Neural Computing

Computer Science Tripos Part II, Lent Term 1997
12 Lectures by J G Daugman

1. Levels of analysis. Mechanism and explanation. Philosophical issues.
2. Basic architectures for neural networks and neural computing.
3. Central Nervous System. Anatomy and physiology of the brain.
4. Sensation, perception, and cognition. Learning and memory.
5. Information content of neural signals. Spike generation processes.
6. Stochasticity in neural codes. Principal components analysis.
7. Neural operators that encode, analyze, and represent image structure.
8. Face recognition. Invariants and object representation.
9. Associative memory. Hopfield, Hebbian, and delta networks.
10. Layered networks. Back-propagation. Self-organizing networks.
11. Competitive and cooperative networks. Adaptive resonance; chaos.
12. Genetic algorithms. Stochastic annealing; Boltzmann machine.

Summary of Course Content

Natural versus artificial substrates of intelligence. Investigation into how biological nervous systems accomplish many of the goals of machine intelligence, but while using radically different strategies, architectures, and hardware. Comparison of those differences, and examination of their importance or irrelevance. Levels of analysis; mechanism and explanation; philosophical issues.

Neurobiological wetware, processing and signaling. Human brain architecture. Sensation and perception. Learning and memory. Information content of neural signals. Spike generation processes. Stochastic neural codes; Principal Components Analysis of spike trains. Visual operators that encode, analyse, and represent image structure. Face recognition, perceptual learning, and higher cognitive functions. How stochastic communications media, unreliable and randomly distributed hardware, very slow and asynchronous clocking, and imprecise connectivity blueprints, give us unrivalled performance in real-time tasks involving perception, learning, and motor control.

Artificial neural networks and neurocomputing. Simplifying models that seek to emulate biological designs for computing via connectivity dynamics and statistics, instead of by sequential formal algorithms. Supervised and unsupervised learning by specification of network connectivity. Synapses and update rules. Layered networks; feedforward, backpropagation, and counterpropagation. Hebbian synapses; Hopfield and Widrow-Hoff networks. Self-organizing networks. Competitive and cooperative networks. Energy minimization, relaxation, regularization. Adaptive resonance and chaos. Genetic algorithms.

Reference books:

Haykin, S. (1994). *Neural Networks: A Comprehensive Foundation.* MacMillan.

Hecht-Nielsen, R. (1991). *Neurocomputing.* Addison-Wesley.

McClelland, J., and Rumelhart, D. (1988) *Parallel Distributed Processing.*
Vol. 1: Foundations. Vol. 2: Physiological and Psychological Models. M.I.T. Press.

Anderson, J., and Rosenfeld, E. (1988, 1990) *Neurocomputing.* M.I.T. Press.

Wechsler, H. (1992) *Neural Networks for Perception.* Vol. 1: Computation, Learning, and Architectures. Vol. 2: Human and Machine Perception. Academic Press.

Aleksander, Igor (1989) *Neural Computing Architectures.* North Oxford Academic Press.