Neural Network Fundamentals
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Lec 2: Introduction to Neural Network

Outline:

1. **Introduction to Neural Networks**
2. **Biological Neural Network and Nervous System**
3. **Biological Neuron**
4. **Model of an Artificial Neuron**

1. Introduction

Neural networks are simply a class of mathematical algorithms, since a network can be regarded essentially as a graphic notation for a large class of algorithms. Such algorithms produce solutions to a number of specific problems. At the other end, that these are synthetic networks that emulate the biological neural networks found in living organisms.

2. Biological Neural Network and Nervous System

A human brain consists of approximately 10^{11} computing elements called neurons. They communicate through a connection network of axons and synapses having a density of approximately 10^{4} synapses per neuron.

The **neurons** operate in a chemical environment that is even more important in terms of actual brain behavior **as in Fig1**. We thus can consider the brain to be a densely connected electrical switching network conditioned largely by the biochemical processes. The vast neural network has an elaborate structure with very complex interconnections. The input to the network is provided by **sensory receptors**. **Receptors** deliver stimuli both from within the body, as well as from sense organs when the **stimuli** originate in the external world. The **stimuli** are in the form of electrical impulses that convey the information into the network of neurons. As a result of information processing in the central nervous systems, the **Effectors** are controlled and give human responses in the form of diverse actions. We thus have a **three stage system**, consisting of **receptors, neural network**, and **effectors**, in control of the organism and its actions.

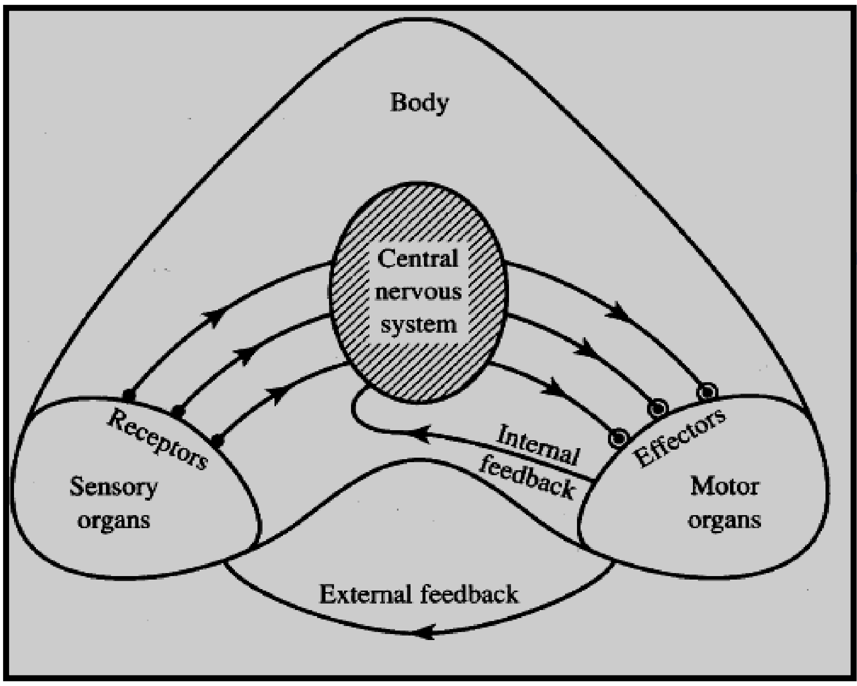
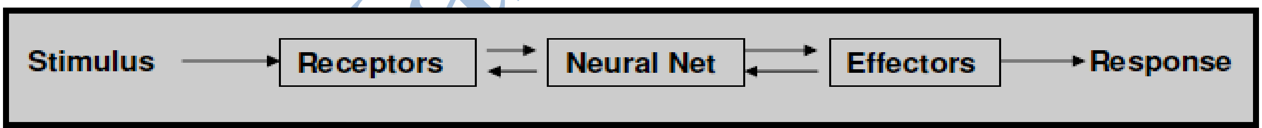


Figure 1: Flow of Information within nervous system.

The human nervous system can be broken down into three stages that can be represented in block diagram form as



The **receptors** convert stimuli from the external environment into electrical

Impulses that convey information to the neural net (brain)

The effectors convert electrical impulses generated by the neural net into responses as system outputs

The **neural net** (brain) continually receives information, perceives it and makes appropriate decisions.

The flow of information is represented by arrows – feed forward and feedback

2.1 Brains vs. Computers

Processing elements: There are 10^{14} synapses in the brain, compared with 10^{8} transistors in computer

Processing speed: 100 Hz for the brain compared to 109 Hz for the computer

Style of computation: The brain computes in parallel and distributed mode, whereas the computer mostly serially and centralized.

