



CSCI 564 (NEUR 535): Fall 2009 Brain Theory and Artificial Intelligence

Tu Th 11:00am-12:20pm

Instructor: Prof. Michael A. Arbib; HNB-03, (213)740-9220, arbib@usc.edu. (Office hours: 1:30-2 pm TuTh, HNB 03.)

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Brains have proved highly successful in integrating perception, planning, memory and action in guiding creatures that interact with a complex world. The course has two overlapping aims: “To understand the workings of our own brains” and “To explore the implications of brain function for developing exotic, highly distributed adaptive embodied computing systems,” although the emphasis will be on the former. As we move to distributed computation, sensor networks, embedded systems, and robots interacting with humans in complex ways, we will discover Brain Operating Principles (BOPs) that will not only illuminate our understanding of ourselves but will also guide us in the development of new brain-style adaptive, distributed embedded computing technologies.

The course will introduce you to the basic facts about the brain, teach you how to model various facets of brain function conceptually; how to implement those models in our Neural Simulation Language (NSL), and how to keep track of BOPs and brain models in our Brain Operation Database (BODB).

Course Requirements:

The mid-term exam will cover the entire contents of the lectures and required readings up to that time. The final will emphasize, but not be restricted to, material covered after the mid-term.

Each student will be required to prepare a three- or four-part project to get an overall feel for the architecture of a largish brain model, understand how models are related to empirical data, and think through the details of at least one important subsystem.

- Part 1: Document a brain model from a list given by the instructor.
- Part 2: Document a follow-up model and related brain data that you find in the literature.
- Part 3: Specify a project for developing a brain-inspired model testable against brain data or the demands of an AI application.
- Part 4: Implement the model specified in Part 3.

Students who perform well on Part 3 will be invited to submit a Part 4 in which they develop an implementation based on Part 3, but such students need only work on Part 4 if they feel it will improve the benefits they gain from the course. (See below for the implications of this choice for grading.) **Prerequisites:**

Graduate standing; ability to program in MatLab *or* willingness to learn to program in MatLab; basic undergraduate mathematics (e.g., linear algebra and elementary differential equations; a summary of basic knowledge will be posted on the website). Basic background in neuroscience will *not be required* it will be supplied in class. However, students with experience in neuroscience are still invited to join the course to gain an understanding of the computational approach to the brain.

Neuroscience and other non-engineering students less skilled in computer programming will still study MatLab and the NSL homework but with a reduced grade loading so long as this is negotiated in the first 3 weeks of the course and may either (a) negotiate a project that involves analysis of a neural system without computer implementation, or (b) conduct joint work on Parts 3 and 4 of the Project taking responsibility for literature review and system design rather than programming..

Texts:

[NSL Book]: A. Weitzenfeld, M.A. Arbib and A. Alexander, 2002, *NSL Neural Simulation Language*, MIT Press (A draft version is available at <http://neuroinformatics.usc.edu/mediawiki/index.php/NSL#Manual>

[HBTNN] Selected articles from M.A. Arbib, Ed., 2003, *The Handbook of Brain Theory and Neural Networks*, MIT Press, **Second** Edition. (The Handbook is available as one of the reference works on-line at the Cognet website of The MIT Press. This can be reached from USC machines by going to <http://cognet.mit.edu>.)

Other articles will be placed on the class Website including extracts from

[TMB2] M.A. Arbib, 1989, *The Metaphorical Brain 2: Neural Networks and Beyond*, Wiley-Interscience.

Grades:

Homework: 25%; Mid-term: 25%; Final 25%; Project Part 1 - 5%; Part 2 - 10%; Part 3 - 10%, Part 4 – 25%

Total Grade for Students who do not do Part 4:

Homework + Mid-term + Part 1 + Part 2 + Part 3 + Final

Total Grade for Students who do Part 4:

Homework + Mid-term + Part 1 + Part 2 + Part 3 + Max(Final, Part4).

Part of the Homework grade will be based on your answers to questions designed to encourage you to keep on top of the course as the semester progresses: (a) For on campus students, handed out at the start of each class, and due at the end of the class; (b) For DEN students, emailed after each class and due back within 30 hours.

