

# ME 597 / 780: Autonomous Mobile Robotics

## Course Syllabus

### Fall 2013

#### 1) Contact Info

##### Instructor

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#### 2) Communication

UW Learn (Angel Course Environment): <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)*, 2<sup>nd</sup> 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 and Thursday, 1:30- 3:00, RCH 309.

There will be no lectures on October 22<sup>nd</sup> and 24<sup>th</sup>, 2013, 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 and Motion Modeling
3	Controller Design
4	Planning: Graph Based, Probabilistic Methods
5	Planning: Optimal, Measurement Modeling
6	Estimation: Bayes Filter, Kalman Filter
7	Estimation: Kalman Filter, Extended Kalman Filter
8	Estimation: Particle Filter
9	Mapping: Localization, Mapping
10	Mapping: SLAM
11	Mapping: SLAM
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 – 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.
- 3) Lab #3 – SLAM: Code your own SLAM algorithm to build a 2D map of the environment using one of the methods developed in class.

Each lab will span two weeks of the term, with Wed/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 up to 4 people and submit a list of members to me by Friday September 14<sup>th</sup>, 2013. 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 23-27 Week 2: Sept 30-Oct 4 Due: Oct 11, 5 PM, Dropbox submission of pdf.
Lab #2	Week 1: Oct 21-Oct 25 Week 2: Oct 28-Nov 1 Due: Nov 8, 5 PM, Dropbox submission of pdf.
Lab #3	Week 1: Nov 18-22 Week 2: Nov 25-29 Due: Before final exam start, 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 everyone must submit their own code, which may be checked for duplication. A zip file containing all necessary files to run should be uploaded as well.

Assignment #1	Assigned: Oct 3 Due: Oct 25 <sup>th</sup> , 5PM in dropbox, one pdf, one m-file zip archive
Assignment #2	Assigned: Nov 5 Due: Nov 22 <sup>nd</sup> , 5PM in dropbox, one pdf, one m-file zip archive

## 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 25<sup>th</sup>, 5PM in the dropbox. 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, outlining updated goals, progress, initial simulations and timeline is due on Nov 6<sup>th</sup> by 5PM in a dropbox. A half day presentation session will be held on the week of November 25<sup>th</sup> -30<sup>th</sup>, where each team will present their work in 15 minutes. A final report is due on Friday, December 13<sup>th</sup> by 5PM in a dropbox, in two column IEEE conference paper format not to exceed 6 pages.

## 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 6-17<sup>th</sup> 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](http://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/](http://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](http://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/](http://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](http://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](http://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](http://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.