IE 482/582: Special Topics in Robotics

Course Syllabus – Fall 2016

Updated August 18, 2016. Subject to change

Instructor: Dr. Chase Murray
E-mail: cmurray3@buffalo.edu Please include “IE 482:” or “IE 582:” (as applicable) in the subject.
Twitter: @chase_c_murray
Office: 309 Bell Hall
Office Hours: Posted on Slack

Teaching Assistant (TA): See Slack for contact information, office hours, and office location.

• Credit Hours: 3
• Course Websites:
  – Slack: To be announced...
  – Trello: See link in Slack. (Used to post assignments and to track due dates)
  – Box: See link in Slack. (Used to post course documents)
  – UBlearns (Used for all course grades)
• Class Meetings: M/W/F, 11:00 - 11:50am, Bell 216

This course introduces Industrial Engineering students to robots and robotic systems, including the design of robot controllers, coordination of multiple robots, simulation of robotic systems, and optimization of robot task scheduling.
Learning Outcomes

Through this course, students will learn the following skills:

- **Systems Engineering** – Each component of the system will be modular. Students must design the components such that they are integrated into an overall system that works. Additionally, components from one team’s system must be able to interact with components from all other teams.

- **Programming** – In order to make this system work, students must gain familiarity with the Python programming language. Additionally, students will learn how to design a database and to visualize the movement of the UAVs in Google Maps (or something similar).

- **Project Management** – Students will be developing a complex system with numerous deadlines. To be successful, each student team must establish (and hit) their milestones.

- **Optimization** – Each UAV must be given a mission plan (i.e., a sequence of GPS coordinates to visit). Software like Gurobi can be used to solve small integer programs, but custom heuristics may be required to solve larger problems.

- **Research** – To successfully complete the course project, students will need to learn how to find solutions to challenges. This will involve looking for code examples online and reading journal articles.
## Required Course Materials

Students will be required to purchase the following items:

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
<th>Purchasing Options (not an exhaustive list)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Textbook: Programming Robots with ROS, by Quigley, Gerkey, and Smart</td>
<td><a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>1</td>
<td><strong>Raspberry Pi 3 (Model B)</strong> * – This is our computing platform for the course</td>
<td><a href="https://sparkfun.com">sparkfun.com</a>, <a href="https://adafruit.com">adafruit.com</a>, <a href="https://mcmelectronics.com">mcmelectronics.com</a>, <a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>1</td>
<td>Protective Case – Reduce damage to your Pi 3</td>
<td><a href="https://sparkfun.com">sparkfun.com</a>, <a href="https://mcmelectronics.com">mcmelectronics.com</a>, <a href="https://amazon.com">amazon.com</a>, <a href="https://adafruit.com">adafruit.com</a></td>
</tr>
<tr>
<td>1</td>
<td>HDMI Cable (3- to 6- feet in length) – Allows the use of the monitors in the lab</td>
<td><a href="https://sparkfun.com">sparkfun.com</a>, <a href="https://adafruit.com">adafruit.com</a>, <a href="https://monoprice.com">monoprice.com</a>, <a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>1</td>
<td>USB (A) to Micro USB (B) Cable – Allows you to power your Pi 3 from a computer</td>
<td><a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>1</td>
<td><strong>5V 2A+ AC Power Supply</strong> (2A to 2.5A is good) – Allows you to safely power your Pi from a wall socket</td>
<td><a href="https://adafruit.com">adafruit.com</a>, <a href="https://mcmelectronics.com">mcmelectronics.com</a>, <a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>2</td>
<td><strong>8GB micro SD Cards (plus one micro SD adapter)</strong> – The micro SD cards are the hard drive for your Pi 3.</td>
<td><a href="https://sparkfun.com">sparkfun.com</a> [Comes with Micro SD adapter and USB adapter, but only ONE SD card (you need TWO)] <a href="https://amazon.com">amazon.com</a> [Comes with TWO SD Cards and a Micro SD Adapter, but no USB Reader]</td>
</tr>
<tr>
<td>1</td>
<td>USB Micro SD Card Reader – Allows you to make backups of your Pi 3</td>
<td><a href="https://sparkfun.com">sparkfun.com</a> [Comes with Micro SD adapter and USB adapter, but only ONE SD card (you need TWO)] <a href="https://amazon.com">amazon.com</a></td>
</tr>
<tr>
<td>1</td>
<td>USB Keyboard (optional, but recommended)</td>
<td><a href="https://monoprice.com">monoprice.com</a></td>
</tr>
<tr>
<td>1</td>
<td>USB Mouse (optional, but recommended)</td>
<td><a href="https://monoprice.com">monoprice.com</a></td>
</tr>
<tr>
<td>1</td>
<td>USB mic (optional)</td>
<td><a href="https://amazon.com">amazon.com</a></td>
</tr>
</tbody>
</table>

* **Raspberry Pi 3** is required (The original Raspberry Pi, Raspberry Pi 2, or Raspberry Pi Zero are NOT acceptable substitutes).
You Might be Wondering...

