# CS 5970-003: Visual Navigation for Autonomous Vehicles
# University of Oklahoma
# School of Computer Science
# Fall 2023

**General Information:**

**Lecture time and location:** Tuesdays/Thursdays 1:30-2:45 PM CST, Carson Engr Center (CEC) 121
**Instructor:** Golnaz Habibi golnaz@ou.edu
**Course website:** https://canvas.ou.edu/courses/301154/ and course webpage (TBD)
**Course Materials:** all the materials will be posted on Canvas
**Course Announcement and discussions:** canvas and Teams
**Course Assignment Submission:** Github
**Instructor:** Golnaz Habibi golnaz@ou.edu
**Instructor's Office hours:** Mondays/Wednesdays 1-2 PM, DEH 245

**Course Description*:**
This graduate-level course covers fundamental mathematics and implementations of state-of-the-art autonomous navigation algorithms with the application for self-driving cars, delivery robots, and autonomous aerial vehicles such as drones. This course is a branch of robotics, and it covers topics on autonomous navigation, motion planning, computer vision, localization and mapping on single robotic platform which is extended to multi-agent platforms in terms of multi-robot coordination and planning. In this course students learn how to control autonomous vehicles including drones and race cars to navigate safely using visual sensing (e.g., camera). The course also covers topics beyond visual sensing such as using LiDAR solely or in the combination with cameras for autonomous navigation.

**Course Outcome:**
During this course, the students learn broad topics in autonomous navigation system, with focus on 3D trajectory planning and optimization, basics on 3D geometric control, object detection and tracking, Visual Inertial Odometry, place recognition and Simultaneous Localization and Mapping (SLAM), sensor fusion and the extension of the navigation multi-agent coordination and mapping. As a final project, students will integrate three modules of perception, planning, control and implement end-to-end autonomous navigation. This pipeline will be implemented on aerial and ground vehicles such as self-driving cars. 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 racing car and drones. 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 provides a set of physical racecars for students to design and implement autonomous driving in a mini-city environment as their final project.
During the course, we will have guest speakers from industry and academia in robotics and autonomous vehicles.

* This course syllabus is adapted from the opensource course VNAV, which has been taught at MIT for 4 years with a great success and the instructor (Golnaz Habibi) 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/

**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 Topics:**

- 3D Geometry and 3D vision
- 3D trajectory and motion planning and optimization
- Visual Inertial Odometry (VIO) and state estimation
- Visual Simultaneous Localization And Mapping (VSLAM)
- Object detection and tracking
- Beyond vision (Radars and LiDARs) and multi-sensors fusion
- Multi-agent systems: communication, multi-agent coordination and navigation
- Collaborative SLAM
- Analysis the robustness of visual navigation
- Reinforcement Learning and autonomous navigation

**Course Perquisites**:
- CS 2413 (Data Structure)
- MATH 3333 (Linear Algebra)
- Or instructor's permission

**Recommended Programming Skill:**
Projects are heavily based on Robotics Operating Systems (ROS) and OpenCV. Most of the projects are in C++. Previous experience in robotics and programming in ROS is a plus.
**Course textbooks:**
There is no required textbook for this course, but following books are recommended:
- Timothy Barfoot, *State Estimation for Robotics*, Cambridge University Press, 2017. ISBN: 9781107159396.
- Sebastian, Thrun, Wolfram Burgard, Dieter Fox, *Probabilistic Robotics*, MIT Press, Aug 19, 2005. ISBN-13: 978-0262201629
- Yi Ma , Stefano Soatto , Jana Košecká , S. Shankar Sastry, *An Invitation to 3-D Vision: From Images to Geometric Models,* Springer, 2003. ISBN: 9780387008936.
- Howie Choset; Kevin M. Lynch; Seth Hutchinson; George A. Kantor; Wolfram Burgard; Lydia E. Kavraki; Sebastian Thrun, *Principles of robot motion: theory, algorithms, and implementations,* MIT press; 2005 May 20.

**Course Leaning Activities:**

**Attendance:**
Attending class is a part of the grading and students are expected to attend the class discussions.

**Course Evaluation:**
This course has not any final or midterm exam and the grading is based on the set of lab assignments and final project.
The course has nine lab assignments. Each lab has two parts: homework and project. Homework focuses on the theoretical aspects of the course and should be **done and submitted individually**, projects focus on the implementation of the materials discussed in the class. All projects are mostly based on C++ and are implemented in ROS. The final project could be in Python or C++.

**Course Evaluation Metrics:**
- Projects and lab assignment: 65%
- Final Project Report, Demo, Presentation: 30%
- Class attendance and teammate assessment: 5%

**Course Grade Scaling:**

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

**Robot Operating System (ROS):**
The Robot Operating System (ROS) is open source, and it includes a set of software libraries and tools that help you build robot applications. ROS provides components, tools, and interface to build an advanced robot. We extensively use ROS in this course. The second assignment includes ROS installation and prepare the students to implement a simple package in ROS.

**Final Project:**
According to students' preference, students work in group of 1-3 on the final project. 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.

**Course Outcome as a Research paper:**
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:**

Course has a set of milestones and deadlines that you need to follow during the semester. The milestones are guidelines for you to make sure you are on track to complete the assignments on time. The assignments submitted after the deadline are considered late assignment and late policy will apply to them.
There are a total of five grace days that you can use for your lab assignments (up 2 days for each set of assignment). After that your grade is penalized by 10% for every day late.

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

**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.

**Religious 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