ME 586: Biology-Inspired Robotics

University of Washington, Winter 2020. Instructor: Dr. Sawyer B. Fuller

Survey and paper preferences.

Please return to instructor by Wednesday January 8.

Name: ________________________________

Part I Survey to get a sense of the background and level of students in the class. Please mark your answers in the space provided and return to the instructor by the end of the second class session.

1. What is your department? (ME, EE, Aero, etc.) _______
2. Master's/Ph.D. and year? (M1, M2, Phd1, etc.) _______
3. Put a check mark next to any of the courses you have already taken. Put a "C" if you are currently enrolled in the course:
   _______ ME 373/374 or equivalent (undergrad): Analysis of spring-mass-damper lumped-parameter dynamics
   _______ ME 471 or equivalent (undergrad): Feedback control theory
   _______ ME 489/599: Biomechanics of movement
   _______ CSE 571: Probabilistic robotics
   _______ EE 543/544: Kinematics of robot manipulators
   _______ AMATH/CSE 579: Intelligent control through learning and optimization
   _______ BI 427: Animal biomechanics
   _______ CSE/EE 576: Computer vision
   _______ ME599: Advanced Robotics (Instructor: Ashis Banerjee)
4. (optional) Are there specific biology-inspired robotics concepts or applications that you are interested in?

Part II Please indicate four papers, based on your interests, that you would be most interested in presenting by making a check mark in the spaces below. These papers are available for download in the "files" section of the course's public website.

1. _______ Braitenberg, V., *Vehicles: Experiments in Synthetic Psychology*, 1984.
   A conceptual investigation about how hard-to-analyze behavior forms the basis of life-like systems.
2. _______ Libby, Moore, Siu, ... and Full, "Tail-assisted Pitch Control in Lizards, Robots, and Dinosaurs," *Nature* 2012.
3. _______ Franceschini, Ruffier, Serres, "A Bio-inspired Flying Robot Sheds Light on Insect Piloting Abilities," *Current Biology*, 2007.
   How insects regulate their altitude above the ground using vision, without a specific sensor for distance, is not known. This paper suggests a new possible explanation that matches anecdotal evidence for how insects respond to wind.

4. _______ Cheney N, Bongard J, SunSpiral V, and Lipson H, "Scalable Co-Optimization of Morphology and Control in Embodied Machines," *ArXiv preprint:* June 2017.
Robots designed through artificial evolution tend to get stuck at local equilibria, limiting their performance. This paper shows that by "protecting" innovations, allowing them a number of generations to adapt to sudden changes in shape, evolution is enhanced.

5. _______ Brooks R, "A Robust layered control system for a mobile robot," *IEEE Transactions on Robotics*, 1986.
Suggested additionally: Brooks R, "Intelligence without representation," *Artificial Intelligence*," 1991.
Rather than robots that perform with a traditional sense-predict-act control loop, Brooks suggests layering reflexive behaviors, each of which can perform a sense-act loop. Higher layers can inhibit lower layers and produce higher-level behaviors in a biologically-inspired framework.

6. _______ Srinivasan, Zhang, Lehrer, & Collett, "Honeybee navigation *en route* to the goal: visual flight control and odometry," *Journal of Experimental Biology*, 1996.
Simple behaviors in the honeybee help them navigate between flowers and the hive.

7. _______ Ijspeert, Crespi, Ryczko, & Cabelguen, "From swimming to walking with a salamander robot driven by a spinal cord model," *Science*, 2007.

8. _______ Smith, "An investigation of the mechanism underlying nest construction in the mud wasp," *Animal Behavior*, 1974.
This paper revealed an example of stigmergy: how animals can perform complicated tasks by storing and interacting with information encoded in the environment, e.g. parts of a nest. In concert with a series of reflexive behaviors in the animal, a sophisticated nest is formed.

9. _______ Jindrich & Full, "Dynamic stabilization of rapid hexapedal locomotion," *Journal of Experimental Biology*, 2002.
A canon mounted to the back of a running cockroach reveals that it recovers from perturbation primarily by properties intrinsic to its musculoskeletal system, rather than by feedback from its nervous system.

10. _______ Wood, Robert J., "The first takeoff of a biologically inspired at-scale robotic insect*," IEEE Transactions on Robotics*, 2008.
Suggested Additionally: Ma, Chirarattananon, Fuller, & Wood, "Controlled flight of an insect-scale, biologically-inspired robot," *Science* 2013.
How to design and build a mechanical fly.

11. _______ SH Collins, Wisse, & Ruina. "A three-dimensional passive-dynamic walking robot with two legs and knees," *The International Journal of Robotics Research*, 2001.
This paper built on a classic passive dynamic walking robot result to add a more realistic 3D walking gait, partly by using swinging arms.
Suggested follow-on paper: Collins, Ruina, Tedrake, & Wisse, "Efficient bipedal robots based on passive dynamic walkers," *Science*, 2005.

12. _______ Webb, "What does robotics offer animal behavior?" *Animal Behavior*, 2000.

13. _______ Werfel, Petersen, Nagpal, "Designing collective behavior in a termite-inspired robot construction team," *Science*, 2014.
Simple rules are downloaded onto a collection of termite robots that encode the design of a construction. Each robot's interaction with the environment and the portion of the construction that has already been placed determine the shape of the final result.

14. _______ Macnab & Koshland, "The Gradient-Sensing Mechanism in Bacterial Chemotaxis," *Proc. National Academy of Sciences*, 1972.
A simple, reactive model that explains how bacteria can move toward a source of sugar without any sort of high-level controller or knowledge of where it is.

15. _______ Hawkes E, Blumenschein L, Greer JD, and Okamura A, "A soft robot that navigates its environment through growth," *Science Robotics*, 2017.

16. _______ De Croon, O'Connor, Nicol, and Izzo. "Evolutionary robotics approach to odor source localization," *Neurocomputing,* 2013.

17. _______Fuller, Straw, Peek, Murray, & Dickinson, "Flying Drosophila stabilize their vision-based velocity controller by sensing wind with their antennae," *Proc. National Academy of Sciences*, 2014.

18. _______ J. Bongard, "Morphological change in machines accelerates the evolution of robust behavior," *Proc. National Academy of Sciences*, 2011.
Scaffolding – helping the learning process by starting with a comparable but easier-to-learn initial task – can help learning to walk go faster.

The following require a background in machine learning and probability as is covered in CSE571, ME/EE 549 (Kalman filtering), or ME599 (Advanced robotics). If you request and are assigned one of the papers below, please make sure to *skim it early* to make sure you will be able to understand it.

19. _______ M Milford and G Wyeth, "Mapping a Suburb With a Single Camera Using a Biologically Inspired SLAM System," *IEEE Transactions on Robotics,* 2008.
This paper uses a rat-inspired minimalist mapping approach to use a single camera to build a topological map and determine where a robot car is in a suburban neighborhood.

20. _______ Heess N, Sriram S, Lemmon J, Merel J, Wayne G, Tassa Y, Erez T, Wang Z, Eslami A, Riedmiller M, Silver D. "Emergence of locomotion behaviors in rich environments." *arXiv:1707.02286.* July 7 2017.
Results from Google's DeepMind: walking behavior emerges.