Laboratory in Neural Modeling
And
Brain-Like Computation

Cognitive, Linguistic and Psychological Sciences CLPS 1491

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What I cannot create, I cannot understand.
Richard Feynman, 1988
(On his blackboard at the time of his death.)

CLPS1491 is an introduction to neural network models for cognition, with various computer exercises as laboratory "experiments."

The lectures in the course will be in Metcalf 104, MWF, 10:00-10:50.

The course has recently become more concerned with issues involving the construction of brain-like computers, that is, a hardware (brain) and software (cognition) architecture that can be programmed to perform efficiently a number of important tasks that are hard for traditional (Von Neumann) computers to do.

My feeling is that understanding the brain in any sense - either in cognitive science or neuroscience - needs to be constructive and computational, that is, theories actually have to work well enough to do cool stuff. I feel it is critical to take a very wide perspective. The neuroscience is there to get the cognition and behavior implemented properly otherwise the animal will not survive. Therefore you have to work with both areas, and perhaps with computer science, at once.

The mathematics is only there to provide insights for people (us) into how the system is working because we want to understand it or reproduce its computational strategies artificially. Models we as humans can understand and work with tend to be simple. The brain could care less about what we think.

The instructor of this course is **James Anderson.** The teaching assistant this year is David Mely. Email addresses are David Mely@brown.edu and James Anderson@brown.edu.

Conference hours will be arranged later. Mely and Anderson are often available at times other than conference hours but may be surly when disturbed, Anderson in particular.

The email system is much preferred. Email gives fast response and requires precision in communication that is conducive to well posed questions and rapid answers. Text messages will be ignored.

When you do the computer assignments, **you can use any language or any machine you want**. However, if you do use your own machine, or work in a language other than ones we know, you are on your own as far as most detailed technical help is concerned. In the recent past almost all students have used their own computers.

Course Topics

1 Random number generators. Statistical properties of random vectors. Brief discussion and demonstration of **Monte Carlo** methods. Generation of random vectors.

2 Why we need to build brain like computers.

3 Biological background: Brief discussion of neuron function and brain organization. Neurons as transducers and integrators of their inputs. Fascinating yet profound historical anecdotes and philosophical digressions.

4 Signal averaging as useful signal processing and useful cognitive technique.

5 The wonders of animal eyes. *Limulus*: a simple visual system and its simulation. Deep lessons about neural computation derived from *Limulus*.

6 Memory. The Hebb synapse and the linear associative model. The biology of the **Hebb** synapse. Systems using the simplest form of Hebb synapse.

7 The linear associator extended. Simple error correction algorithms. Gradient descent. The **Widrow-Hoff** (LMS) algorithm: its use and limitations.

8 Concepts, categories, and prototypes and categories in cognitive science. 'Concept forming' averaging neural net systems and their implications and applications. Language as the paradigm of categorization.

9 Associative computation and semantic networks. Network disambiguation.

10 When it comes to association, Aristotle got it right. So did William James.

11 Attractor networks and non-linear dynamical systems. **Hopfield** networks, **Boltzmann** machines. Energy functions. The **BSB** model. Simulated annealing. Categorical perception. Unsupervised clustering and a radar application.

12 Speculations about brain like computer architectures: hardware and software. The Ersatz Brain Project. The Network of Networks. If one dynamical system is good, how about lots of them?

13 Building a brain for fun, insight, and profit.

14 Research project in neural modeling. This is the most important part of the course and will form the major part of your grade, if such things concern you. Neural networks are tools to be applied to problems. You should be thinking about what you want to do all during the term.

Texts

1. (Required) *An Introduction to Neural Networks*, James A. Anderson, MIT Press.

2. A good reference book for the mathematically oriented is Simon Haykin's, *Neural Networks and Learning Machines* (Prentice-Hall), now in a third edition but expensive. This book is designed for graduate level engineers and is difficult but very good on the mathematical analysis of algorithms.

3. There are some good books on machine learning available now, of which neural networks form one part. This area changes fast and look around for the best current review.