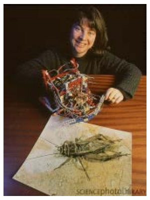 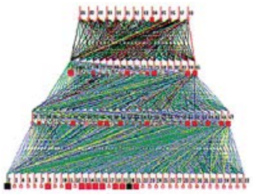 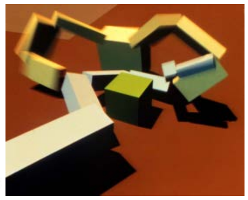 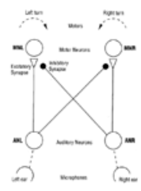 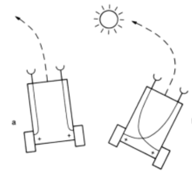 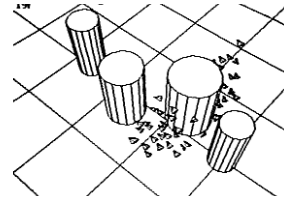

Computational Modeling, Autonomous Robots, & Embodied Cognition

Philosophy 321h, Winter 2016

Pettingill 257, MW, 8:00-9:30 am

Lab, M, 1-4p,\m: The Computer Room, The Imaging Center, Bates College

Professor Seeley, Office Hours: 12:30 – 1:30

G05 Hedge, wseeley@bates.edu

Course Description:
This course explores current research models in embodied cognition and artificial intelligence that use simulations, robotics, and genetic algorithms to explore flexible and adaptive behaviors constitutive of our conception of intelligence. These approaches provide alternative models for intelligent behavior that challenge traditional representational and computational theories of mind. This course includes a weekly lab in which students use hands-on robotics exercises using the Lego Mindstorms and Arduino robotics platforms to explore the ideas they encounter in the class. Topics covered include: the nature of intelligence; the computational theory of mind; representation; embodied cognition; behavior-based robotics; biorobotics modeling; dynamic systems; neural networks; genetic algorithms; learning, memory and categorization; and philosophical questions surrounding the use of computer simulations and robotics as research tools in psychology and cognitive science. No prior programming experience is necessary.

see Rolf Pfeifer's Ted talk, "How the body shapes the way we think"
https://www.youtube.com/watch?v=mhWwoaoxIyc

Narrative:
This course explores current research models in embodied cognition and artificial intelligence that use simulations, robotics, and genetic algorithms to explore flexible and adaptive behaviors constitutive of our conception of intelligence. These approaches provide alternative models for intelligent behavior that challenge traditional representational and computational theories of mind. Standard computational theories of mind model intelligent behavior on the human capacity for rational decision making and general problem solving. On this account thoughts are constructed from abstract symbols that represent aspects of the environment, and minds are treated as general purpose symbol manipulation systems that can be realized in any of a potentially infinite number of natural organisms or artificial systems. Although the computational model of mind has been a powerful research tool in cognitive science, it has proven difficult to implement in computer simulations and mobile robotics. For instance, general purpose problem solvers fall prey to what is called *the frame problem*: they have difficulty filtering task salient information out of noisy signals and so often follow inefficient procedures or get stuck in blind alleys. This and other difficulties have inspired researchers in embodied cognition and artificial life to look towards insect and animal models of intelligent behavior for alternatives.

Our bodies have evolved in lock step with our cognitive systems, and both can be thought of as adaptations fine-tuned to the kinds of environmental features necessary to help satisfy an organisms' basic needs and interests. As a result, the general structure of an organism's body (i.e., its effectors and the structure and placement of its peripheral sensory organs) is a strong constraint on the ways it acquires, manipulates, and uses information from its environment – a constraint that focuses cognitive systems on task salient information in the environment, simplifying the computational demands of flexible and adaptive behavior. Researchers in embodied cognition and artificial life therefore challenge the assumption that minds are general purpose symbol manipulation systems . They argue instead that intelligent behavior emerges from the interaction between (evolved and well adapted) bodies and the environment. To this end research in autonomous (sometimes called agent- or behavior-based) robotics is used to explore the role of agent-environment interactions in the production of intelligent behavior.

Embodied theories of cognition have proven to be equally powerful research tools. However, one can question whether the kinds of adaptive behaviors that can be successfully captured by insect and animal models have the structure necessary to explain the full range of human cognitive behaviors that interest us (e.g., counterfactual reasoning processes involved in long term planning). At the very least these types of processes seem to require abstract concepts that enable organisms to consider alternative strategies, model potential environmental change, and represent novel outcomes. This suggests that rather than think of embodied and computational approaches as mutually exclusive alternatives, perhaps it is better to argue that they compliment one another and can be used together to produce a more comprehensive theory of cognition. The course explores this dialectic. Readings are drawn from contemporary sources in philosophy, psychology, neuroscience, and computer science. In addition to course readings and written assignments, students use a range of computer simulations and robotics exercises to explore the ideas introduced in class.

