Harvey Mudd College

Computer Science 152

Neural Networks

Fall 2006

Trailer:

Can a computer be taught to read words aloud, recognize faces, perform a medical diagnosis, drive a car, play a game, balance a pole, predict physical phenomena?

The answer to all of these is *yes*. All these applications and others have been demonstrated using varieties of the computational model known as "neural networks", the subject of this course.

The course will develop the theory of a number of neural network models. Participants will exercise the theory through both pre-developed computer programs and ones of their own design.

Instructor:

Professor Bob Keller, x 18483, 1253 Olin, keller at cs.hmc.edu

Catalog Description:

Modeling, simulation, and analysis of artificial neural networks. Relationship to biological neural networks. Design and optimization of discrete and continuous neural networks. Backpropagation, and other gradient descent methods. Hopfield and Boltzmann networks. Unsupervised learning. Self-organizing feature maps. Applications chosen from function approximation, signal processing, control, computer graphics, pattern recognition, time-series analysis. Relationship to fuzzy logic, genetic algorithms, and artificial life.

Prerequisites:

CS 60 (Principles of Computer Science) and
Mathematics 12 (Multi-variate Calculus and Linear Algebra),
or permission of the instructor.

Grader/Tutor:

Carl Nygaard

Text:

Vojislav Kecman, Learning and Soft Computing, MIT Press, 2001, ISBN 0-262-11255-8

Course Requirements and Grading:

There will be some homework, mostly programming assignments, but no exams. The assignments will constitute about 40% of your grade. 40% of your grade is from a substantial final project involving either creation of a working neural network application or a research paper. The grade on the project will be determined by the comprehensiveness and degree to which you explored competing approaches. The projects will be presented orally. 10% of your grade will be based on a preliminary presentation you make, ideally on material related to the your project. Finally, 10% will be based on general participation, which includes attendance.

CS 152 Topic Outline (Approximate):

Because I am not here the first week of class this year, I am permuting the introductory material slightly from its logical progression. Also, I reserve the right to change some topics.

Rather than start reading with chapter 1, which contains a lot of the math basis, you may wish to skim that and we'll bring in the math as needed. We're going to start with chapter 3, which is the most basic on the topic of neural networks.

Week 1: Single-Layer Networks (Chapter 3)

- Perceptrons
- Adalines
- Least Mean Square (LMS) algorithm

Week 2:

- Biological motivation
- Historical overview
- Perceptron convergence theorem

- Adaptive filtering

Weeks 4: Backpropagation (Chapter 4)

Week 4: Backpropagation performance optimization

- Conjugate gradient
- Newton's method
- Levenberg-Marquardt
- Quickprop
- Resilient backpropagation

Week 5: Sequential networks

(Sections 7.1-7.2 and supplementary material not in text)

- Adaptive filtering
- Time series
- Backpropagation through time
- Real-time recurrent learning
- Control applications
- Finite Impulse Response (FIR) MLP
- Temporal difference Method

Week 6: Radial basis function networks (Chapter 5)

Week 7: Support Vector Machines (SVM) (Chapter 2)

Week 8: **Supervised and unsupervised Hebbian learning** (supplementary material)

- Supervised Hebbian learning
- Pseudoinverse rule
- Filtered learning rule
- Delta rule
- Unsupervised Hebbian learning

Week 9: Associative learning (supplementary material)

- Unsupervised Hebb rule
- Hebb rule with decay
- Instar rule
- Kohonen rule
- Outstar rule

Week 10: Competitive networks (supplementary material)

- Hamming network
- Self-Organizing feature maps (SOM)
- Counterpropagation networks (CPN)
- Learning vector quanitization (LVQ)
- Principal component networks (PCAN)
- Independent component analysis (ICAN)
- Bi-directional associative memory (BAM)
- Adaptive resonance theory (ART)

Week 11: Physics-based networks

- Hopfield networks
- Solving constraint-satisfaction problems (e.g. TSP)
- Spin-glass model and simulated annealing
- Boltzman networks
- Cauchy networks
- Cascade correlation learning
- Helmholtz machine

Week 12: Other soft computing concepts

- Fuzzy logic
- Evolutionary computation
- Artificial life

Weeks 13-14: Final Presentations by Students