

ME 597 / 780: Autonomous Mobile Robotics

Course Syllabus

Fall 2014

1) Contact Info

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2) Communication

UW Learn: <http://learn.uwaterloo.ca>. UW Learn will be used mainly for distributing homework, lecture notes and course announcements.

3) Course Overview

This course presents the fundamentals of Autonomous Mobile Robotics, including both perception and planning for autonomous operation. Topics in onboard perception include sensor modeling, vehicle state estimation using Bayes Filters, Kalman Filters, and Particle Filters as well as onboard localization and mapping. Topics in Planning include vehicle motion modeling and control, as well as graph based and probabilistic motion planning. An emphasis on examples from recent research in the area pervades the course content.

4) Course Objectives

By the end of this course, you should be able to

- Develop motion and measurement models for a large variety of vehicles and sensors
- Design and implement estimation algorithms for state estimation
- Implement localization and mapping algorithms to enable vehicles to navigate in unknown environments
- Plan collision free paths through environments based on maps
- Automate the operation of a ground robot to simultaneously map and plan its way through an unknown environment

5) Recommended Textbooks

- Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. (2011). *Introduction to Autonomous Mobile Robots (Intelligent Robotics and Autonomous Agents)*, 2nd Ed., the MIT Press, Cambridge, MA.
- Thrun, S., Burgard, W., & Fox, D. (2005). *Probabilistic Robotics*, The MIT Press. Cambridge, MA. Third edition has far fewer mistakes.
- Choset, H., Lynch, K. M., Hutchinson, S., Kantor, G., Burgard, W., Kavraki, L. E., & Thrun, S. (2005). *Principles of Robot Motion: Theory, Algorithms, and Implementations (Intelligent Robotics and Autonomous Agents)*, the MIT Press, Cambridge, MA.

6) Lectures

Schedule: Tuesdays 12:30 – 2:00 in RCH 112 and Wednesday, 4:00- 5:30 in RCH 110.

There will be no lectures on September 16 and 17, 2014, as Prof. Waslander will be away on travel. We will arrange make-up lectures, to be discussed in class.

Week	Description
1	Syllabus, Introduction, Probability, State Space
2	Coordinate Transforms, Motion Modeling
3	Measurement Modeling, Estimation: Bayes Filter,
4	Estimation: Kalman Filter, Extended Kalman Filter
5	Estimation: Particle Filter, Mapping: Localization
6	Mapping: Mapping, EKF SLAM
7	Mapping: Graph SLAM
8	Mapping: Scan Registration
9	Control: Linear, Nonlinear
10	Planning: Motion Primitives, Graph Based
11	Planning: Probabilistic, Optimal
12	Case Study: Quadrotor Helicopters, Review

7) Laboratory Sessions

ME 597 / 780 labs are a bit more unstructured and open ended than you might be used to. We will be working with Turtlebots, using the Robot Operating System (ROS) in Ubuntu Linux with a full simulation environment to test your code before putting it on the actual vehicle. You will be in groups of up to 4, and each group must have access to at least one Linux installation (and preferably a fast one).

There will be three labs:

- 1) Lab #1 – Getting autonomous navigation running on the Turtlebot: Using existing packages from ROS for both mapping with the Microsoft Kinect in 2D and planning a path through the environment, navigate from a known start position to a known end position as quickly as possible.
- 2) Lab #2 – SLAM: Code your own SLAM algorithm to build a 2D map of the environment using one of the methods developed in class.
- 3) Lab #3 – Motion Planning: Using Indoor Positioning data from a camera rig and a fixed map, code your own motion planning algorithm to navigate through the environment. Stretch Goal: repeat with SLAM code from Lab #2.

