Introduction

Course Objectives

This course gives an introduction to basic neural network architectures and learning rules.

Emphasis is placed on the mathematical analysis of these networks, on methods of training them and on their application to practical engineering problems in such areas as pattern recognition, signal processing and control systems.

What Will Not Be Covered

- Review of all architectures and learning rules
- Implementation
  - VLSI
  - Optical
  - Parallel Computers
- Biology
- Psychology

Historical Sketch

- Pre-1940: von Hemholtz, Mach, Pavlov, etc.
  - General theories of learning, vision, conditioning
  - No specific mathematical models of neuron operation

- 1940s: Hebb, McCulloch and Pitts
  - Mechanism for learning in biological neurons
  - Neural-like networks can compute any arithmetic function

- 1950s: Rosenblatt, Widrow and Hoff
  - First practical networks and learning rules

- 1960s: Minsky and Papert
  - Demonstrated limitations of existing neural networks, new learning algorithms are not forthcoming, some research suspended

- 1970s: Amari, Anderson, Fukushima, Grossberg, Kohonen
  - Progress continues, although at a slower pace

- 1980s: Grossberg, Hopfield, Kohonen, Rumelhart, etc.
  - Important new developments cause a resurgence in the field

Historical Sketch

- 1990s - 2000s: Many researchers

    - Gradual improvements

- 2010s: Hinton, LeCun, Bengio

    - Deep networks become practical (GPUs, big data, ReLU)

    - Neural networks become AI

Applications

- ## Aerospace
  - High performance aircraft autopilots, flight path simulations, aircraft control systems, autopilot enhancements, aircraft component simulations, aircraft component fault detectors

- ## Automotive
  - Automobile automatic guidance systems, warranty activity analyzers

- ## Banking
  - Check and other document readers, credit application evaluators

- ## Defense
  - Weapon steering, target tracking, object discrimination, facial recognition, new kinds of sensors, sonar, radar and image signal processing including data compression, feature extraction and noise suppression, signal/image identification

- ## Electronics
  - Code sequence prediction, integrated circuit chip layout, process control, chip failure analysis, machine vision, voice synthesis, nonlinear modeling

Applications

- ## Financial
  - Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, credit line use analysis, portfolio trading program, corporate financial analysis, currency price prediction

- ## Manufacturing
  - Manufacturing process control, product design and analysis, process and machine diagnosis, real-time particle identification, visual quality inspection systems, beer testing, welding quality analysis, paper quality prediction, computer chip quality analysis, analysis of grinding operations, chemical product design analysis, machine maintenance analysis, project bidding, planning and management, dynamic modeling of chemical process systems

- ## Medical
  - Breast cancer cell analysis, EEG and ECG analysis, prosthesis design, optimization of transplant times, hospital expense reduction, hospital quality improvement, emergency room test advisement

Applications

- Robotics
  - Trajectory control, forklift robot, manipulator controllers, vision systems

- Speech
  - Speech recognition, speech compression, vowel classification, text to speech synthesis

- Securities
  - Market analysis, automatic bond rating, stock trading advisory systems

- Telecommunications
  - Image and data compression, automated information services, real-time translation of spoken language, customer payment processing systems

- Transportation
  - Truck brake diagnosis systems, vehicle scheduling, routing systems

Biology

- Neurons respond slowly
    - 10^{-3} s compared to 10^{-9} s for electrical circuits
- The brain uses massively parallel computation
    - $\approx 10^{11}$ neurons in the brain
    - $\approx 10^4$ connections per neuron

Dendrites

Axon

Cell Body

Synapse