1. Do I need to know how to write computer code to take this course?
   No. However, we will be writing code (mostly in Python) every day. The expectation is that you will gain familiarity with programming through the process of completing the course assignments.

2. Is this course open to non-IE students?
   Not this year. This course is designed with IE students in mind. Perhaps in future years we’ll open the course to outside majors.

3. What is ROS?
   From the textbook: “ROS, the Robot Operating System, is an open source framework for getting robots to do things.” It has a large (and growing) user community. ROS simplifies the process of interacting with robots.

4. Why do I need to purchase a Raspberry Pi computer?
   There are a few reasons. First, ROS works best in a Linux environment (not on Windows or Mac). Since most students don’t have a spare laptop on which to install Linux, the Raspberry Pi is an inexpensive, highly portable Linux-capable computer. Second, having everyone on a common system will make it easier to manage the systems we’re developing. Third, there are some fun side-projects that can be conducted with the Raspberry Pi. For example, you can create an Amazon Alexa service with your Pi. Finally, by purchasing your own Raspberry Pi, you’ll be able to use the code you’ve written after the semester is over.

5. Why do I need a Raspberry Pi 3 (Model B), instead of an older Raspberry Pi?
   You will be installing a custom version of the “Raspbian” operating system (OS) that was compiled specifically for the Raspberry Pi 3. This OS will not run on other versions of the Pi.

6. Will this class help me to program robots other than UAVs?
   Absolutely. ROS is currently being used for over 80 different types of robots.

7. Will we be flying UAVs outside?
   Sadly, no. The Federal Aviation Administration (FAA) has not granted us permission to fly. As a result, we will be using flight simulators in this course. However, all of the commands that we send our simulated UAVs will be the same as what we’d send to real/physical UAVs.
Course Outline (subject to change)

The course will begin with an introduction to the software environment:

- **Linux** – We will use a variant of Linux (specifically, Raspbian Jessie) as the operating system.
- **ROS** – The “robot operating system”, which is used to manage communications with our robots. For this class, our robots are unmanned aerial vehicles (UAVs, or drones).
- **Python** – All ROS programming will be done in Python.
- **MAVlink** – A protocol used to send commands – such as “takeoff”, “visit a waypoint”, “loiter”, or “land” – to micro aerial vehicles.
- **HTML and JavaScript** – These Web programming languages will be used to help us visualize our UAVs on maps.

Students will then learn the basics of using ROS to manage the process of sending/receiving messages to/from our robots.

Once students are comfortable with the ROS environment, we’ll begin developing an integrated system that will control the movement of our robots (UAVs) to accomplish a mission. The mission will be to fly multiple UAVs to visit waypoints (GPS coordinates). There’s one catch: The UAVs must be constantly monitored so that mid-air collisions are prevented.

During the last 1/3 of the semester, students will work in small teams to develop effective algorithms for preventing the UAVs from crashing into each other.

<table>
<thead>
<tr>
<th>Week(s)</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &amp; 2</td>
<td>Module 1 – Basic Leaflet Maps</td>
</tr>
<tr>
<td>3</td>
<td>Module 2 – Getting to Know your Raspberry Pi</td>
</tr>
<tr>
<td>4 &amp; 5</td>
<td>Module 3 – Introduction to the Robot Operating System (ROS)</td>
</tr>
<tr>
<td>6</td>
<td>Module 4 – Software in the Loop (SITL) Simulation</td>
</tr>
<tr>
<td>7 &amp; 8</td>
<td>Module 5 – Mission Planning</td>
</tr>
<tr>
<td>9 &amp; 10</td>
<td>Sprint 1 – Avoid Buildings</td>
</tr>
<tr>
<td>11 &amp; 12</td>
<td>Sprint 2 – Avoid other UAVs</td>
</tr>
<tr>
<td>13 − 15</td>
<td>Final Project</td>
</tr>
</tbody>
</table>

Details on these subjects are available in the course box.com repository.

**Grading**

Students will be evaluated on:

<table>
<thead>
<tr>
<th>Item</th>
<th>Approximate Dates</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework Assignments</td>
<td>Miscellaneous, approximately 1 per Module</td>
<td>25%</td>
</tr>
<tr>
<td>Intermediate Projects</td>
<td>Approximately 2 during the last 1/3 of the semester</td>
<td>30%</td>
</tr>
<tr>
<td>Final Project</td>
<td>Due at the end of the semester</td>
<td>30%</td>
</tr>
<tr>
<td>Attendance</td>
<td>Throughout the semester</td>
<td>5%</td>
</tr>
<tr>
<td>Extra Features</td>
<td>Throughout the semester</td>
<td>10%</td>
</tr>
</tbody>
</table>

- **Homework**: Homework assignments are designed to help you better understand the course material, and are aimed at helping you to understand the concepts required to complete the
course project. Although you may discuss the assignments with your classmates, all work that you submit must be your own work. Homework assignments are due at the beginning of lecture on their due date. **Late homework will not be accepted.**

- **Intermediate Projects:** There will be two (2), perhaps three (3) if time permits, intermediate projects that help you to prepare for your final project. These projects will be team-based and will address the following problems: (1) Avoiding collisions with buildings, (2) Avoiding collisions with other UAVs, and (3) Modeling UAV swarm behaviors (time permitting).