Each lab will span two weeks of the term, with Mon/Tues/Thurs/Fri slots for each team to have one day with the Turtlebot to test their simulator proven code on the real system. The first week should be sufficient for most teams to complete the lab (if they are organized), and the second week can be used to refine the results or debug issues that arose the first week. In between, it is expected that you will work in the simulator

The instructions for the labs and requirements for the brief lab reports will be posted on UW-Learn before the labs start. Please form teams of 3-4 people and sign up for your lab group slot on Learn by September 12th, 2014. Groups 1-6 have their labs on Monday, 7-12 on Tuesday, 13-18 on Thursday and 19-24 on Friday. All labs start at 2:30 PM and the TAs will be available until 5:30 PM. You can stay longer and return all equipment to the SDC Clean room carts when complete. Please come to the labs prepared, with your base code working in simulation, so you can spend the time on the hardware debugging actual robot problems. Lab reports are due on the Friday one week after all the labs are completed. Late labs will have 25% of the lab mark deducted for each day or part of a day that the lab is late.

Lab #1	Week 1: Sept 22-26 Week 2: Sept 29-Oct 3 Due: Oct 10, 5 PM, Dropbox submission of pdf.
Lab #2	Week 1: Oct 20-Oct 24 Week 2: Oct 27-Oct 31 Due: Nov 7, 5 PM, Dropbox submission of pdf.
Lab #3	Week 1: Nov 17-21 Week 2: Nov 24-28 Due: Dec 12, 5PM, Dropbox submission of pdf.

8) Assignments

Two assignments will be required, and will take the form of a coding exercise in Matlab. A single exam-type question will be assigned, and both your solution method and code will be submitted.

Collaboration is allowed, but groups of up to two students can submit together. A single PDF is to be submitted by each group. Pick an arbitrary group number and sign up with/without a partner.

Assignment #1	Assigned: Oct 1 Due: Oct 24 th , 5PM, Dropbox submission of pdf.
Assignment #2	Assigned: Nov 5 Due: Dec 4 th , 5PM, Dropbox submission of pdf.

9) Graduate Student Projects

The project component for graduate students of the course will be on a topic of their choosing, agreed to by Prof. Waslander upon receipt of the max. two page project proposal due on Friday, September 27th, 5PM in the dropbox (10%). Groups of up to three students are allowed, and the project content should be related to some aspect of the course, although it does not need to pertain strictly to mobile robots. A three page interim update (10%), outlining updated goals, progress, initial simulations and timeline is due on Friday, Nov 8th by 5PM in a dropbox. A final presentation symposium will be held in the first week of December, with 15 minute presentations by each group (30%). A final report is due on Friday, December 12th by 5PM in a dropbox, in two column IEEE conference paper format not to exceed 6 pages (50%).

10) Final Exam

The final will be a 24 hour take-home exam which will require significant coding in Matlab. The final will cover the entire course with an emphasis on the second half. The final exam will fall between December 5-17th on a date to be decided by the class. The final will be posted on UW-Learn at the designated time, and uploaded 24 hours later to the dropbox, or in person (if you used paper). If you wish to work on paper, you must arrange either to hand in the paper at the appropriate time in my office, or to scan it in for online submission. Only a single pdf file will be accepted, containing all figures, text and equations. Please make sure you can scan and combine the files easily into a single pdf before you start the exam.

ABSOLUTELY no collaboration or communication of any kind concerning any part of the exam is allowed during the exam period, except to ask me clarification questions over email.

Talking to anyone about the exam in any way during the 24 hour period is cheating, no ifs, ands or buts. Helping someone else is cheating, even if you get nothing out of it yourself. There is no grey area.

11) Grading Criteria

For ME 597, your final grade is based on the following activities:

- Three (3) Laboratory Reports (30%)
- Two (2) assignments (20%)
- One final exam (mandatory 24 hour take-home exam) (50%)

For ME 780, your final grade is based on the following activities:

- Three laboratory reports (20%)
- Two assignments (15%)
- One project (30%)
- One final exam (mandatory 24 hour take-home exam) (35%)

12) Academic Integrity, Grievance, Discipline, Appeals and Note for Students with Disabilities

See www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf. The text for this web site is listed below.

Academic Integrity

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check www.uwaterloo.ca/academicintegrity/ for more information.]

Grievance

A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline

A student is expected to know what constitutes academic integrity [check www.uwaterloo.ca/academicintegrity/] to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties check Guidelines for the Assessment of Penalties, www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

Appeals

A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals)

www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for Students with Disabilities

The Office for persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.