Chapter XVII
Fundamental Theory of Artificial Higher Order Neural Networks

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ABSTRACT

In this chapter, we aim to describe fundamental principles of artificial higher order neural units (AHONUs) and networks (AHONNs). An essential core of AHONNs can be found in higher order weighted combinations or correlations between the input variables. By using some typical examples, this chapter describes how and why higher order combinations or correlations can be effective.

INTRODUCTION

The human brain has more than 10 billion neurons, which have complicated interconnections, and these neurons constitute a large-scale signal processing and memory network. Indeed, the understanding of neural mechanisms of higher functions of the brain is very complex. In the conventional neurophysiological approach, one can obtain only some fragmentary knowledge

of neural processes and formulate only some mathematical models for specific applications. The mathematical study of a single neural model and its various extensions is the first step in the design of a complex neural network for solving a variety of problems in the fields of signal processing, pattern recognition, control of complex processes, neurovision systems, and other decision making processes. Neural network solutions for these problems can be directly used for business and economic applications.

A simple neural model is presented in Figure 1. In terms of information processing, an individual neuron with dendrites as multiple-input terminals and an axon as a single-output terminal may be considered a multiple-input/single-output (MISO) system. The processing functions of this MISO neural processor may be divided into the following four categories:

i. *Dendrites:* They consist of a highly branching tree of fibers and act as input points to the main body of the neuron. On average, there are 10^3 to 10^4 dendrites per neuron, which form receptive surfaces for input signals to the neurons.

ii. *Synapse:* It is a storage area of past experience (knowledge base). It provides long-term memory (LTM) to the past accumulated experience. It receives information from sensors and other neurons and provides outputs through the axons.

iii. *Soma:* The neural cell body is called the *soma*. It is the large, round central neuronal body. It receives synaptic information and performs further processing of the information. Almost all logical functions of the neuron are carried out in the soma.

iv. *Axon:* The neural output line is called the *axon*. The output appears in the form of an action potential that is transmitted to other neurons for further processing.

The electrochemical activities at the synaptic junctions of neurons exhibit a complex behavior because each neuron makes hundreds of interconnections with other neurons. Each neuron acts as a parallel processor because it receives action potentials in parallel from the neighboring neurons and then transmits pulses in parallel to other neighboring synapses. In terms of information processing, the synapse also performs a crude pulse frequency-to-voltage conversion as shown in Figure 1.

Figure 1. A simple neural model as a multiinput (dendrites) and single-output (axon) processor
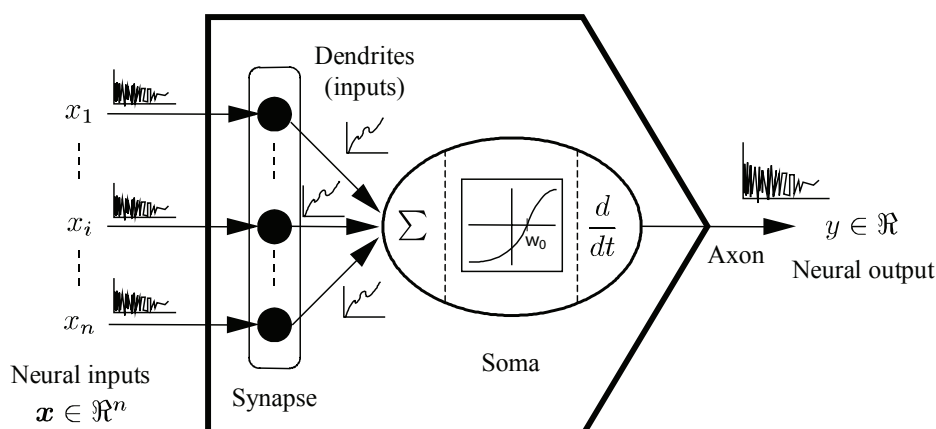
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