ME 412 – Autonomous Mobile Robots
Fall Semester – 2022
Department of Mechanical Engineering, Albert Nerken School of Engineering
The Cooper Union for the Advancement of Science and Art

Description	Graduate Course - The objective of the course is to build a mobile robot capable of competing in a competitive robot tank battle game. This course introduces basic concepts, technologies, and limitations of autonomous mobile robots. Topics include digital and analog I/O, tactile sensing, IR sensing and range finding, light sensing, sonar, magnetic field sensing, inertia sensing, encoders, electric motor actuators, high-level microprocessor control, low-level microprocessor control, power management, and prototyping. Students will form teams to design and build autonomous mobile robots configured to compete in a singles-match game, or to perform a team-oriented task. During the semester, students are expected to demonstrate progress on the development of their robot and complete project assignments that will lead to the final competition-ready robot and accompanying quality research paper. *3 credits. Prerequisites: ME 353 or ECE 251*
References	Jones, J.L., Flynn, A.M., and Seiger, B.A., "Mobile Robots: Inspiration to Implementation", 2nd Edition, AK Peters. (1998) Martin, F.G., "Introduction to 6811 Programming", MIT Media Laboratory. (1994) Ulrich, N., "Mobile Robotics: A Practical Introduction", 2nd Edition, Springer. (2003) "ME 412: Autonomous Mobile Robots", http://faculty.cooper.edu/mar/mobile_robots_fall2022.html. (2022) "Ericson Mar's Robotics Links", http://faculty.cooper.edu/mar/robotics_links.htm. (2022)
Instructor	Ericson Mar, Adjunct Professor, Mechanical Engineering, ericson.mar@cooper.edu Office hours by appointment, contact through MS Teams.
Course Objectives	1. Collaborate with teammates of mixed skills to solve a robotics problem. 2. Design and develop sensor, actuator, controller, and software systems that will synergize into an autonomous mobile robot. 3. Present progress and functional demonstrations to class. 4. Document and compile a quality research paper on the project.
Course Topics	The planned main course topics are: Sensors (digital, analog, tactile, light, infrared, proximity, range, sonar, magnetic field, and inertial). Actuators (inductive loads, DC motors, servo motors, stepper motors, and encoders). Power (batteries, voltage regulation, and current limitations). Controllers and Programming (Handyboard robot controller to demonstrate basic principles of robotics microcontrollers, students may pick their own commercially available controller with suitable modules or use the few available Handyboards supplied by the department). 68HC11 Assembler (basic principles of computer architecture and microcontrollers and their applications to autonomous robotics). Behavioral Programming Concepts (subsumption architecture, emergent phenomena, multitasking control algorithms, and reactive programming concepts). Project – Design and develop an autonomous mobile robot capable of participating in the "Robot Tank Battle" competition at the end of the class (research, procurement, experimentation, instrumentation, prototyping, and programming).
Class Schedule	Tuesday, 6-9PM, 41 Cooper Square, RM 306.
Professional Component	The course directly addresses engineering topics consisting of engineering sciences, engineering design, and prototyping. It includes the blending of advanced mechanics, electronics, and computer science to solving engineering problems using an interdisciplinary approach.
Program Objectives	The course directly addresses Criterion 3 issues a, b, c, d, e, f, g, h, i, j, and k. See last page.

Course Outline

The course initially involves lectures and the formation of student teams that will develop autonomous mobile robots to compete against each other in a singles-match game. Students will conduct research on commercially available technologies, perform experiments with procured parts, and present their progress to the class while addressing questions. There will be some video documentaries shown to present examples of the state of the art in mobile robotics application and research. We will hold laboratory classes where each team will perform their own designed experiments with the instructor's commentary and recommendations. The final class will involve the demonstration of their robot in the singles-match game.

Students are expected to cover all the costs for parts, although some parts may be salvaged from past projects. There will be no constraints on the design apart from size, safety considerations, and the stipulation that a robot may not intentionally physically damage another robot or its environment. Students will be granted access to appropriate prototyping/laboratory facilities and resources.

