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Neural Networks and Fuzzy Logic (630514)

Lecture 1

Neural Network Definitions and Concepts

Outline

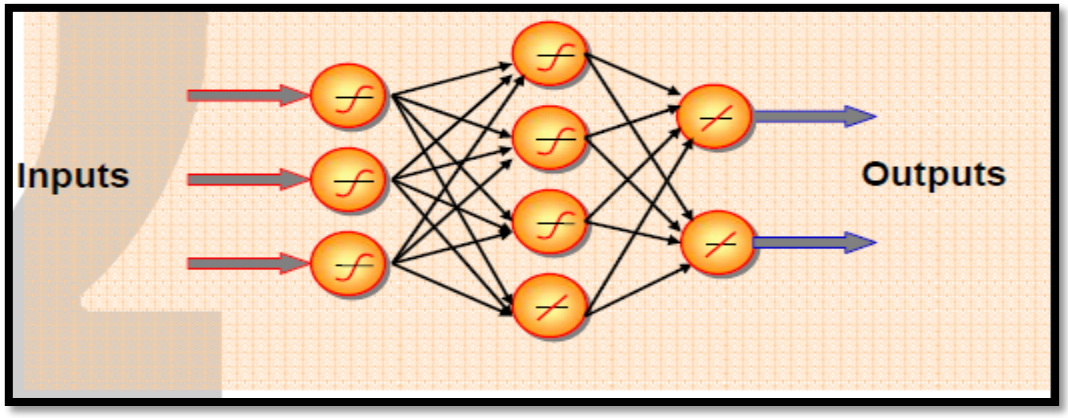
Introduction.

- ♣ **Definition of neural network.**
- ♣ **A brief history of neural networks.**
- ♣ **Neural Network Applications.**
- ♣ **Biological neural networks.**

Introduction

Definition of neural network

- **Artificial Neural Networks** (**ANN**) are computers whose architecture is a simplified model of the brain, they typically consist of many hundreds of simple processing units which are wired together in a complex communication network.
- Each unit or node is a simplified model of a **real neuron** which fires (sends off a new signal) if it receives a **sufficiently strong** input signal from the other nodes to which it is connected.
- Study of artificial neural networks is motivated by their similarity to successfully working biological systems.



Comparison between the brain and the computer	
Brain	**Computer**
Working continuously.	Passive data storage.
Parallel.	Serial.
Can reorganize itself and therefore is able to learn (capability to learn) Generalize and associate data	Static.
Fault tolerance against noisy input data.	Fault non-tolerance against noisy input data.

- So let us summarize the main characteristics we try to adapt from biology:
- **Self-organization and learning capability.**
- **Generalization capability.**
- **Fault tolerance.**

A brief history of neural networks

The beginning

- **As soon as 1943: Warren McCulloch and Walter Pitts** introduced models of neurological networks, calculate nearly any logic or arithmetic function (electronic brains).
- **1947: Walter Pitts and Warren McCulloch** indicated a practical field of application, namely the recognition of spacial patterns by neural networks.
- **1949: Donald O. Hebb** formulated the classical Hebbian rule which represents in its more generalized form the basis of nearly all neural learning procedures. The rule implies that the connection between two neurons is strengthened when both neurons are active at the same time.
- **1950:** The **Karl Lashley** defended the thesis that brain information storage is realized as a distributed system.

Golden age

- **1951:** For his dissertation **Marvin Minsky** developed the neurocomputer Snark.
- **1957-1958: Frank Rosenblatt** developed the first successful neurocomputer, Mark I perceptron, which was capable to recognize simple 20 × 20 pixel image
- **1959: Frank Rosenblatt** described different versions of the perceptron, formulated and verified his perceptron convergence theorem. He described a learning rule adjusting the connecting weights.
- **1960: Bernard Widrow and Marcian E. Hoff** introduced the ADALINE (ADAptive LInear NEuron), a fast and precise adaptive learning system being the first widely commercially used neural network (analog telephone for real-time adaptive echo filtering) and was trained by Widrow-Hoff rule or delta rule.
- **1961: Karl Steinbuch** introduced technical realizations of associative memory.
- **1969: Marvin Minsky and Seymour Papert** published a precise mathematical analysis of the perceptron to show that the perceptron model was not capable of representing many important problems (XOR problem and linear separability).
  Two of the reasons for the "**quiet years**" of the 1970s were the failure of single layer perceptrons to be able to/solve such simple problems (mappings) as the **XOR function** and the **lack of a general method of training a multilayer net**.
- **1974: Paul Werbos** developed a learning procedure called backpropagation of error.