- **Final Project:** Your final project will involve the execution of algorithms to safely navigate your UAV through a cluttered environment (with buildings and other UAVs) to visit as many geographic locations as possible within a limited time. A significant portion of your grade will depend on how well your system functions during a simulated demonstration.

- **Attendance:** Attendance will be a component of your grade. You are allowed 2 absences without penalty. Each absence beyond this allowance will result in a 1% reduction in your overall course grade (with a maximum reduction of 5%). Tardiness equals absence; you are expected to arrive to class and be seated by 11:00am.

- **Extra Features:** Throughout the semester there will be opportunities for you to develop novel add-ons to the work we’re doing in class. You have the freedom to select the particular extra features that you want to develop.

- **Quizzes and Exams:** There will be neither quizzes nor exams in this course.

Final course grades will be determined based on the following scale:

- Final Avg $\geq$ 94.0% A High Distinction
- Final Avg $\geq$ 90.0% A- High Distinction
- Final Avg $\geq$ 87.0% B+ Superior
- Final Avg $\geq$ 83.0% B Superior
- Final Avg $\geq$ 80.0% B- Superior
- Final Avg $\geq$ 77.0% C+ Average
- Final Avg $\geq$ 73.0% C Average
- Final Avg $\geq$ 70.0% C- Average
- Final Avg $\geq$ 67.0% D+ Minimum Passing Grade
- Final Avg $\geq$ 60.0% D Minimum Passing Grade
- Final Avg < 60.0% F Failure

Do not expect your grade to be “rounded up.”

**Grade Disputes**

If you disagree with the manner in which an assignment was graded, you may request a re-evaluation of your assignment within two (2) weeks of the due date of that assignment. A re-evaluation request should consist of two (2) components:

- Page 1: A photocopy of the graded assignment.
- Page 2: A detailed explanation, not exceeding one-half page in length, describing why you believe your answer was correct.

The instructor will consider each case at the end of the term, but only if it appears that it may change your final grade. Obvious arithmetic errors will be corrected immediately.
Accessibility Resources

If you require classroom or testing accommodations due to a disability, please contact Accessibility Resources (AR), located in 25 Capen Hall. AR can be reached by phone at (716) 645-2608 or by email at stu-accessibility@buffalo.edu. Please inform the instructor as soon as possible about your needs so that he can coordinate your accommodations. Please also visit http://www.buffalo.edu/accessibility.

Academic Honesty and Integrity

The University at Buffalo has a responsibility to promote academic honesty and integrity and to develop procedures to deal effectively with instances of academic dishonesty. Students are responsible for the honest completion and representation of their work, for appropriate citation of sources, and for respect for others’ academic endeavors. By placing their name on academic work, students certify the originality of all work not otherwise identified by appropriate acknowledgments. Please take the time to visit http://academicintegrity.buffalo.edu.

If you fail to meet the UB policy and the instructor’s policy for academic honesty and integrity, you will receive an ‘F’ in the course, and may be subject to suspension or expulsion from the university.

Violations include, but are not limited to:

- **Cheating on an examination, homework assignment, quiz, etc.** – This includes such things as copying from another’s paper, using unauthorized notes, calculators, etc., or giving or receiving unauthorized aid, such as trading examinations, whispering answers, passing notes, or using electronic devices to transmit or receive information.
- **Plagiarism** – This is using someone else’s work without giving credit. It is, for example, using ideas, phrases, papers, laboratory reports, computer programs, data - copied directly or paraphrased - that you did not arrive at on your own. Sources include published works such as book, movies, web sites, and unpublished works such as other students’ papers or material from a research service. In brief, representing someone else’s work as your own is academically dishonest. *The risk of plagiarism can be avoided in written work by clearly indicating, either in footnotes or in the paper itself, the source of any major or unique idea or wording that you did not arrive at on your own*. Sources must be given regardless of whether the material is quoted directly or paraphrased.
- **Copying any part of another student’s assignment and putting your name on it is plagiarism.**
- **Unauthorized collaboration** – This is working with or receiving help from others on graded assignments without the specific approval of the instructor. *If in doubt, seek permission from the instructor before working with others.* Students are encouraged to learn from one another: Form study groups and discuss assignments, but each assignment must be individual work unless specifically stated and turned in as a group assignment.
- You are encouraged to talk to one another about your assignments, however, all assignments must be done by the student(s) whose name is (are) on it!
- **Multiple submission** – This means using the same work to fulfill the academic requirements in more than one course. *Prior permission of the instructors is essential.*