# MEC 559 - Mobile Robotics and Autonomous Vehicles

Instructor: Nilanjan Chakraborty

## Contact Information

**Office**: Heavy Engineering 212.
**Email**: nilanjan.chakraborty@stonybrook.edu

## Lecture Hours

**Time**: Tuesday, Thursday 8 : 00 PM to 9 : 20 PM.
**Location**: Frey Hall 217.

## Office Hours

**Location**: Heavy Engineering 212
**Time**: Tuesday, 12 : 30 PM - 2 : 00 PM; Thursday, 12 : 30 PM - 2 : 00 PM.
**Alternate Times**: Please send me an email to make an appointment.

## Teaching Assistant

Nicholas Baiata
**TA Office Hours**: Monday, 1 : 00 PM - 2 : 00 PM; Wednesday 1 : 00 PM - 2 : 00 PM.

## Course Description

This course will cover the fundamentals of planning, state estimation, and control techniques for mobile robots and autonomous vehicles. Key topics include: Kinematics of wheeled mobile robots; State estimation, Localization, and Mapping; Simultaneous Localization and Mapping (SLAM) Algorithms; Path planning, Obstacle Avoidance, and Non-holonomic Control; Mobile robot programming and control architecture.

## Expected Student Background

Students are not expected to have a background in robotics, although having a background will be helpful. Students are expected to have undergraduate level knowledge of linear algebra and probability theory. Students should be comfortable programming in either MATLAB or Python or C or C++.

## Books

The books below are for reference. They are not required.

- Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, MIT Press, 2011.
- Alonzo Kelly, *Mobile Robotics: Mathematics, Models, and Methods*, Cambridge University Press, 2013.
- Sebastian Thrun, Wolfram Burgard, and Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.
- Steve Lavalle, *Planning Algorithms*. `https://lavalle.pl/planning/`

## Course Learning Objectives

1. Be able to construct kinematic motion models of mobile robots as well as sensing models for different sensor systems.
2. Use motion models, sensor models, and sensor data in a Bayesian framework to solve localization and mapping problems.
3. Understand and implement sensor-based collision avoidance and path planning algorithms.

## Assignments, Exams, and Projects

- **Assignments**: There will be approximately 6 assignments. You will have about $1-2$ weeks to complete an assignment. Assignments will be due in class. The assignments will include coding. You are allowed to discuss with your colleagues, but you have to submit your individual work. Any discussion or help that you have taken from your colleagues or other sources should be acknowledged. In other words, you should write the name of the persons with whom you have worked and explicitly state the kind of help you have received.
- **Paper Critique**: There will also be one paper review report that you have to submit. You have to select two/three related papers from a list of papers that I will provide (or you can choose your own paper based on your final project), and you have to write a critical review of the papers. You will have approximately two weeks for the paper critique.
- **Exam**: There will be a take-home exam. The exam will be open book, open notes. You will have 5 days or 120 hours to complete your exam. You are not allowed to consult with your colleagues for the exam. The scheduled exam date is 03/31 to 04/04 (tentative).
- **Final Project and Presentation**: There will be a final project that will be carried out in groups of at most 2 students. You have to do two reports for the final project. The first report will be a project proposal in which you describe the problem you want to solve and what your plans are to solve the problem. The final report will be a comprehensive description of your work. The reports are to be written using Latex. I will provide the supporting style files.

## Policy on usage of AI software like ChatGPT

You are free to use software like ChatGPT to help you code or answer any question on the homework or take-home exam. However, any usage of the software should be noted and you should include the prompts that you used as part of your answer. **You are responsible for verifying the accuracy of your answers**. The use of any LLM-based software without explicit acknowledgment will be considered cheating and will be subject to an academic honesty policy detailed later in the syllabus. To clarify, although ChatGPT is mentioned by name, this policy applies to all similar software (or coding assistants like Copilot) based on generative AI technology.

## Grading Breakdown and Policy

Your overall grade will be based on your performance in all the class work mentioned above. The weight distribution on grades for the different components is given below.

- Assignments (25%).
- 1 Take Home Midterm Exam (35%).
- 1 Paper Critique (10%).
- Final Project and Project Presentation (30%).

The GRADING SCALE will be an accumulation of your course work, as follows (there will probably be no curves): A (100-90), A- (89-85), B+ (84-80), B (79-75), B- (74-70), C+ (69-65), C (60-64), F (59 or below).

**Late Assignment Policy**: Assignments are due in class unless otherwise stated or you have made prior arrangements with me. You are allowed at most two late days for each homework or paper critique. If you submit your homework late, you will be penalized 20% of the points. Assignments will not be accepted after the late days expire. No late submission is allowed for the mid-term exam or the final project report.

**Collaboration Policy**: You are allowed and encouraged to collaborate with your fellow students on assignments. However, you are required to turn in your own work, and you should not copy the work of another person. Any collaboration or help should always be acknowledged explicitly. **No collaboration is allowed** on the take-home midterm exam. As stated above, you are allowed to use any LLM-based software for assistance. However, you have to explicitly acknowledge it and you are responsible for the correctness of the answers.

## Weekly Lecture Schedule (Tentative)

Week 01: Rigid Body Kinematics (Planar and Spatial).

Week 02: Motion Models of Wheeled Mobile Robots.

Week 03: Basics of Estimation and Sensor Models in Robotics.

Week 04: Bayes Estimation, Kalman Filtering, and Extensions.

Week 05: Localization in a Known Map.

Week 06: Mapping with Perfect Localization.

Week 07: Simultaneous Localization and Mapping - Pose Graph Techniques.

Week 08: **Spring Break**.

Week 09: Simultaneous Localization and Mapping - Monte Carlo Techniques.

Week 10: Path Planning - Grid-based Techniques. (Take-Home Exam)

Week 11: Path Planning - Randomized Search.

Week 12: Path Planning - Collision Avoidance. (Paper Critique Due)

Week 13: Neural Networks for Estimation from Point Cloud Data - PointNet

Week 14: Neural Networks for Estimation from Point Cloud Data - Transformers

Week 15: Non-holonomic Control and Parallel Parking (Final Project Due)

## Brightspace

All homework assignments and solutions will be posted on the Brightspace course account. I will use email and Brightspace exclusively to communicate with you off class. It is your responsibility to make sure that your email id is a current one on the Brightspace system. I suggest that you use a university email id for this class; it is free and official. I am not responsible for the emails not delivered to your commercially available email accounts. To learn more and for SUNY Online helpdesk information, visit: `https://brightspace.stonybrook.edu`.

## Academic Honesty

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at `http://www.stonybrook.edu/commcms/academic_integrity/index.html` Academic dishonesty is an extremely serious offense and will not be tolerated in any form. Academic dishonesty in general is the presentation of intellectual work that is not originally yours. Examples include, but are not limited to, copying or plagiarizing class assignments including homework, reports, designs, computer programs, graphics, and other submitted materials; copying or otherwise communicating answers on exams with other students; bringing unapproved aids, either in physical (written) or electronic form to an exam; obtaining copies of an exam prior to its administration, etc. Academic dishonesty violates both the ethical and moral standards of the Engineering profession and all infractions related to academic dishonesty will be prosecuted to the fullest via the CEAS CASA committee.

## Americans with Disabilities Act

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at `sasc@stonybrook.edu`. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential. Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: `https://ehs.stonybrook.edu/programs/fire-safety/emergency-evacuation/evacuation-guide-disabilities` and search Fire Safety and Evacuation and Disabilities.

## Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Further information about most academic matters can be found in the Undergraduate Bulletin, and the Undergraduate Class Schedule, and the Faculty-Employee Handbook.