Lectures and accompanying handouts are designed by Ericson Mar. The handouts and related discussion material can be found in the following link:
http://faculty.cooper.edu/mar/mobile_robots_fall2022.html

Assignments

Assignments are designed to help the student teams progress toward the competition ready robot. Each team must be ready for scheduled mandatory presentations that will be part of the final grade. There will also be presentations of working deliverables which demonstrate the incremental operation of their robots; this will also be part of the final grade.

Typically, assignments will be presented by students in class. They may use any medium to present and must do so neatly and legibly with accompanying explanations of their method and why they have taken their approach and chose certain parts.

Because of the variable nature of this design process, there will be some flexibility regarding working deliverables. The working deliverables have a recommended due date, however extra points toward the final grade may be earn by presenting their working deliverables early, and points will be deducted by presenting said deliverables past the recommended due date.

They must consult with teammates on the best way to approach the problem and to present their results in class. They may draw upon experiences from past robot teams, but the overall design must be theirs and not mostly a replication of either a past team's efforts, or a commercial product.

Project

There will 3 intermediate working deliverables (mentioned above) required prior to the final working deliverable. There will be in class opportunities to discuss each working deliverable, which may address issues and open new avenues to proceed onto the next phase of the project.

Final Paper

A quality research paper will be required at the end of the class. Past papers with annotations will be provided for students to use as a reference.

Schedule and Grading

Apart from the final paper submission, each student must be present to support their teammates in order to receive credit for the project due.

Week	Date	Topic	Project Due (Type) [Worth]
1	30-Aug-22	Introduction and Overview	
2	6-Sep-22	Sensors	Formed Groups
3	13-Sep-22	Actuators/Controllers and programming	
4	20-Sep-22	Tools Overview/ Individual Robot Proposal Review	Robot Proposal (Hand-In and Discussion) [5%]
5	27-Sep-22	68HC11 Assembler	Finalized Robot Proposal (Hand-In and Discussion) [5%]
6	4-Oct-22	Behavioral Programming Concepts	
7	11-Oct-22	Videos, State of the Industry, Applications	Robot Construction Progress Class Presentation [5%]
8	18-Oct-22	Videos, State of the Industry, Applications	Robot Construction Progress Class Presentation [5%]
9	25-Oct-22	Videos, State of the Industry, Applications	Robot Construction Progress Class Presentation [5%]
10	1-Nov-22	Lab/Discussions	Completed Robot Platform (Demo***) [10%]
11	8-Nov-22	Lab/Discussions	Light Tracking behavior (Demo***) [10%]
12	15-Nov-22	Lab/Discussions	Obstacle Avoidance behavior (Demo***) [10%]
13	29-Nov-22	Lab/Discussions	TBD
14	6-Dec-22	Lab/Discussions	TBD
15	13-Dec-22	Contest Running	Final Projects Due (Demo + Final Paper) [45%]

*** Each of these 3 "Demos" may be presented earlier (+2% per week) or later (-2% per week) up to the December 6 class.

Past the December 6 deadline, any incomplete Demo will receive 0%.

Grading Scale

Letter grades will be assigned at the end of the semester based on the percentage earned in the course, using this mapping:

90-100	A - superior and comprehensive grasp of the course principles
80-89	B - good degree of familiarity with the course principles
70-79	C - average knowledge of the course principles and fair performance
60-69	D - minimum workable knowledge of the course principles
<60	F - - unsatisfactory understanding of the course principles

Course Policies

I try to create course policies that support a fair and equitable classroom and set high performance standards for all students. Please make an appointment with me if you are having any issues related to me, the course, or your fellow students.

While I want you to feel comfortable coming to me with issues you may be struggling with or concerns you have, please be aware that I have reporting requirements that are part of my responsibilities as a member of the faculty. If you inform me of an issue of sexual harassment, sexual assault, or discrimination, I will keep the information as private as I can, but I am required to report the basic facts of the incident to Cooper's Title IX Coordinator. The Cooper Union Title IX policy on sexual misconduct can be found here.

Counseling Services at The Cooper Union are coordinated through the Office of Student Affairs. The Cooper Union counseling and mental health services website can be found here.

