Biology-Inspired Robotics

University of Washington, Autumn 2017

ME 599 (3) *graduate level.* Offered jointly with EE546

Syllabus (v. 3)

Meeting time: MW 10:30-11:50 in MEB room 259
Instructor: Prof. Sawyer B. Fuller
`minster@uw.edu` (I promise to reply to emails within 48 hours, excluding weekends)
Office Hours: Wednesday 1:30-2:20, MEB room 321
Website: `http://faculty.washington.edu/minster/bio_inspired_robotics`
and on Canvas.

1 Summary

Human-made robotic systems are not yet able to match their biological counterparts in many important performance metrics. In particular, robots are *far less robust* to uncertainty and complexity in the environment and their own components. Witness how a mountain goat can quickly scale a steep cliff or a honeybee can navigate to and land on a flower buffeted by wind. These are capabilities that lie far outside the abilities of robotics.

This course takes the view that there are two key elements that differentiate animals from current robots.

1. *Mechanical Intelligence.* Animals' bodies act in concert with their sensorimotor systems in a much more coordinated fashion, which is in many cases manifested as an ability to operate satisfactorily *without any feedback whatsoever.*

2. *Adaptation.* Through both evolution or learning, animals respond to the world by changing in ways that improves their fitness.

We will read and debate primary research papers that have proposed possible solutions for how future robots could make better use of these ideas. As part of the course, we will have the opportunity to create a simulation in which we can attempt to put one or more of these ideas into practice.

2 Course Objectives

This is an advanced, graduate level course designed to help you investigate cutting-edge problems in robotics and biology. By the end of the course, you will be able to:

- Be able to name to two to three revolutionary, biology-inspired advances in robotics and know how to find papers describing them online
- Efficiently read, explain, and note strengths and deficiencies in a research paper
- Find good research problems
- Describe and promote your ideas and discoveries

Prerequisites This course assumes an undergraduate-level training in mechanics, dynamics and controls, as is typically covered in a mechanical engineering Bachelor's degree. You should be prepared to do the following:

- Statics - draw a free body force diagram and solve for forces and moments
- Dynamics - write and solve equations for spring-mass-damper systems
- Differential equations - solve first and second-order ordinary differential equations (ODEs)
- Numerical simulation - simulate a dynamical system of the form $\dot{\boldsymbol{x}} = \boldsymbol{f}(\boldsymbol{x}, \boldsymbol{u})$ (where $\boldsymbol{x}$ is an array of parameters, such as position and velocity, that describe the state of motion) in a numerical computing language such as Python or MATLAB.

3 Coursework

Coursework consists of three main components:

I. Reading and reviewing research papers The homework assignment due for most class sessions will be a written review of an assigned research paper. Your grade will depend on the extent to which you understood and critically analyzed its claims. The review consists of a **paragraph of more than 4 sentences** that *in your own words*

1. succinctly summarizes the main contribution of the paper
2. notes one major strength of the paper
3. notes one major weakness or where it needs correction or improvement, and
4. suggests one question or future work direction that should be followed, or makes some connection to another paper.

Reviews are submitted in Canvas by submitting a post in reply to the appropriate assignment. While you are encouraged to read other posts to get greater insight into the paper and prepare for discussion, you cannot do so until you have posted your own. *Editing posts is not permitted and will result in a zero score.* This prohibits you from making a blank post and then reading other posts before posting your own.

Then, **participate in discussion** about the paper in class. Your *overall course grade depends on your participation.* This helps the instructor know that you read and understood the paper.

II. Paper presentation and discussion lead You will present 1-2 papers (depending on number of students) that you are assigned based on your responses to the paper preferences sheet handed out on the first day of class. For papers you are presenting, you do not have to submit a paper review.

1. Prepare a 30-45 minute informal presentation summarizing the main findings. If you would like feedback on your paper presentation, you are invited to contact Prof. Fuller a few days beforehand, or come to office hours. A suggested structure is
   (a) background on the topic
   (b) key problems and questions
   (c) describe main contribution of paper
   (d) summary of key results
   (e) critique and points for discussion
2. As part of this presentation you will be expected to do extra reading on the topic beyond the assigned paper, and show videos provided in the supplementary material or other informative material related to the topic.