Fault tolerant: The brain is fault tolerant, whereas the computer is not adaptive: The brain learns fast, whereas the computer doesn't even compare with an infant's learning capabilities

Intelligence and consciousness: The brain is highly intelligent and conscious, whereas the computer shows lack of intelligence

Evolution: The brains have been evolving for tens of millions of years, computers have been evolving for decades

3. Biological Neuron

The elementary nerve cell, called a **neuron**, is the fundamental building block of the biological neural network. As **in Fig 2**, **a typical cell has three major regions:** the **cell body**, which is also called the soma, the **axon**, and the **dendrites**. Dendrites form a dendritic tree, which is a very fine bush of thin fibers around the neuron's body. **Dendrites** receive information from neurons through axons-long fibers that serve as transmission lines. An **axon** is a long cylindrical connection that carries impulses from the neuron.

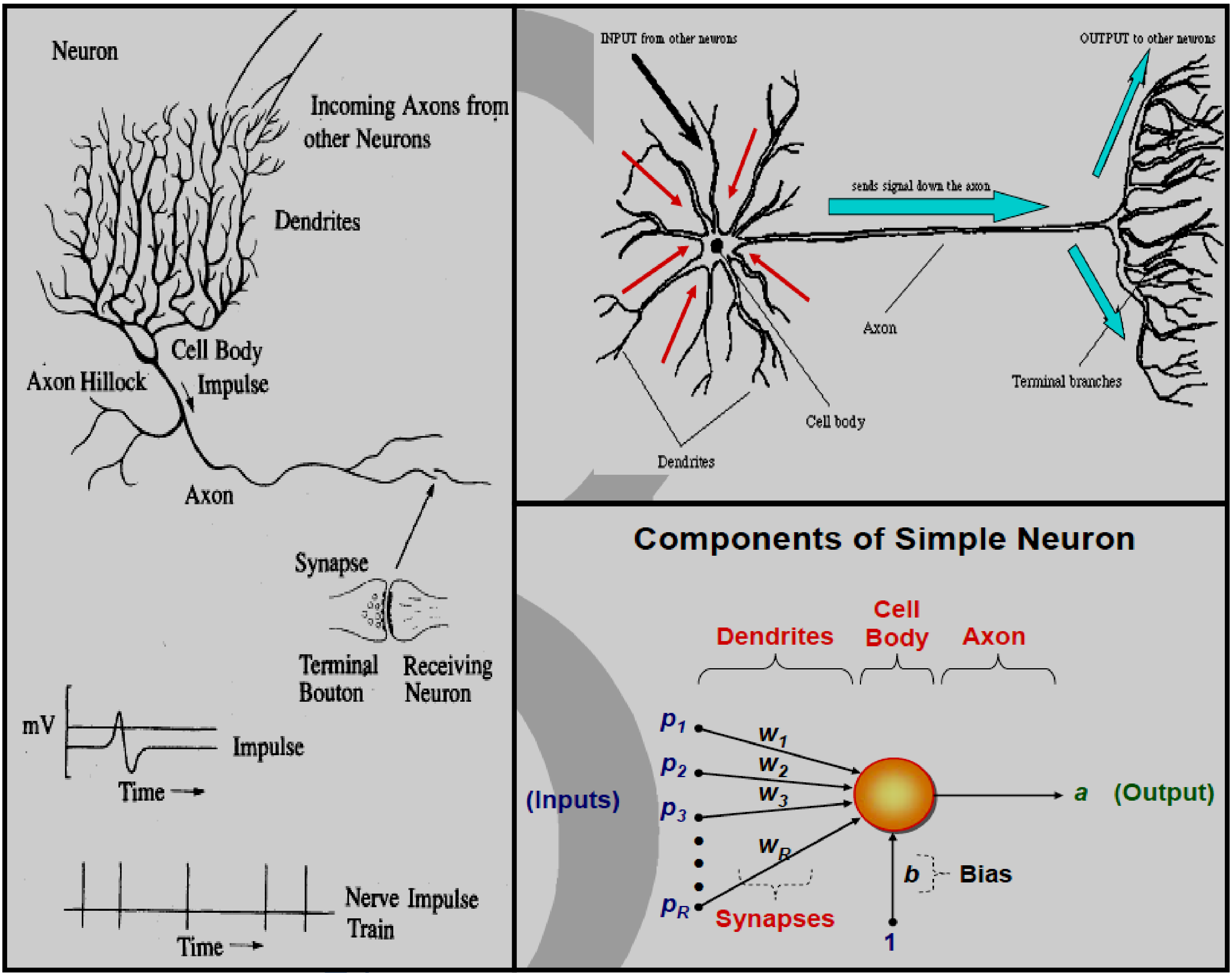


Figure 2: Schematic diagram of a neuron and a sample of pulse train

4. Model of an Artificial Neuron

The **McCulloch-Pitts model** of a neuron is characterized by its formalism and its elegant, precise mathematical definition. However, the model makes use of several drastic simplifications. It allows binary 0, 1 states only, operates under a discrete-time assumption, and assumes synchrony of operation of all neurons in a larger network. Weights and the neurons' thresholds are fixed in the model and no interaction among network neurons takes place except for signal flow Thus, we will