	SLAM - Landmark Estimation and bundle adjustment		Final Project
Week 14	Concluding SLAM : real-world examples Reinforcement Learning in autonomous navigation		Final Project
Week 15	Robustness of Visual Navigation Limitation of Visual navigation -Course overview		Final project

Course Leaning Activities:

Attendance:
Students are expected to attend the class discussions which is 5% of your final grade.
Lab assignments:
The course has nine* lab assignments, each lab has two parts of pen and paper (homework) assignment and mini projects. Homework focuses on the theoretical aspects of the course, and projects focus on the implementation of the materials discussed in the class. All projects are mainly based on C++ and are implemented in ROS.

Lab teams: Lab 1 and 2 should be done individually. Lab 3-9 can be done in group of 1 to 3. You have to choose your lab partner by week 3 (deadline is September 6, 2022). Final project cstudentsan be done in a group of 1 to 3 students.
*Depending on the average class performance, this number is subject to change
Lab schedule: labs are usually announced on Tuesdays and due on Fridays.

Lab simulator:
For this course, we use TESSE simulator platform. TESSE is an open-source Unity based simulator developed and designed at MIT.

Final Project:
Students work in group of 1-3 on the final project related to the topics discussed in the course. The project proposal is due on Oct 21, 2022. The grading for the final project will be based on:

1. Technical report, formatted according to ICRA/IROS guidelines
2. Final demo, showcasing the outcome of the project
3. Team presentation, including videos describing the project and its implementation

If the project establishes a new state-of-the-art, it can be considered for submission to a related conference (ICRA, IROS, CVPR, ICCV, ICML, etc).

Late policy for the homework and projects:
There are the total of five grace days that you can use for your lab assignments (you can use maximum 2 days for each lab). After that your grade is penalized by 15% for every day late.
Important note: If you do not want to use your grace days for a lab, you have to notify the course staff, otherwise, your remaining grace days are considered by default.

Communication:
Students are encouraged to pose their questions in discussion section in canvas so it may be helpful for other students as well. For any questions regarding the course (HW, projects, grading, material, etc) you can reach out the course staff via email or canvas or during office hours.
Grading:

Score	Grade
>=90	A
80-89	B
70-79	C
60-69	D
<60	F

OU's academic integrity:
Copying another's work for homework and project assignments, or possession of unauthorized electronic computing or communication devices in the testing area, is the course violation and grounds for penalties in accordance with school policies.

Please see OU's academic integrity website.

Accommodations:
Any student with a disability should contact the instructor so that reasonable accommodations may be made for that student.

Adjustments for Pregnancy/Childbirth Related Issues:

Should you need modifications or adjustments to your course requirements because of documented pregnancy-related or childbirth-related issues, please contact me as soon as possible to discuss. Generally, modifications will be made where medically necessary and similar in scope to accommodations based on temporary disability.

Please see http://www.ou.edu/eoo/faqs/pregnancy-faqs.html for commonly asked questions.

Title IX Resources

For any concerns regarding gender-based discrimination, sexual harassment, sexual misconduct, stalking, or intimate partner violence, the University offers a variety of resources, including advocates on-call 24.7, counseling services, mutual no contact orders, scheduling adjustments and disciplinary sanctions against the perpetrator. Please contact the Sexual Misconduct Office 405-325-2215 (8-5) or the Sexual Assault Response Team 405-615-0013 (24.7) to learn more or to report an incident.

Holidays:

It is the policy of the University to excuse the absences of students that result from religious observances and to provide without penalty for the rescheduling of examinations and additional required class work that may fall on religious holidays.

Related Documents:

Students should also read the related documents on Replacement Assignments or Extensions and Discussions of Scores and Grades.

Foods and drinks in the class:

Food and drink are not permitted in the classroom or lab, with the exception of covered water bottles, which may be used sparingly in these locations and the cap immediately returned to the bottle after each drink.

Laptop in the class:

Using laptops in the class is discouraged as it could distract the owner and other students. But if you need to use your laptop during the lecture, please seat at the last row to minimize distracting others.

Emergency Protocol

During an emergency, there are official university procedures that will maximize your safety.

- **Severe Weather:** If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather 1. LOOK for severe weather refuge location maps located inside most OU buildings near the entrances 2. SEEK refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building. 3. GO to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows. 4. GET IN, GET DOWN, COVER UP. 5. WAIT for official notice to resume normal activities.

Links: Severe Weather Refuge Areas, Severe Weather Preparedness

- **Armed Subject/Campus Intruder:** If you receive an OU Alert to shelter-in-place due to an active shooter or armed intruder situation or you hear what you perceive to be gunshots: 1. GET OUT: If you believe you can get out of the area WITHOUT encountering the armed individual, move quickly towards the nearest building exit, move away from the building, and call 911. 2. HIDE OUT: If you cannot flee, move to an area that can be locked or barricaded, turn off lights, silence devices, spread out, and formulate a plan of attack if the shooter enters the room. 3. TAKE OUT: As a last resort fight to defend yourself.

  Links: OU Emergency Preparedness, Responding to Gunshots

- **Fire Alarm/General Emergency:** If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates: 1. LEAVE the building. Do not use the elevators. 2. KNOW at least two building exits 3. ASSIST those that may need help 4. PROCEED to the emergency assembly area 5. ONCE safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues. 6. WAIT for official notice before attempting to re-enter the building.

  Links: OU Fire Safety on Campus