Sample Course Outline, ELEC 502 / COMP 502
Artificial Neural Networks and Information Theory I.
Approximately 12 x 3 = 36 lecture hours, 3 credits

Notation: CF k/m = *based on Colin Fyfe text*, volume k, chapter m*
EM, <list> = *compiled by Erzsébet Merényi from works in <list>*
Grey highlight: topics will be selected as time permits.

1. **Introduction** (CF 1 & 2 / 1 and EM)
   - What is an ANN, defining characteristics
   - Categories of ANN paradigms
   - Learning, adaptation, intelligence, learning rule categories: supervised / unsupervised / reinforcement
   - Application areas, history
   - Major ANN simulation software, major journals and literature sources
   - Hardware ANNs
2. **Review of Information Theory and Statistics** (CF 2/2)
   - Gaussian and uniform distribution, covariance, correlation, moments
   - Conditional probability, least squares, maximum likelihood
   - Quantification of information, entropy, joint and conditional entropy, mutual information, Kullback-Leibler divergence
   - Principal Components, subspaces
3. **Associative Memory** (CF 1/2)
   - Memory, autoassociation, heteroassociation
   - Memory matrix, recall and crosstalk,
   - Bi-directional autoassociative memories, recall from partial and noisy samples
   - Stability of bi-directional memory
4. **Simple Supervised Learning** (CF 1/3)
   - Perceptron, linear separability, XOR problem, linear and non-linear neurons
   - Error descent, Delta-rule
5. **The Multilayer Perceptron (MLP), Backpropagation (**CF 1/4, EM)
   - The Backpropagation algorithm (BP)
   - MLPs are universal approximators: theorems
   - Convergence, local minima, speeding up the learning, number of hidden units, weight pruning
   - Training concerns: generalization vs memorizing, overtraining, number of training samples, stopping criteria; scaling of inputs and outputs, preprocessing of data
   - Function approximation, prediction, classification with MLPs
6. **Unsupervised Learning** (CF 1/5, CF 2/3, EM)
   - Hebbian learning, stability, weight decay, Grossberg star, anti-Hebbian learning
   - Oja's PCA nets, Sanger's Generalized Hebbian Algotrithm, Földiák method, negative feedback
   - Hebbian learning and Information Theory – PCA and subspace connections; regression and minor component analysis
   - Competitive learning, LVQ, ART (competitive Hebbian learning will be discussed further in 10.)
   - Original Kohonen SOM, WEBSOM
7. **Recurrent Nets** (CF 1/7)
   - Hopfield networks, Boltzmann Machine, Simulated Annealing
   - Cellular automata – as a contrast to learning, a very simple dynamical system; game of life, self-replication (Neumann), Emergent Behaviour (swarm-like behaviour)
8. **Accelerating Supervised Learning** (CF 1/8)

- Radial Basis Functions, Error Descent, QuickProp, Conjugate Gradients, Cascade Correlation

9. Objective Function Methods in ANN Learning (CF 2/5.1 – 2/5.7)

- Backpropagation and PCA
- Cross-entropy, maximum mutual information (I-Max), maximum correlation (Canonical Correlation Analysis) as objective functions; use of contextual information

10. Identifying Independent Sources (Blind Source Separation) with ANNs (CF 2/6)

- Competitive Hebbian learning; Anti-Hebbian and competitive learning; sparse coding
- Multiple cause models, Factor Analysis
- Non-linear PCA as an extension to Oja's Subspace Algorithm (Hebbian learning)
- Predictability minimization
- The use of noise
- Probabilistic models

11. *Time permitting:* Independent Component Analysis (CF 2/7, EM new ICA book by Hyvärinen/Karhunen/Oja)

- Independent Component Analysis – definition of the problem
- Information maximization
- Projection Pursuit – maximally 'interesting' projections (non-linear)

Exercises/home work will involve programming in Matlab or C. Students with strong research interest can request access to my research environment for specific projects. Hypereye (proprietary ANN software developed under my NASA projects), NeuralWare software (installed on my research computers), Khoros image processing software, and more, are part of this environment. NeuralWare is the developer of one of the top commercial neural net simulation software, www.neuralware.com .

** Colin Fyfe text: developed by Prof. C. Fyfe for his classes at the Department of Computing and Information Systems, University of Paisley, Paisley, Scotland.*