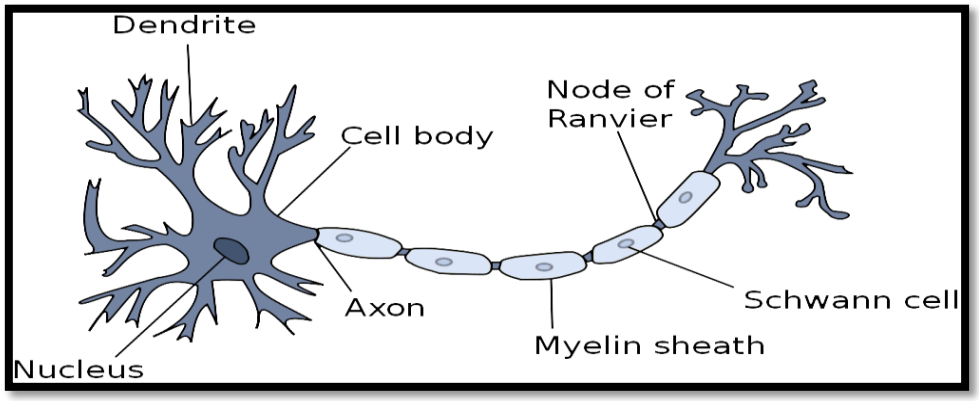
- **1982:**
  - **Teuvo Kohonen** described the self-organizing feature maps (SOM)– also known as Kohonen maps. He was looking for the mechanisms involving self-organization in the brain.
  - **John Hopfield** also invented the so-called Hopfield networks (Hopfield has developed a number of neural networks based on fixed weights and adaptive activations).
- **1983**: **Fukushima, Miyake and Ito** introduced the neural model of the Neocognitron which could recognize handwritten characters.
- **1986:** The backpropagation of error learning procedure as a generalization of the delta rule was separately developed and widely published by the **Parallel Distributed Processing Group**: Non-linearly-separable problems could be solved by multilayer perceptrons.

Neural Network Applications (Where are neural nets being used?)

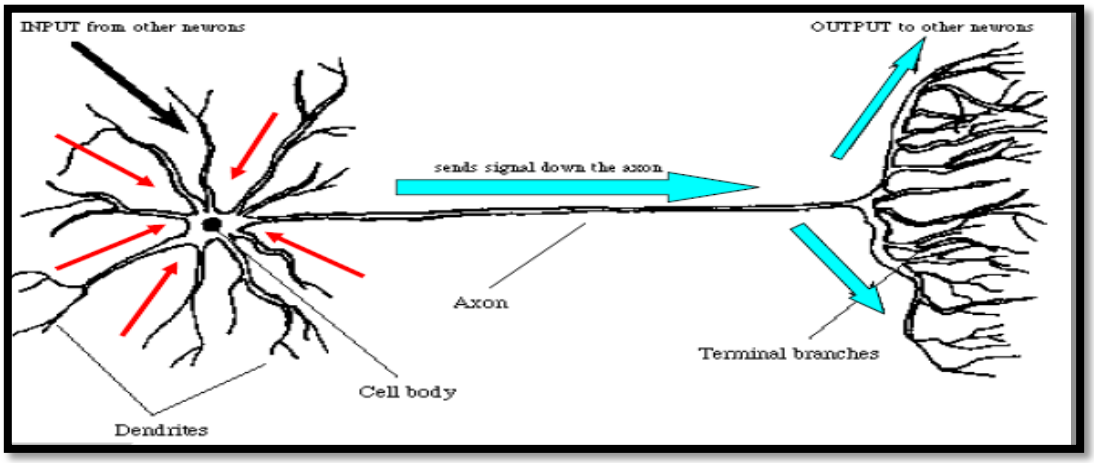
- **Signal Processing.**
  - **Electronics**
- **Control.**
  - **Automotive**
  - **Defense**
- **Pattern Recognition.**
- **Medicine.**
- **Speech Production and Recognition.**
- **Industrial**
  - **Robotics**
  - **Transportation**
  - **Manufacturing**
  - **Oil & Gas**
- **Business.**
  - **Banking**
  - **Credit Card Activity**
  - **Checking**
  - **Financial**
- **Entertainment**
- **Insurance**
- **Securities**
- **Telecommunications**

Biological neural networks

- Neurons are information processing cells.
- A neuron is nothing more than a switch with information input and output. The switch will be activated if there are **enough stimuli** of other neurons hitting the information input. Then, at the information output, a pulse is sent to, for example, other neurons.



Components of biological neuron



Components of a neuron

- The dendrites of a neuron receive the information by special connections, the synapses (Incoming signals from other neurons or cells are transferred to a neuron by synapses).
- The signals are electric impulses that are transmitted across a synaptic gap by means of a **chemical process**. The action of the chemical transmitter modifies the incoming signal (typically, by **scaling the frequency of the signals that are received**) in a manner similar to the action of the weights in an artificial neural network.
- Some synapses transfer a strongly stimulating signal, some only weakly stimulating ones.
- Dendrites branch like trees and receive electrical signals from many different sources, which are then transferred into the nucleus of the cell.
- In the **soma** the weighted information is accumulated.
- After the cell nucleus (soma) has received a plenty of activating (=stimulating) and inhibiting (=diminishing) signals by synapses, the soma accumulates these signals. If the accumulated signal exceeds a certain value (called threshold value), the soma of the neuron activates an electrical pulse which then is transmitted to the neurons connected to the current one.
- The **axon** transfers outgoing pulses.