ME 599/EE 546: Biology-inspired robotics

Lecture 1
Sawyer B. Fuller

Goals:
• Describe the need for “biology-inspired robotics”
• Describe how this course works
biology-inspired robot control

- MW 10:30-11:50 in MEB259
- Instructor: Prof. Sawyer B. Fuller (minster@uw.edu)
- Office hours: Wednesdays 1:30-2:20 in MEB 321
- Prereq’s: an undergraduate degree in ME, EE, or Aero
- Website: http://faculty.washington.edu/minster/bio_inspired_robotics/
  - lecture slides, papers, and other materials will be posted there
  - submit all coursework on Canvas
Robot (*noun*)

a machine capable of carrying out a complex series of actions *automatically*
UW Classes that take a more classical approach to robotics:

• Mechatronics:
  • ME581: Digital control systems (spring)

• Dynamics and control:
  • EE 543/544: Kinematics and dynamics of robot arms/manipulators
  • ME583: Nonlinear control

• Perception and planning:
  • EE 576: computer vision and robotics (spring)
  • CSE 571 Probabilistic Robotics: Perception, localization, mapping (fall)
  • AMATH / CSE 579: Intelligent control through learning and optimization (Emo Todorov)
  • ME599: Advanced Robotics: Perception and multi-robot control (fall. Ashis Banerjee)

• Also:
  • CSE 590: Robotics colloquium seminar (weekly speakers)
  • BI 427: Animal biomechanics (fall, Tom Daniel)
“biology-inspired robotics”
current state of the art

Honda’s Asimo

- very power hungry (20x human of same weight)
- only in controlled environments
current state of the art

Google’s self-driving car

- power hungry - requires a bank of computers
- only in controlled environments
application areas where current robotics is still outperformed by nature

- tiny robots (minimal computation, limited sensing)
- complex environments and robots (models are inadequate and behavior must be learned)
- agile robots (limited time to compute)
- soft robots (nonlinear stress/strain curve hard to model)
animal locomotion

- rich behavioral repertoire
animal locomotion
Animal locomotion

• aggressive, dynamic motions
Animal locomotion

- complex environments
- minimal energy expenditure on computation
Aerial autonomy at insect scale
Ma, Chirarattananon, Fuller, and Wood, *Science* 2013
previous work

• external power
• external sensing
• external computation

current research

• improved capabilities
• onboard sensing
• onboard computing
• onboard power
355 nm laser micromachining
assembly

fold, add piezo & wing
bimorph actuator

piezo actuation

wing

flexure joints

$V_s$
Dr. Sawyer B. Fuller

- **ocelli**
  - (direction of sun/sky)

- **antennae**
  - (wind, smell, sound, gravity)

- **gyroscopic halteres**
  - (angular velocity)

- **flapping wings**

- **compound eyes**
current research

vision (tiny camera)

odor (using moth antenna)

onboard power
Biology-inspired robotics

Bio-Inspiration, Biological Models

Biology
- Observe
- Modeling
- Experiment
- Analysis

Robotics
- Design
- Modeling
- Control
- Experiment
- Analysis

Robotic Technologies
- Bionics
- Biomimetics
- Biorobotics
- Bio-inspired robotics

Synthetic Methodology
Robotics Models

Biological Understanding
- Biological cybernetics
- Artificial life
- Adaptive behaviors
this course focuses on two areas where biology excels

1. mechanical intelligence

2. adaptation through evolution and learning
mechanical intelligence

- this fish is dead!

- system is stable without active feedback

Liao, 2004
robot mechanical intelligence

walks with no feedback and very little power

collins 2001
example of adaptation: reflexive/model-free control
how mud wasps build nests

• minimal internal representation

• cascaded behaviors

Smith, 1978
example of model-free control

a gait learned by a neural network

bongard 2011
how this course works

• This is a research-oriented course

• Three parts to the coursework:

  1. **Reviewing and discussing** 1-2 assigned papers per class session

  2. **Presenting** 1-2 papers to the class
      • assigned based on a lottery and your preferences

  3. **Final project**
      • this year: you’re the funding agency
This year’s final project

• You’re the funding agency!

• each team/individual submits a research proposal at the end of the quarter
  • format: 3 pages, NDSEG graduate fellowship format
  • includes preliminary work you did in this course
    • show a “proof-of-concept” initial work in some aspect of biology-inspired robotics, probably in simulation
  • can be used to for your actual application

• There will be a peer vote for best proposals
  • criteria: quality of preliminary results, future promise

• top 3 proposals split the money
Wednesday

• due by Tuesday 9pm: Review of paper 0
  • because of the short time available, only complete part 1 (synopsis) of the four elements of the review.

next week

• paper 1 review due Sunday
• paper 2 review due Tuesday