3. Lead a 30-60 minute discussion after your talk. To do this, it is suggested that you prepare three non-trivial questions that result from your attempt to understand the material, its implications, or connections to other work. In addition, read the reviews by other students and **incorporate their questions or comments into the discussion**. For example, a discussion prompt could be: "one reader stated that finding x was not supported by the paper's results. Do you agree or disagree?"

4. As the expert on the paper, you will peer review other students' reviews. By assessing peer performance, you will learn how other students have solved the same task, and get direct experience with what kind of writing does and doesn't work from the perspective of a reader. Grading: 4 pts = sufficient detail, clearly written, and thought-provoking. 3 pts = long enough, but could be more thoughtful. 2 pt = not long, not thought-provoking. 0 pts = no submission. When in doubt, please ask the instructor.

   To receive course credit for performing peer review, **please submit your grades within a week of presenting**. Download the Course Enrollee List from Canvas, insert your grades with Excel or a text editor, and email it to the instructor.

III. Course project This should be related to some aspect of biology-inspired robotics. Projects can be done either individually or in pairs. A few suggested example topics will be provided, or you can choose your own topic (subject to instructor approval of feasibility).

- The primary deliverable for your project will be a **computer simulation**, such as in python or Matlab, and a **presentation** a **short paper** describing the results. Robotic implementations will also be accepted, as long as the main component consists of motion control, and not electronics hardware development, which can consume too much time to fit into a quarter. Example code will be provided that can be used as a starting point for simulations. The specifics of this assignment may vary from year to year. More specifics will be provided early in the quarter.
- To facilitate consistent progress, there will be a few milestones: (see calendar for due dates)
  1. Early in the quarter, each person/team will submit a $<$ 1 page proposal
  2. Mid-quarter, each person/team will give a short, $<$10 minute presentation about their project including a short description, why it is significant, major accomplishments so far, and a set of 2-week milestones tasks until the end of the quarter.
  3. During the final week of the quarter, each person/team will give a short, $<$10 minute presentation of their work. A short 3-5 page paper describing the work will be due the last day of class.

Grading The final grade will be weighted as follows:

20%	paper reviews
20%	participation in class discussions
10%	paper presentation
10%	peer reviews of paper review
40%	final project
	15% problem set 1
	15% proposal
	10% mid-term project update
	30% final presentation
	30% final report

If you feel that an assignment was graded incorrectly, please return your work along with a written description of what you believe to be the grading error. But if you request a review, your grade can go up or **down** as a result, depending on the quality of your argument.

You may have three grace periods of two days each that can be used at any time for paper reviews, but no more than 1 grace period per review. **This does not apply for project due dates or your paper presentation dates** – these cannot be extended.

Course schedule*

Dates	Topic	Paper reviews	Project
Sept 27	no class (instructor away at robotics conference)		
Oct 2, 4	Course overview, paper 0	paper 0 review	problem set 1
Oct 9–30	**Adaptation, learning, and reflexive control** central pattern generators, neural networks, insect visual flight control, reinforcement learning	paper reviews	proposal due
Nov 6, 8	**Project updates**		presentation
Nov 9–29	**Mechanical intelligence** passive dynamic stability, insect robotics, soft robotics, wasp nest building, termite bots	paper reviews	
Dec 4, 6	**Final Project Presentations**		presentation, paper due

*syllabus is subject to change.

Plagiarism Plagiarism (copying other people's work without acknowledgement) or cheating will not be tolerated. Please see `http://www.engr.washington.edu/mycoe/am/ampolicy` for the University of Washington's Policy on Academic Misconduct for more information. If I find any evidence of plagiarism or cheating, I will give a grade of zero for the assignment, and the student may be subject to disciplinary action. If you have any questions, don't hesitate to contact me.