Course Goals:

a) to introduce and explore the central philosophical problems within cognitive science.
b) to introduce and explore fundamental concepts in autonomous robotics and the contributions this field has made to cognitive science and neuroethology.
c) to introduce and explore embodied cognition as an alternative to classical models of mind and cognition in cognitive science

Requirements:

- A 4 page paper due at the end of January on an assigned topic (10%).
- A 6 page paper due at the midterm on an assigned topic (20%).
- A 6 page final paper on a paper of your choosing (30%).
- Lab exercises (15%)
- Robot Group journal and documentation (15%).

Texts:

- Stefano Nolfi and Dario Floreano, *Evolutionary Robotics* (Cambridge, MA: MIT Press). ***(NFER)***
- Rolf Pfeifer and Christian Schier, *Understanding Intelligence* (Cambridge, MA: MIT Press, 2001). ***(PSUI)***

Recommended Supplemental Text:

- Valentino Braitenberg, *Vehicles: Experiments in Synthetic Psychology* (Cambridge, MA: MIT Press, 1984). ***(VESP)***
- Andy Clark, *Being There* (New York" Oxford University Press, 1996).
- Maja Mataric, *The Robotics Primer*
  http://hci.ucsd.edu/hutchins/cogs8/mataric-primer.pdf

Date	Schedule of Readings	Assignments
01/11	**Course Introduction: representation, computation, & intelligence** • Darwin's earthworms • Kohlers apes • autonomous robots *supplemental readings (not required):* - Charles Darwin, *The Formation of Vegetable Mould Through the Actions of Worms with Observations on Their Habits*, New York: D. Appleton and Company, 1896, 55-89. ***(ebook, Ladd Library)*** http://www.biodiversitylibrary.org/title/48549#page/71/mode/1up - Wolfgang Kholer, *The Mentality of Apes*, *2nd Edition*, New York: Harcourt, Brace, & Company, 1927, 7-9; 39-45; 135-139. ***(L)*** - Daniel Dennett, "True Believers: The Intentional Strategy and Why It Works," in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 57-80. ***(L)*** **Lab 1: Fixed Action Patterns** • Introduction to Robot C • Introduction Lego Mindstorms Robots	
01/13	**A brief primer on intelligence II: Symbol Systems and the Chinese Room** • Haugeland, What is mind design?: 8-21. ***(LYCEUM)*** • Searle, Minds, brains, and programs: 183-193. ***(LYCEUM)*** • Pfeifer & Scheir: The symbol grounding problem: 15-20, 69-71 ***(PSUI)***	
01/18	**MLK Day / No Class!**	
01/20	**A brief primer on intelligence III: The Frame Problem** • Pfeifer & Scheir, Situatedness & the Frame Problem: 65-69; 71-73 ***(PSUI)*** • Boden, Some philosophical problems: 769-775. ***(LYCEUM)*** • Copeland, Knowledge Representation: 91-95. ***(LYCEUM)***	
01/25	**Solving the frame problem: the subsumption architecture** • Brooks, Intelligence without representation: 395-420. ***(LYCEUM)*** • Pfeifer & Schier, The Subsumption Architecture: 199-206; 213-218. ***(PSUI)*** **Lab 2: Braitenberg Vehicles** • please look at *Vehicles 1-4* (pages 1-19) of Valentino Braitenberg's *Vehicles* • https://drive.google.com/a/bates.edu/file/d/0B8DzH-_rb9JvQWUtNXdjM2VCaTQ/edit	
01/27	**A brief primer on intelligence IV: insect intelligence** • Beer, Chiel, & Sterling, A Biological perspective on…: 169-186. ***(L)***	1st paper Friday @ 5pm.
02/01	**Intelligence, Invertebrates, and Autonomous Robots** • Webb, Robots in invertebrate neuroscience: 359-363. ***(LYCEUM)*** • Webb & Harrison, Phonotaxis in crickets and robots: 533-552. ***(LYCEUM)*** * Huber & Thorson, Cricket Auditory Communications: 60-68. ***(LYCEUM)*** * Webb, A cricket robot: 94-99. ***(LYCEUM)*** * Webb, A spiking neuron controller for robot phonotaxis: 3-20. ***(LYCEUM)*** **Lab 3: Didabots / stigmergy & collective intelligence** • Maris & te Boekhorst, Exploiting Physical Constraints: 1-6. ***(L)*** • Dawson et al, Embodiment, Stimergy, and Swarm Intelligence: 226-237. ***(Onl)*** ***** Hafner, An example of cooperative behavior: 1-3. ***(Onl)***	
02/03	**Self Organization & Intelligence: Artificial Neural Networks I** • Nolfi & Floreano, The Role of Self-Organization…: 6-19. ***(NFER)*** • Pfeifer & Schier, Neural Networks for Adaptive Behavior: 140-177. ***(PSUI)***	

