Chapter 4
Biologically-Inspired Learning: An Overview and Application to Odor Recognition

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ABSTRACT
A general overview of biologically-inspired learning in the paradigm of artificial neural systems is described. In order to have the reader become familiar with fundamentals underlying this paradigm, a substantial and concise hierarchical background from neurophysiology to neuro-computational models is provided with as much clarity as possible. As an application of a well-known artificial neural network algorithm called feed-forward multi-layer perceptron with back-propagation training algorithm is utilized in implementation of an artificial olfactory system also called electronic nose. For improved classification performance, an algorithm as a preprocessing called linear-discriminant analysis is adapted to chosen neural architecture. The main purpose of the preprocessing stage is to lend better scattered input patterns for classes in the feature space compared to that without preprocessing. The performance improvement is also investigated in terms convergence rate, i.e. the number of iteration, given a number of layers, and recalling or generalization capability of the classifier.

INTRODUCTION
An ANN is an information processing paradigm that is inspired by the way biological nervous system, mainly human and primates, process sensory information. It is proposed in that environmental information in biological central nervous system (CNS) undergoes three processing stages as shown in Figure 1, (Arbib, 2003; Haykin, 2003; Dayan, & Abbot, 2001).

1. Conversion into encoded electrical signals by the sensory systems, e.g. auditory, vision etc, and transmission to central nervous system, mainly the brain, through forward links,
2. Generation of motor commands through both internal and external feedback lines for verification,
3. Supervision of the motor organs given motor commands.
The brain is the main information processor and it is mostly represented as a neural network. It receives and evaluates the coded sensory impulses continuously for appropriately decision-making based on comparison to stored information. The outcome of the processing by the brain is the commands to motor organs, called effectors, through forward links. The main function of the effectors is to convert coded electrical impulses coming from the brain into distinct system output responses. During this processing, central nervous system also supervises motor organs by feedback lines. It is seen that the operation which is performed by nervous system exhibits similarity to a closed-loop control system, (Potter, 2007).

It has been known for long that the processing of sensory information is performed by the associated unit(s) in the brain in parallel by enormous number nerve cells called neuron, (Sherrington, 1933). The brain is composed of $10^{14}$ connections (synapses) shared by $10^{11}$ neurons. Therefore, each neuron carries and process approximately 1200 incoming information. This is the main reason of enormous processing speed by biological systems despite almost $10^7$ times lower speed in signal transmission per connection compared to its silicon counterpart. Such a huge parallel architecture has evolved while developing natural features for respective sensory and motor system patterns. Nevertheless it is still not completely known which selective features are employed and how they are formed even for the best-known sensory perception mechanisms, such as visual and audio, (Guyon, & Elisseeff, 2003).

Contrary to natural processing carried out by nervous system, however, processing with sequential computer systems solely relies upon predefined algorithms and modeled stimuli so as to reproduce a desired pattern flow. Due to sequential nature, the latter conjugates best suitable algorithm, if possible, only if it is available among others. Despite many scientific, and mathematical tasks including numerical problem solving; database management; computer graphics, there are many problems unsolvable by such systems including sensing, perception and most automated recognition of objects, (Porto, & Pazos, 2006).

Inspired by the operational capability of biological information processing, it is desirable to mimic such systems with closest performance to real counterparts. Developing biologically-inspired systems poses a need for modeling the physical and functional understanding of the relationships between input and output quantities. Therefore, at elementary level, it is customary to elucidate and pass through the biology and physics and interrelate both so as to attain the furthest possible scenario for applying it to real-world problems.

Although not much has revealed about activities inside the brain, there has been enough experimental evidence which complies with even presumed models, which can be attributed to artificial neural network (ANN). However, as it will be seen almost all details are hidden within the physiology of individual neurons in terms of incoming and outgoing information flow. In the following sections, we will present a general overview of biological structure and physiological functioning to understand happenings inside the brain and as an introduction to construction of ANN systems.
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