ME 586: Biology-Inspired Robotics

University of Washington, Autumn 2018

Instructor: Prof. Sawyer B. Fuller

term project overview (v.1)

Overview This year, the term project is *You are the funding agency!* Teams (self-selected, we will have an in-class to help you find a team), will submit and present a research proposal to the class that is related to biology-inspired robotics. The idea is to give you practice at the art of finding research funding. At the end of the quarter, you will change roles and assume the duties of the funding agency (e.g. National Science Foundation, Department of Defense, National Institute of Health) and decide which proposal merits funding. In our case, it will be by giving you enough money to buy the first coffee that will get the project started!

As part of your project, you are expected to perform initial research related to your proposal, because all good proposals contain initial results. These will be in simulation, or on a robot platform. Results will take the form of a few figures in your proposal. Think of this as a sort of advanced problem set, equal in work to 2-3 regular problem sets, but where you assign the problems based on your interest and curiosity.

Proposal format and contents To make the proposal realistic, and to potentially help you in applying for future scholarships, your proposal must conform to the format of the NDSEG fellowship application. The National Defense Science and Engineering Graduate Fellowship (NDSEG) is a prestigious 5-year Ph.D. fellowship whose application is typically due in December. This opportunity is only available to US citizens, but the work you do for this proposal could be adapted to other fellowships. More information is available at `http://www.ndsegfellowships.org/application`. Their main criteria are that:

> A reader should be convinced that your project will make an important contribution and the proposal be a persuasive argument for why your project/proposed training deserves to be funded.

The only differences for your assignment for this course are:

1. You don't need to suggest a specific agency, as is required for NDSEG proposal.
2. The 1-page personal statement and recommendation letters are not required for this assignment.
3. Rather than a 3 page proposal, your proposal will consist 1–2 pages per team member. The division of labor for who contributes what will be decided by the team according to team member preferences.
4. Your team will additionally present your proposal to the class.
5. Note that in the actual NDSEG proposal, you must suggest a specific agency, but this is not a requirement for this course's assignment.

Below is a suggested outline for the sections of almost any good proposal. This same outline can be used effectively for your oral presentation as well.

1. **Summary** (≈150 words). A short summary of your proposal, which describes the main problem and includes a shortened version of the remaining sections below.

2. **Introduction and Technical Need**. Two to three paragraphs to describe to the reader your particular area, and its relation to other investigations. For example, if your topic is ball catching, the first paragraph might summarize the physics of a ball in flight and catching, while the second would describe (and give citations for) previous suggestions for how it is done or learned by humans. Here you will state what is not yet known, and describe who or what would benefit from a better understanding.

3. **Research Objectives.** Answer what the main scientific challenges you would like to address are, given in one of the research objective formats described above. This is a good section to include the preliminary work you have already done this term so that you can use it as a springboard to highlight what still needs to be done. For example, you could say that you have laid the groundwork by implementing a simulation of a ball-intercepting feedback law that shows that a simple servo-feedback controller exhibits characteristics similar to human ball catching, and that you will use this to find out what parameters are most important to match human behavior.

4. **Research Plan.** Describe the series of steps you will perform, and discuss possible expected results. How will you measure progress? Here, you will include a description of the milestones during the course of the research, which for this proposal is a 5-year Ph.D. Include a Gantt chart (google it) to show milestones. Example tasks might be recruiting test subjects, constructing an apparatus, or performing data analysis. It is understood in a research proposal that these plans are not rigid, but represent a best-guess and will change as research progresses.

Note that this outline provides a structure to answer the set of questions that all good proposals must answer, known as the "Heilmeier Catechism:"

- What are you trying to do? Articulate your objectives. In research, the primary product is knowledge. Four generally-acceptable ways to state a knowledge objective are:
    1. "test the hypothesis that ..."
    2. "measure X with accuracy Y"
    3. "prove (or show with a high degree of confidence that) the conjecture that ..."
    4. "apply a method from field A to solve a problem in field B"
- How is it done today, and what are the limits of current practice?
- What is new in your approach and why do you think it will be successful? Who cares?
- If you are successful, what difference will it make?
- What are the risks?
- What are the mid-term and final "exams" to check for success?
- How long will it take?
- (How much will it cost?)