02/08	**Self Organization & Intelligence: Artificial Neural Networks II** • Pfeifer & Schier, Neural Networks for Adaptive Behavior: 140-177. ***(PSUI)*** * Nolfi and Floreano, Evolutionary and Neural Techniques: 27-38. ***(NFER)*** **Lab 4: Lemmings I** Dawson et al, Embodiment, Stimergy, and Swarm Intelligence: 253-262. ***(Onl)***	
02/10	**Self Organization & Intelligence: Evolutionary Robotics I** • Pfeifer & Schier: Artificial Evolution & Artificial Life (excerpt): 227-241. ***(PSUI)*** • Nolfi & Floreano, How to Evolve Robots: 49-68. ***(NFER)***	
02/15	**Self Organization & Intelligence: Evolutionary Robotics II** • Sims, Evolving virtual creatures: 1-8. ***(LYCEUM)*** **Lab 5: Lemmings II** * Holland and Melhuish, Stimergy, Self-Organization, and…: 1-30. ***(Onl)*** ***** Perez and Dawson, A Brick Sorting LEGO Robot: 19-23. ***(Onl)***	
02/17	**No Class**	
02/20 - 02/28	**WINTER BREAK**	
02/29	**Embodiment & Intelligence: Morphology vs. Computation** • Pfeifer & Schier, Design principles of Autonomous Agents: 299-325. ***(PSUI)*** • Pfeifer & Bongard, *How the Body Shapes the Mind*: 123-137. ***(LYCEUM)*** **Lab 6: Flocking** • Reynolds, Flocking behavior: http://www.red3d.com/cwr/boids/ • dynamics & cognition: TBA	
03/02	**Embodiment & Intelligence: sensorimotor coordination & concepts I** • Pfeifer& Schier, The principle of sensorimotor coordination: 377-434 ***(PSUI)***	
03/07	**Embodiment & Intelligence: sensorimotor coordination & concepts II** • Pfeifer & Scheir, Human memory: a case study: 503-534. ***(PSUI)*** **Lab 7: The Data File: putting it all together**	
03/09	**Embodiment & Intelligence: sensorimotor coordination & concepts II** • Pfeifer & Scheir, Human memory: a case study: 503-534. ***(PSUI)***	
03/14	**Embodiment & Intelligence: sensorimotor coordination & concepts III** • Glenberg, What memory is for: 1-19. ***(LYCEUM)*** • Land & McLoed, From eye movements to…batsmen: 1340-1345 ***(LYCEUM)*** • Land & Hayhoe, I what ways do…everyday activities: 3559-3565. ***(LYCEUM)*** * Ballard et al, Deictic codes for the embodiment of cognition: 1-20. ***(LYCEUM)*** **Lab 8: Artificial Neural Networks – Hebbian Learning**	
03/16	**Beyond Reactive Intelligence I** • Nolfi & Floreano, The Power & Limits of Reactive Intelligence: 93-120. ***(NFER)*** * Cheng, Whither Geometry? 355-361. (***LYCEUM)***	

03/21	**Beyond Reactive Intelligence II** Nolfi & Floreano, Beyond Reactive Intelligence: 121-152. ***(NFER)*** **Lab 9: Artificial Neural Networks – Learning & Extinction**	
03/23	**Beyond Reactive Intelligence II**I • Nolfi & Floreano, Learning & Evolution: 153-188. ***(NFER)***	
03/28	**Navigation, Localization, & Mapping** • Mataric, Navigating with a Rat Brain…: 169-175. ***(L)*** • Mataric, Think the Way You Act, Behavior Based Control: 187-205. (***LYCEUM)*** **Lab 10: Genetic Algorithms: Evolving Neural Control for Wall Avoiders**	
03/30	**Navigation without Localization & Mapping** • Hutchins, *Cognition in the Wild*, Navigation: 49-116. (***LYCEUM)*** • Hutchins & Hinton, Why the Islands Move: 629-632. ***(LYCEUM)***	2nd paper Friday @ 5pm.
04/04	**Navigation without Localization & Mapping** • Hutchins, *Cognition in the Wild*, Navigation: 49-116. (***LYCEUM)*** • Hutchins & Hinton, Why the Islands Move: 629-632. ***(LYCEUM)*** **Lab 11: Genetic Algorithms: Evolving Neural Control for Wall Avoiders**	
04/06	**NO CLASS: Group Robotics work**	
Exam Week	Robot Rodeo: Exam Date	Final Papers Due End of Exam Week Robot Group Journals & Documentation Due End of Exam Week