بسم الله الرحمن الرحيم.

• Introduction to Neural Networks

Textbooks:

- Martin T. Hagan, Howard B. Demuth, Mark Beale, Orlando De Jesús, *Neural Network Design*. 2014.
- Simon Haykin, Neural Networks and Learning Machines, 3rd Edition, 2009.
- Christopher M. Bishop, Neural Networks for Pattern Recognition,1995.
- I. Goodfellow, Y. Bengio, A. Courville, Deep Learning 2016.
- Michael Nielsen, Neural Networks and Deep Learning, 2017 (Online).
- Ke-Lin Du, M. N. S. Swamy, Neural Networks and Statistical Learning-Springer London 2014.
- L. Fausett, Fundamentals of Neural Networks- Architectures, Algorithms and Applications.

Outline

- Introduction
- Neuron Model and Network Architectures
- An Illustrative Example
- Perceptron Learning Rule
- Signal and Weight Vector Spaces
- Linear Transformations for Neural Networks
- Supervised Hebbian Learning
- Performance Surfaces and Optimum Points
- Performance Optimization
- Widrow-Hoff Learning
- Backpropagation
- Variations on Backpropagation

- Generalization
- Dynamic Networks
- Associative Learning
- Competitive Networks
- Radial Basis Networks
- Grossberg Network
- Adaptive Resonance Theory
- Hopfield Network
- Deep Networks
- Convolutional Networks

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

Chapter 1
Introduction

Computers vs. Neural Networks

"Standard" Computers	Neural Networks
one CPU	highly parallel processing
fast processing units	slow processing units
reliable units	unreliable units
static infrastructure	dynamic infrastructure

Why Artificial Neural Networks?

There are two basic reasons why we are interested in building artificial neural networks (ANNs):

- **Technical viewpoint:** Some problems such as character recognition or the prediction of future states of a system require massively parallel and adaptive processing.

- **Biological viewpoint:** ANNs can be used to replicate and simulate components of the human (or animal) brain, thereby giving us insight into natural information processing.

Why Artificial Neural Networks?

Why do we need another paradigm than symbolic AI for building "intelligent" machines?

- Symbolic AI is well-suited for representing **explicit** knowledge that can be appropriately formalized.
- However, learning in biological systems is mostly **implicit** – it is an adaptation process based on uncertain information and reasoning.
- ANNs are inherently parallel and work extremely **efficiently** if implemented in parallel hardware.

How do NNs and ANNs work?

- The "building blocks" of neural networks are the **neurons**.
- In technical systems, we also refer to them as **units** or **nodes**.
- Basically, each neuron
  - receives **input** from many other neurons,
  - changes its internal state (**activation**) based on the current input,
  - sends **one output signal** to many other neurons, possibly including its input neurons (recurrent network)

How do NNs and ANNs work?

- Information is transmitted as a series of electric impulses, so-called **spikes**.
- The **frequency** and **phase** of these spikes encodes the information.
- In biological systems, one neuron can be connected to as many as **10,000** other neurons.
- Usually, a neuron receives its information from other neurons in a confined area, its so-called **receptive field**.

History of Artificial Neural Networks

1938 Rashevsky describes neural activation dynamics by means of differential equations

1943 McCulloch & Pitts propose the first mathematical model for biological neurons

1949 Hebb proposes his learning rule: Repeated activation of one neuron by another strengthens their connection

1958 Rosenblatt invents the perceptron by basically adding a learning algorithm to the McCulloch & Pitts model

History of Artificial Neural Networks

1960 Widrow & Hoff introduce the Adaline (Adaptive Linear Neuron or later Adaptive Linear Element), a simple network trained through gradient descent

1961 Rosenblatt proposes a scheme for training multilayer networks, but his algorithm is weak because of non-differentiable node functions

1962 Hubel & Wiesel discover properties of visual cortex motivating self-organizing neural network models

1963 Novikoff proves Perceptron Convergence Theorem

History of Artificial Neural Networks

1964 Taylor builds first winner-take-all neural circuit with inhibitions among output units

1969 Minsky & Papert show that perceptrons are not computationally universal; interest in neural network research decreases