Syllabus (Version of 08-19-09. Subject to Updating)

	Topic	Readings
1. 8/25	Brain-Inspired Computer Architecture	Deepak Khosla (September 2006) Biologically-Inspired Cognitive Architecture for Integrated Learning, Action and Perception (BICA-LEAP), HRL Laboratories, Malibu http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.112.8842&rep=rep1&type=pdf Cynthia Breazeal, Larry Barsalou & Linda Smith (May 2007) An Integrated Architecture for Grounded Intelligence in its Development, Experiential, Environmental, and Social Context, MIT Media, Cambridge MA. http://handle.dtic.mil/100.2/ADA473768
2. 8/27	The Brain as a Network of Neurons	TMB2: Chapter 1; Section 2.3; Section 9.1 HBTNN: Part I, Sections I.1 and I.2; Part III, Single Cell Models
3. 9/1	The Structure of Brains	TMB2: Section 2.4
4. 9/3	Early Visual Processing	TMB2: Chapter 3.3 HBTNN 2e: Feature Analysis
5. 9/8	Differential equations for Neural Networks; Arrays; Winner-Take-All	TMB2: 4.3, pp. 194-197. Prey Selection - or Winner Takes All; 4.4. A Mathematical Analysis of Neural Competition HBTNN: Part I, Sections I.1 and I.2; Part III, Single Cell Models
6. 9/10	Competitive Queuing and Visual Attention	HBTNN article on competitive queuing; Didday, R. L. & Arbib, M. A. (1975) Eye movements and visual perception: 'two visual systems' model. <i>International Journal of Man-Machine Studies</i> , 7, 547-569; Itti, L. & Koch, C. (2000) A saliency-based search mechanism for overt and covert shifts of visual attention. <i>Vision Research</i> , 40, 1489-1506.
7. 9/15	Practical Introduction to NSL-MatLab 1: Introduction to the MatLab & Simulink Environment. (Everist)	MatLab & SimuLink documentation (to be specified)
8. 9/17	Practical Introduction to NSL-MatLab 2: Winner-Take-All (Everist)	NSL Book: Chapter 1 & Chapter 2: The book uses Java and C++, but we will use the MatLab version of NSL.
9. 9/22	Depth Perception + Optic Flow	TMB2 Sections 7.1 & 7.2; HBTNN article; HBTNN articles. Supplementary reading: Poggio, T., Torre, V., and Koch, C., 1985, Computational vision and regularization theory, <i>Nature</i> , 317:314-319; Poggio, T., Gamble, E.B., and Little, J.J., 1988, Parallel integration of visual modules, <i>Science</i> , 242:436-440.
10. 9/24?x	Schemas & Cooperative Computation HEARSAY & VISIONS	TMB2: Sections 2.1, 2.2, 4.2 (on HEARSAY), 5.3 (VISIONS) HBTNN: Visuomotor Coordination in Frog and Toad; Hybrid Symbolic/Connectionist Systems
11. 9/29	Scene perception – Bayesian Methods	To be specified
12. 10/1	BOPS & BODB; The 3 or 4 Parts that make one Project; Brief introduction to Dominey-Arbib model	Anon Plangprasopchok, Nantana Tinroongroj, James Bonaiuto & Michael A. Arbib, September, 2008, <i>User's Manual, The Brain Operation Database: BODB</i> , (Version 2.5), Los Angeles: University of Southern California Brain Project (USCBP). Reprint: Dominey, P. F., and Arbib, M. A., 1992, A Cortico-Subcortical Model for Generation of Spatially Accurate Sequential Saccades, <i>Cerebral Cortex</i> , 2:153-175.

