Online Research Seminar Syllabus

1. Overview

<table>
<tr><td>Title</td><td colspan="3">Sensing for Robotics</td></tr>
<tr><td>Mode</td><td colspan="3">Leading Instructor Sessions & Teaching Fellow Sessions</td></tr>
<tr><td>Targeted Students</td><td colspan="3">This course is for students who wish to learn about sensors and sensing technologies, with a focus on how they are used in robotic systems. The course will be especially useful to students who are studying or wish to study robotics, automation, or control. It will also be useful to students in almost any type of engineering or science.</td></tr>
<tr><td rowspan="4">Prerequisites</td><td rowspan="2">High School Students</td><td>Required course/Knowledge</td><td>Trigonometry, calculus, exposure to C++ or similar programming language.</td></tr>
<tr><td>Recommended Materials for preparing for the course</td><td>Courses available online in calculus, C++, MATLAB, linear algebra (e.g., Coursera, Khan Academy).</td></tr>
<tr><td rowspan="2">College Students</td><td>Required course/Knowledge</td><td>Trigonometry, calculus, exposure to C++ or similar programming language.</td></tr>
<tr><td>Recommended Materials for preparing for the course</td><td>Courses available online in calculus, C++, MATLAB, linear algebra (e.g., Coursera, Khan Academy).</td></tr>
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2. Program Introduction and Objectives

Course Description In a paragraph, please specify：What kind of program is it? What field is the program based in? What knowledge/concepts does the program include? What is the final outcome of the program (types of projects/ What do the students do to demonstrate their learning outcome, etc.)	The course will give a basic introduction to sensing technologies commonly used in robotics. The course will begin with a presentation of general sensing principles and techniques used for sensor integration. The discussion will then move on to discuss specific types of sensors, including optical and image sensors, navigation sensors, range sensors, and force sensors. Students will gain knowledge by solving problems relevant to sensing, and by doing a final project that includes a sensing experiment.
Software/Tools (if any)	C++ programming language, MATLAB, Arduino IDE.

3. Program Schedule

Week		Leading Instructor Session	Teaching Fellow Session (lab/case study, etc.)	Assignment	Reading Materials
1	Topic	Introduction to course	Arduino sensing lab	Students will solve three problems dealing with the lecture topic. (Details will be provided in Assignment 1.)	Fraden, J. (2015) *Handbook of Modern Sensors*, 5th edition, chapters 1-4, 6. Dellaert. Sensor fusion as weighted averaging (https://piazza.com/class_profile/get_resource/hpa4u5hmxk599/hs3g1ig289y5r6)
	Detail	This lecture will provide an introduction to the course. The nature of signals and noise will be discussed. An introduction to sensing technologies will be provided, and techniques for sensing interfacing and sensor signal processing will be presented.	This session will provide an introduction to the programming and use of the Arduino microprocessor for sensing experiments.		
2	Topic	Navigation	Introduction to filter design using MATLAB	Students will solve three problems dealing with the lecture topic. (Details will be provided in Assignment 2.)	Fraden, ch. 9. Shaeffer (2013). MEMS inertial sensors: A tutorial overview. *IEEE Communications Magazine*, 51(4), 100-109. Groves (2015). Navigation using inertial sensors. *IEEE Aerospace and Electronic Systems Magazine*, 30(2), 42-69. Welch & Bishop (2006) An introduction to the Kalman filter. (https://www.cs.unc.edu/~welch/kalman/kalmanIntro.html)
	Detail	This lecture will cover sensing technologies used for navigation, including odometry, inertial navigation, and GPS.	This session will provide an introduction to MATLAB computing software. It will also provide a brief demonstration of techniques for design and use of signal filters using MATLAB.		