1982 Hopfield develops his auto-association network

1982 Kohonen proposes the self-organizing map

1985 Ackley, Hinton & Sejnowski devise a stochastic network named Boltzmann machine

History of Artificial Neural Networks

1986 Rumelhart, Hinton & Williams provide the backpropagation algorithm in its modern form, triggering new interest in the field

1987 Hecht-Nielsen develops the counterpropagation network

1988 Carpenter & Grossberg propose the Adaptive Resonance Theory (ART)

Since then, research on artificial neural networks has remained active, leading to numerous new network types and variants, as well as hybrid algorithms and hardware for neural information processing.

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

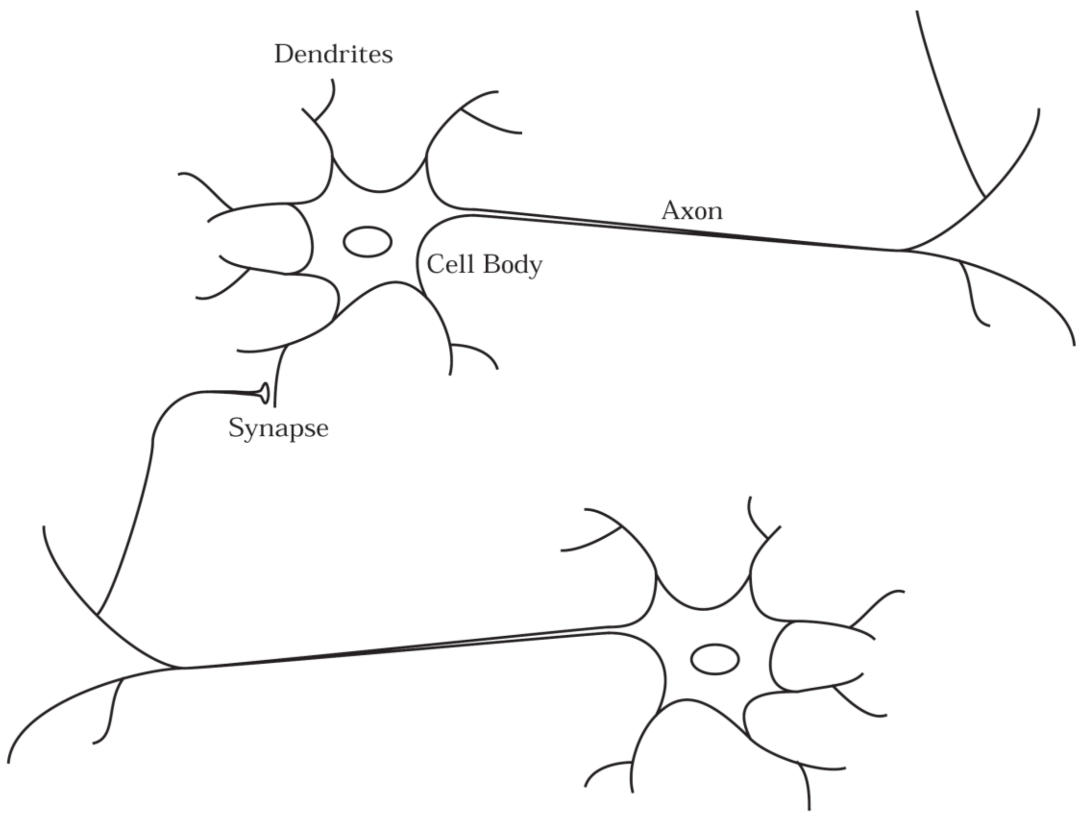
- Financial
  - Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, credit line use analysis, portfolio trading program, corporate financial analysis, currency price prediction
- Manufacturing
  - Manufacturing process control, product design and analysis, process and machine diagnosis, real-time particle identification, visual quality inspection systems, 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
- 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
  - Transportation
- Telecommunications
  - Image and data compression, automated information services, real-time translation of spoken language, customer payment processing systems
  - 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



Downloads

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