13. 10/6	More on the Dominey-Arbib Model	Required Readings: TMB2, Section 6.2. HBTNN: Collicular Visuomotor Transformations for Saccades Supplementary Reading: NSL Book: Chapter 14 – The Modular Design of the Oculomotor System in Monkeys [Even though it uses Java-NSL, not MatLab-NSL, this will help you prepare for the lecture on 10/16: Practical Introduction to MatLab-NSL 4: Basal Ganglia: Learning Associations and Sequences.]
14. 10/8x	Practical Introduction to NSL-MatLab 3: Dynamic Remapping (Everist)	NSL Book: Chapter 14 – The Modular Design of the Oculomotor System in Monkeys
15. 10/13	Computing with Attractors	Required: TMB2: 3.2. Material on Stability; 8.2 Material on Associative Networks and Hopfield Networks. HBTNN 2: Associative Networks (Anderson); Computing with Attractors (Hertz). Optional: HBTNN: Dynamics and bifurcations in neural nets (Ermentrout).
10/15x	Mid-Term	Closed Book: Covers all material through Lecture 14. Conceptual material on NSL may be included, but programming details will not.
16. 10/22	Adaptive Networks 1: Hebbian learning; Supervised Learning (Perceptrons)	
17. 10/27	Adaptive networks 2: Landmark learning Reinforcement learning;	Required Reading for lecture: HBTNN: Reinforcement Learning; Reinforcement Learning in Motor Control
18. 10/29	Basal Ganglia: Learning Associations and Sequences	HBTNN: Basal Ganglia; Dopamine, Roles of. Reprint: Dominey, P.F., Arbib, M.A., and Joseph, J.-P., 1995, A Model of Corticostriatal Plasticity for Learning Associations and Sequences, <i>J. Cog. Neurosci.</i> , 7:311-336
19. 11/3	Adaptive networks 3: Gradient descent and backpropagation; backpropagation through time	HBTNN: I.3 Dynamics and Adaptation in Neural Networks; Perceptrons, Adalines, and Backpropagation; Sensorimotor Learning Supplementary Reading: HBTNN: Backpropagation
20. 11/5	Practical Introduction to NSL-MatLab 4: Basal Ganglia: Learning Associations with Reinforcement Learning (Everist)	
21. 11/12	Feedback & Feedforward	TMB Section 3.2
22. 11/14	Forward & Inverse Models	HBTNN: Sensorimotor Learning; Jordan, M. I. & Rumelhart, D. (1992) Forward Models: Supervised Learning with a Distal Teacher. <i>Cognitive Science</i> , 16, 307-354.
23. 11/17	Population coding	Georgopoulos “versus” Hubel & Wiesel. Supplementary Reading from HBTNN: Decoding Population Codes; New Pouget article
24. 11/19	The FARS model of control of grasping	TMB 2, Sections 5.3, 6.3. Fagg, A. H., and Arbib, M. A., 1998, Modeling Parietal-Premotor Interactions in Primate Control of Grasping, <i>Neural Networks</i> , 11:1277-1303. Supplementary Reading from HBTNN: Grasping Movements: Visuomotor Transformations.

25. 11/24x	Modeling the mirror neuron system (Bonaiuto)	Oztop, E., and Arbib, M.A., 2002, Schema Design and Implementation of the Grasp-Related Mirror Neuron System, <i>Biological Cybernetics</i> , 87:116-140 Bonaiuto, J., Rosta, E., and Arbib, M.A., 2005, Extending the Mirror Neuron System Model, I: Audible Actions and Invisible Grasps
26. 12/1	Prefrontal cortex and decision making	Shadlen & Gold HBTNN 2e. Required: Cortical Memory; Prefrontal Cortex in Temporal Organization of Action; Patricia S. Goldman-Rakic, Seamas P. O Scalaidhe, and Matthew V. Chafee, 2000, Domain Specificity in Cognitive Systems, In <i>The New Cognitive Neurosciences</i> (2nd ed.), Edited by Michael S. Gazzaniga et al., Cambridge, MA: MIT Press. (You can find this book by going to Cognet.)
27. 12/3	From Action to Language: The Mirror System Hypothesis	Required: Arbib, M.A., 2005, From Monkey-like Action Recognition to Human Language: An Evolutionary Framework for Neurolinguistics, Behavioral and Brain Sciences, 28:105-167.) and recent papers
12/15, 8-10	Final Exam	Closed book. Covers all non-NSL-MatLab material in course, but with emphasis on Lecture 15 onward.