Biology-Inspired Robot Control

University of Washington, Autumn 2015

ME 599 (3) *graduate level.* Offered jointly with AA546 and EE546

Meeting time: WF 3:30-4:50 in MEB room 250
Instructor: Dr. Sawyer B. Fuller
`minster@uw.edu` (I will reply to emails within 48 hours, excluding weekends)
Office Hours: Thurs 3:30-4:30, MEB room 321 (formerly 309 directly across the hall)
Website: materials available on Canvas, announcements will be made through Canvas as well

Summary Despite decades of advancements, human-made robotic systems have not yet reproduced the capabilities seen in biological systems, such as how a mountain goat can scale a steep cliff or a honeybee can navigate to and land on a flower buffeted by wind. **This course will survey the latest thinking about how to improve robots by taking inspiration from animals**. A central theme will be the role of feedback and control.

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 should be able to:

- Understand concepts, methods, and tools used in the field
- Analyze simple biological or robotic system and use tools from control systems to control its dynamic behavior
- Find good research problems
- Describe and promote your ideas and discoveries

Prerequisites This course assumes an undergraduate-level training in 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 representing the state of motion) in a numerical computing language such as Python or MATLAB using a fixed time step, or variable-step integrator such as the ODE45 function.

Coursework Coursework consists of three main components:

1. **Paper reviews and class discussion**. 1–2 papers will be assigned for each lecture, and will be posted at least 1 week ahead of time on Canvas in the "discussion" section. For each lecture, if you are not the discussion leader, you will submit a short review of the paper(s). The idea here is to get you to think critically about what it claims. Read the paper and prepare a **paragraph (more than 4 sentences)**

in your own words that 1) succinctly summarizes the paper, 2) notes what parts need correction or improvement, and 3) how you would build on this work. Then, **participate in discussion** about the paper in class.

- **Submit your reviews in Canvas** by replying to the post in the "discussion" section under the appropriate paper's heading

2. **Paper presentation and discussion lead** for 1-2 papers during the quarter (depending on number of students). Based on your preferences, you will be assigned paper(s) and date(s) at the end of the first week.

   (a) Make a 30-45 minute informal presentation summarizing the main findings. It is more important to convey the main findings of the paper than to show every figure, if there are many. As part of this presentation you will be expected to do extra reading on the topic beyond the assigned paper, and show videos in the supplementary material or other informative material. Before your presentation you should meet with Sawyer 2–3 days beforehand to discuss your presentation. Suggested talk structure:

   - background on the topic
   - key problems and questions
   - main contribution of paper
   - summary of key results
   - critique and points for discussion

   (b) Lead a 30-60 minute discussion after your talk. Prepare three non-trivial questions that result from your attempt to understand the material, or its implications or connections to other work. To keep the discussion going, **read the reviews by other students** and integrate them into the discussion.

   (c) Grade other students' reviews, which will be available in the Discussion section of the course on Canvas, and send grades to me over email, e.g. in a text or excel file, within the first week after your presentation. Grading: 4 pts = sufficiently long, 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 me!

3. **A research project** of your choosing that should be related to control of robot motion. This can be done either individually or in pairs, and will consist of exploring some aspect of bio-inspired robot control. For example, topics could include honeybee-inspired navigation, legged locomotion, swimming, or bacterial navigation. The primary deliverable will be computer simulation, such as in python or Matlab, and 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 paper should be formatted as if it were a submission to an IEEE robotics conference such as ICRA or IROS. You can find templates here: `http://ras.papercept.net/conferences/support/tex.php` (latex, recommended), `http://ras.papercept.net/conferences/support/word.php` (MS Word).

   Milestones (see calendar below for due dates):

   (a) Early in the quarter, each person/team will submit a <1 page proposal to me by email.

   (b) Mid-quarter, each person/team will give a 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.

   (c) During the final week of the quarter, each person/team will give a 10 minute presentation of their work. A 5-10 page paper describing the work will be due during finals week, by email to me.

Grading The final grade will be weighted as follows:

15%	Paper reviews (due by 9 pm the day before class)
15%	Participation in class discussions
20%	Paper presentations
50%	Final project
	10% proposal
	10% mid-term project update
	40% final presentation
	40% 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 – and this does not apply for project due dates.

Course schedule*

Week	Dates	Topic	Paper reviews	Project
1	Sept 30–Oct 2	**Course overview**	paper 1 review due 9pm Oct 1	
2–5	Oct 7–30	**Reflexive control** subsumption architecture, stigmergy, insect flight control, central pattern generators, termite bots	due 9 pm the day before each class	proposal due Oct 14
6	Nov 4–6	**Project updates**		
7–8	Nov 11–20	**Mechanical intelligence** passive dynamic stability, open-loop legged locomotion, fish locomotion	"	
9	Nov 25–Dec 4	**Learning controllers**	"	
10	Dec 9–11	**Final project presentations**		paper due Wed Dec 16

*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.