Academic Integrity Policy

The Cooper Union School of Engineering Policy on Academic Integrity is posted here. Plagiarism is the presentation of another person's "work product" (ideas, words, equations, computer code, etc.) as one's own. Whether done intentionally or unintentionally, plagiarism will not be tolerated in this class. You are plagiarizing if:

You present as your own work product a submission that includes the work product of other groups.
You present as your own work product a submission that contains the efforts or work product of other individuals aside from your other group members (i.e. code from the internet).
You present as your own work product material from previous iterations of this course (old projects, old papers).
The help and contributions of other individuals are not acknowledged in writing on your submission (by writing their names or citing their published work).
You submit as part of a assignment or project material that has been copied from any source (including, but not limited to, a textbook, a periodical, an encyclopedia, the internet) without properly citing the source, and/or without using quotation marks. It is also prohibited to submit such materials in a minimally altered form without proper attribution. Improperly copied material might include text, graphics (computer or otherwise), computer source code, etc.

If I have a strong suspicion that you have plagiarized your submission for an assignment, you will be reported to the Dean's Office and likely receive a zero on that assignment.

Disability Accommodations

Students with disabilities or who need special accommodations for this class are required to notify the Dean of Students and meet with me so that arrangements can be made. The Cooper Union has limited resources and extra lead time is required for such arrangements to be feasible. In order to receive accommodations for an exam, you must notify me in writing at least two weeks before the accommodations are needed and you must also be registered with the Dean of Students. Students will not be afforded any special accommodations retroactively, i.e., for academic work completed prior to disclosure of the disability to me and the Dean. Disability support services for students are described here.

Medical Absences

Students who have medical excuses for missing class should contact the Dean of Students promptly. Students will be required to provide the Dean of Students with documentation from a medical provider justifying the absence. The Dean of Students will inform me when an absence is due to a valid medical issue/condition so that the absence can be considered excused. It is important to note that even with excused medical absences; a student is still responsible for completing all of the course requirements. If a student's absences have resulted in their missing vital components of in-class discussions and experiences, students may be required to withdraw from a course and retake it even with valid medical excuses. This is entirely at the discretion of the faculty member teaching the course. In addition to communicating with the Dean of Students, students must remain in regular communication with the faculty teaching the course when they need to miss a class.

Mechanical Engineering Program

Course Assessment Chart

ME 412 Autonomous Mobile Robots

Course Objectives	Strategies	Outcomes	Criterion 3 Requirements	Assessment Methods
Collaborate with teammates of mixed skills to solve a robotics problem.	Collect information on year, major, electronics, programming, design, and prototyping experience. Use this information to help form diverse teams and evenly distribute skillsets across all teams.	Students will form interdisciplinary teams. They will experience collaboration among others with different skillsets. They will appreciate the cross-discipline approach to mobile robotics. They will divide responsibilities and rely on each other to complete tasks in a timely manner.	d, f, g.	In-class discussions.
Design and develop sensor, actuator, controller, and software systems that will synergize into an autonomous mobile robot.	Hold lectures and detailed discussions on advantages and disadvantages of mobile robotics technologies and methodologies. Show video documentaries on the state of the art in mobile robotics application and research. Use prototyping facilities and laboratory resources to conduct experiments on systems designed by students.	Students will learn the general principles, technologies, and current and future prospects of mobile robotics. They will research the market for the latest parts with economic considerations. They will endure a hands-on approach to designing a working mobile robot with low budget parts that simulate the principles their higher budget counterparts.	a, b, c, d, e, g, h, i, j, k.	Working model deliverables. Final project performance. Final paper.
Present progress and functional demonstrations to class.	Hold in-class presentations with instructor and class feedback. Schedule presentations of working model deliverables that will incrementally lead up to final working robot.	Students will be prepared for “conference room style” presentations. They will delegate appropriate topics to each other and support each other’s results. They will understand the importance of “milestone” scheduled deliverables.	d, f, g.	Presentations. In class discussions of accomplishments and issues. Working model deliverables.
Document and compile a quality research paper on the project.	Distribute requirements and guidelines for final paper submission. Provide sample past papers with annotations. Address any questions.	Students will learn how to document their experiments along the course of their project. They will each contribute sections and coordinate the overall flow. They will learn how to write a research paper that meets the standards of the scientific community.	d, f, g.	Final paper.