3	Topic	Optical and image sensing	Kalman filter lab	Students will solve three problems dealing with the lecture topic. (Details will be provided in Assignment 3.)	Fraden, ch. 5 & 15.
	Detail	This lecture will cover the most common types of optical sensors and image sensors. The lecture will include discussion of interferometry.	This session will provide further details regarding Kalman filtering via an interactive session.		
4	Topic	Range sensing and force sensing	Synchronous detection lab	Students will solve three problems dealing with the lecture topic. (Details will be provided in Assignment 4.)	Fraden, ch. 8 & 10.
	Detail	This lecture will cover common types of range sensors and force sensors relevant to robotics. The concept of synchronous detection will also be presented.	This session will provide further details regarding synchronous detection via an interactive session.		
5	Topic	Research Workshop			
	Detail	See Section 5			
6	Topic	Research Workshop			
	Detail	See Section 5			
7	Final Oral Presentations and Written Reports				

4. Problem Sets/Written Assignments/Quizzes

Total Number of Assignments	_4_times
Submission Deadline	_4_Days after class
Is Mentor needed to review and grade assignment?	Yes
Will a standard answer be provided?	Yes
Will there be Quizzes? How often/how many?	No
Other Requirements (if any)	

5. Final Oral and Written Project

The final project will be performed by groups of 3-5 students each.

The final project will involve designing and performing a sensing experiment using the Arduino microprocessor. In case of need (if a group does not have access to an Arduino and is unable to acquire one), the Teaching Fellow can provide experimental data sets which the group can use. The final project will consist of an experiment in which the group performs synchronous detection, or Kalman filtering, or another sensing experiment of their choice (with prior approval). Full details on the options for the final project will be provided in final project requirements).

Students are required to meet the following objectives before attending the session in Week 5:

- Students should prepare a brief slide presentation describing what they achieved during the week, what problems they encountered, how they solved them or plan to solve them, and any unanswered questions on which they desire assistance.

Students are required to meet the following objectives before attending the session in Week 6:

- Students should prepare a brief slide presentation describing what they achieved during the week, what problems they encountered, how they solved them or plan to solve them, and any unanswered questions on which they desire assistance.

5.1 Final Oral Presentation

- Oral Project Theme: Group project review
- Oral Project Requirements: The oral presentation will be a slide presentation describing the group's project and its results. The oral presentation will be presented by all members of the group, with each student presenting the portion of the project that he or she worked on.

5.2 Will you require a written final report as well? Yes.

- Written Project Requirements:

The students should prepare a final report about their experiment.
The report should be written in traditional laboratory report format, with the following sections:

- Introduction
- Methods
- Results
- Discussion
- References

The report should include figures illustrating the methods and results. Links to all source code and any other source files should be included. Links to videos are also welcome, but are not required. The Discussion section should include discussion of any problems that they overcame during weeks 5 and 6. It should also state clearly which tasks were performed by each student. The References section must include all documentary references and sources used in the project, and citations for all of these should be included in the main text of the report. The Introduction section should

include relevant citations that provide context describing the significance or importance of the subject matter of the report.

6. Suggested Future Research Fields/Direction/Topics

Students may wish to continue to develop their skills with the Arduino, as this is a commonly used tool for sensing and control of robot prototypes. They may also wish to continue their study of signal processing and filtering as they pertain to sensing. To advance further with these technologies, students may wish to continue to strengthen their background in calculus, linear algebra, and computer programming. Students with knowledge and interest in the area of this course may be interested in looking for jobs in robotics and automation, or in other fields of engineering and science.

7. Instructor Introduction

7.1 Instructor Title: Cameron, Ph.D., Research Professor, The Robotics Institute, Carnegie Mellon University, USA

7.2 Instructor Bio

Cameron is a Research Professor in the Robotics Institute at Carnegie Mellon University, and the Director of the Surgical Mechatronics Laboratory. He received the Ph.D. in mechanical engineering from The Johns Hopkins University in 1995, and joined the Robotics Institute the same year. He is also an Adjunct Professor in the Department of Rehabilitation Science and Technology at the University of Pittsburgh. He has been a guest editor of special issues on medical robotics in the *IEEE Transactions on Medical Robotics and Bionics*, the *Annals of Biomedical Engineering*, and the *Proceedings of the IEEE*. His research interests include medical robotics, sensing, control systems, signal processing, learning algorithms, and biomedical applications of human-machine interfaces.

7.3 Instructor Profile Photo