For a fellowship application such as this, you may leave out the last answer because it is understood that the funding will cover tuition and your living expenses.

Initial results To strengthen your proposal in the area of "why do you think you will be successful," you will perform initial work to show the promise of your proposed research. The idea is that this initial work will be the starting point of a more comprehensive investigation that would likely involve physical robots or biological research subjects.

The topic will be of your own choosing in the general area of biology-inspired robotics (which can realistically include all of robotics). The suggested approach will be to get your initial results in simulation, but physical robotic implementations (such as on a platform you have access to such as lego mindstorms, robot arms, etc.) are also acceptable so long as the primary component is not hardware development.

Topic area Your topic may come from many different sources of inspiration: you may have a desire to build on results from a reading from class. Or, take a stroll in the park and look for an interesting animal behavior. Criteria for success is that your simulation/robot have some new capability or new way of doing something - that it can do something interesting rather than wiggle randomly. *If your robot senses the environment, you must use a realistic sensor model.* For example, although it might be convenient, it is not realistic for your robot to know its exact position. Instead, it must use realistic sensors such as light sensors. If you want to use a position sensor like GPS, you must add realistic noise to its readings.

We will hold a brainstorming session in class to select topic areas. Below are listed a few possible topics that you can use for your proposal, or as sources of inspiration:

1. In problem set 1, we explored creating a simulation of "Braitenburg Vehicles": simple robots whose wheel speed depends on light or other environmental stimuli. In this project, you would add additional sensor types, actuator types, memory, or other capabilities. The idea is to build in one or two significant new features into the vehicle to make it exhibit more sophisticated behavior such as alternating between different food sources.

2. In Paper 0:McLeod1996, the algorithm by which fielders catch a ball was explored. In this project, you will write a simulation of the ball's trajectory, subject to wind drag and disturbances. Then, use your simulation to investigate the findings of the paper: what components are necessary to intercept the ball if they use the algorithm suggested in the paper? Does your simulation predict the behavior shown in Figure 3? If not, can you propose a plausible additional mechanism or dynamics model (that is, one that could realistically be implemented by a human, such as a proportional, or proportional-integral controller, for example) that can reproduce the observed behavior?

Grading The most important criteria are that your proposal follow the three "C's": Clear, Coherent, and Complete. The first means it is clear to the reader what you are trying to do; the second is that there be a main theme that is reflected throughout the document, and the third is that it persuasively answer as many of the Heilmeier Catechism's questions as possible. More important than strong "initial results" from this quarter is a clear articulation of how these results will lead into a more in-depth plan of research with clear goals, though strong initial results can help.

Below is the rubric we will use to evaluate proposals on a scale of 1 (poor), 2 (fair), 3 (good), 4 (very good), to 5 (excellent). Note: these review rating numbers are the convention commonly used in proposal evaluation but are not equivalent to your grade for the assignment. The instructor will consider these peer review recommendations but will make the final, curved determination of grades.

An evaluation consists of

1. A sentence or two summarizing the objective of the proposal
2. A list of (+)*strengths* and (-)*weaknesses* in the following areas:
   (a) **Intellectual merit:** the potential to advance knowledge in science or engineering.
   (b) **Broader impacts:** the potential benefit to society. Examples include improving the environment, providing opportunities to underrepresented groups, improving education, and improving research infrastructure.
   (c) **Chances of success:** has the proposer demonstrated that there is a good chance that the proposed research will produce the desired knowledge? Strength of initial results can indicate future promise.
3. A final rating and summary sentence or two that provides justification.

Timeline

- In the middle of the quarter, each team will submit a <1 page "letter of intent" that describes the general area you would like to explore and one or two steps you will perform toward collecting the initial results for your proposal.
- Starting the second-to-last week of class your team will give a 10 minute presentation of your proposal and the initial results for it.

- Your written proposal will be due on the last day of class. That day you will perform a peer review of a small number (~3) of other proposals from the class. Then the votes will be tabulated and we will find out which proposals will receive funding.

You will submit written work on Canvas. Deadlines for these and presentations are listed there.