consider this model as a starting point for our neuron modeling discussion. Specifically, the artificial neural systems and computing algorithms employ a variety of neuron models that have more diversified features than the model just presented. the main artificial neuron models can be explained as follow

Every neuron model consists of a processing element with synaptic input connections and a single output (**o**). The signal flow of neuron inputs, x_i, is considered to be unidirectional as indicated by arrows, as is a neuron's output signal flow. A general neuron symbol is shown in Figure 3. This symbolic representation shows a set of weights and the neuron's processing unit, or node. The neuron output signal is given by the following relationship

$$o = f(\mathbf{w}^t\mathbf{x}), \text{ or}$$

$$o = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

$$\mathbf{w} \triangleq \begin{bmatrix} w_1 & w_2 & \cdots & w_n \end{bmatrix}^t$$

$$\mathbf{x} \triangleq \begin{bmatrix} x_1 & x_2 & \cdots & x_n \end{bmatrix}^t$$

where w is the weight vector and x is the input vector

The function f (w^t x) is often referred to as an activation function. Its domain is the set of activation values, net, of the neuron model, we thus often use this function as f(net). The variable net is defined as a scalar product of the weight and input vector

$$net \triangleq \mathbf{w}^t\mathbf{x}$$

The argument of the activation function, the variable net, is an analog of the biological neuron's membrane potential

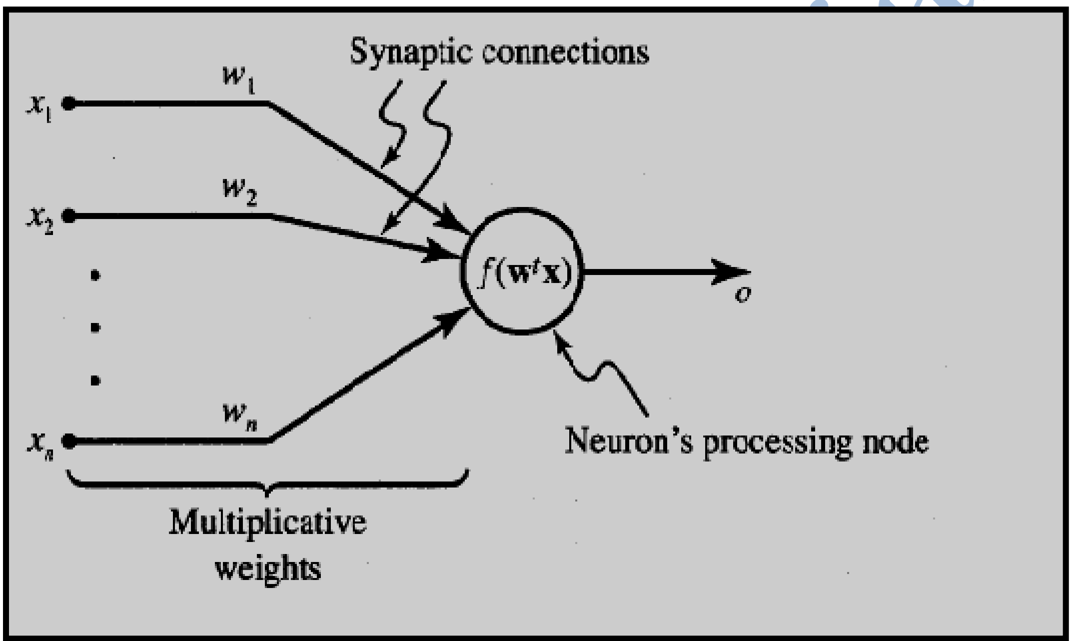


Figure 3: General symbol of neuron consisting of processing node and synaptic connections