CS206: Evolutionary Robotics

Lectures: 209 Votey, 8:30-9:45am Tues/Thurs

Instructor: Josh Bongard (josh.bongard@uvm.edu)
205 Farrell Hall
Office Hours: 10:00am-11:00am Tues/Thurs

Teaching Assistant for this class: Karol Zieba (kzieba@uvm.edu), 347 Votey
Teaching Assistant Office Hours: Mon 4-5pm; Thurs, 4-5pm

Description: This course will explore the automated design of autonomous machines using evolutionary algorithms. The course will cover relevant topics in evolutionary computation, artificial neural networks, robotics, biomechanics, and simulation. Students will conduct a major programming project that will span the course and thus provide hands-on experience with the topics covered. Undergraduates will use their developed system to perform a pre-specified evolutionary robotics experiment; graduate students will formulate their own research hypothesis and use their system to test that hypothesis.

Required Textbook: Floreano, D. & Mattiussi, C. (2008) Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies, MIT Press. (Not available in the bookstore or library.)

Supplementary (Optional) Textbook: Pfeifer, R. & Bongard, J. (2007) How The Body Shapes the Way we Think: A New View of Intelligence, MIT Press. (Available on hold in the library.)

Additional readings from the current literature will be provided.

Prerequisites: Junior standing and programming experience, or instructor permission.

Grading Scheme: The late policy for this class is as follows: material one day late, 25% deduction; two days late, 50% deduction; three days late, 100% reduction.

Ten programming assignments: **10×4=40%**
Over the span of eight weeks, each student will gradually build a software system that allows them to conduct an evolutionary robotics experiment. This system will be composed of 10 software modules. Each programming assignment will involve implementing one of these modules. **Note:** Because the modules will form a final, integrated system, if you fail to hand in one module, you must hand it in along with the new module the following week.

Midterm: **25%**

Final project: **30%**
Over the final six weeks of the semester, each student will use their software system to perform an evolutionary robotics experiment. A written report describing the experiment will be handed in at the end of the semester, and an oral presentation will be given during the exam period. Details about the final project will be available **here**.

Participation: **5%**
Class participation counts toward your final grade. Students are permitted to miss up to and including three classes without being required to provide justification. Missed classes beyond that must be cleared with the instructor.

Course Schedule

[Tu/01/13] L1: Course Logistics; Why Robots? [TAR] [Reading.] [Assn1 assigned]
[Th/01/15] L2: A Short History of Artificial Intelligence [TAR] [Reading.]
[Tu/01/20] L3: Embodied Cognition [TAR] [Reading.] [Assn1 due] [Assn2+assn3 assigned]

The Tools of the Trade

[Th/01/22] L4: Artificial Neural Networks [TAR] [Reading: *BIAI*, pp. 175–191]
L5: Evolutionary Algorithms [TAR] [Reading: *BIAI*, pp. 1–35]
[Tu/01/27] L6: Physical Simulation [TAR] [Bullet User Manual, pp. 11-13, 17-18, 24, 28-29]
[Assignments 2 and 3 due] [Assignment 4 assigned]

History

The First Years of Evolutionary Robotics
[Th/01/29] The Italian Approach; The English Approach [TAR] [*BIAI*, pp. 460–464; 468–477]
[Tu/02/03] The French Approach [TAR] [Reading.] [Assn 4 due] [Assn 5 assigned]

Minimal Cognition
[Th/02/05] Continuous Time Recurrent Neural Networks (CTRNNs) [PDF] [TAR] [Reading, pp. 1-4]
[Tu/02/10] Minimal Cognition [PDF] [TAR] [Reading]
[Tu/02/17] Active Categorical Perception [PDF] [TAR] [Reading]

Legged Locomotion
[Th/02/19] Legged Locomotion [PDF] [TAR] [Reading]
[Tu/02/24] Bipedal Locomotion [PDF] [TAR] [Reading]

Challenges

[Th/02/26] Modularity [PDF] [TAR] [Reading]

[Mo/03/02–Fr/03/06] *Spring Recess*

[Tu/03/10] The Genotype-to-Phenotype Map [PDF] [TAR] [Reading]

Crossing the Reality Gap
[Th/03/12] **Midterm** [Midterm instructions] [Past midterm]
[Tu/03/17] The GOLEM Project [PDF] [TAR] [Reading1] [Reading2]
[Th/03/19] Resilient Machines [PDF] [TAR] [Reading1] [Reading2]
[Tu/03/24] The Radical Envelope-of-Noise Hypothesis [PDF] [TAR] [Reading]
[Th/03/26] Transferability [PDF] [TAR] [Reading]

Collective Intelligence

[Tu/03/31] Swarm Robotics [PDF] [TAR] [Reading]
[Th/04/02] The Evolution of Communication [PDF] [TAR] [Reading]

Evolving Cognitive Architectures

[Tu/04/07] NEAT/HyperNEAT [PDF] [TAR] [Reading1] [Reading2]
[Th/04/09] HyperNEAT for Evolving Robot Bodies [PDF] [TAR] [Reading]

Evolving Robot Bodies and Brains

[Tu/04/14] The First Attempt: Karl Sims [PDF] [TAR] [Reading]
[Th/04/16] LSystem Robots [PDF] [TAR] [Reading]
[Tu/04/21] Soft Robots [PDF] [TAR] [Reading]
[Th/04/23] Why Evolve Morphologies? [PDF] [TAR] [Reading]
[Tu/04/28] Why Evolve Morphologies, Part II [PDF] [TAR] [Reading]

Final Project Presentations

[Date TBD] Exam period: final project presentations (Time TBD)