Chapter 30
Brain-Like System for Audiovisual Person Authentication Based on Time-to-First Spike Coding

Simei Gomes Wysoski
Auckland University of Technology, New Zealand

Lubica Benuskova
University of Otago, New Zealand

Nikola Kasabov
Auckland University of Technology, New Zealand

ABSTRACT

The question of the neural code, or how neurons code information about stimuli, is not definitively answered. In addition to experimental research, computational modeling can help in getting closer to solving this problem. In this chapter, spiking neural network architectures for visual, auditory and integrated audiovisual pattern recognition and classification are described. The authors' spiking neural network uses time to first spike as a code for saliency of input features. The system is trained and evaluated on the person authentication task. The chapter concludes that the time-to-first-spike coding scheme may not be suitable for this difficult task, nor for auditory processing. Other coding schemes and extensions of this spiking neural network are discussed as the topics of the future research.

INTRODUCTION

Artificial information processing systems, despite enormous effort, still struggle to deliver general and reliable solutions, comparable with the performance of the brain. The core of the problem is that we still do not understand the neural code. The brain is a gigantic network of interconnected neurons. Research on the brain information processing has acquired enough evidence to suggest that biological neurons transmit information using short electrical discharges generated by electrochemical activity. Output signals of neurons have constant amplitudes (~100 mV) and short duration

DOI: 10.4018/978-1-4666-2919-6.ch030

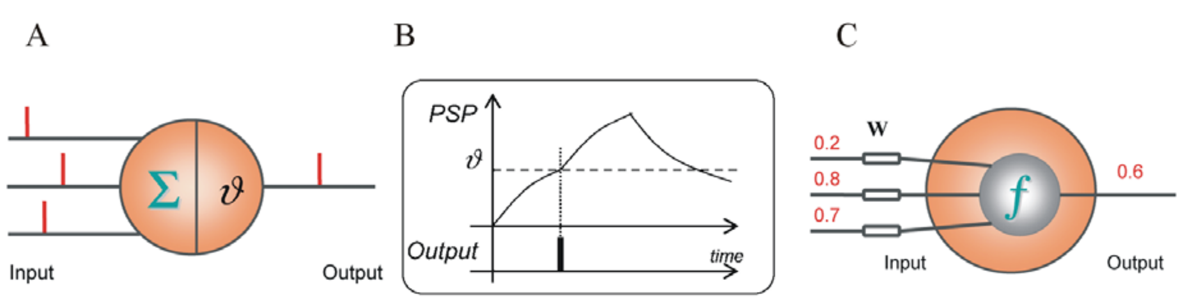
(~1ms). Therefore they are commonly referred as pulses or spikes. Neurons in the brain send messages to each other by spikes. The big scientific question nowadays is: how are the properties of a stimulus encoded in the individual and ensemble responses of neurons? In other words, *how are messages encoded in spikes*? To be able to answer this question will be of tremendous importance in understanding and modeling human intellect.

The typical behaviour of a neuronal unit can be roughly described as follows: an incoming pulse (received by a dendrite or soma) increases the inner potential of a neuron, which is called a postsynaptic potential (PSP). When the inner potential at a neuronal soma reaches a certain threshold, the neuron outputs a spike (through the axon). Figures 1A and 1B illustrate this process.

A wide range of models describing the functional behaviour of a single neuron has been proposed, e.g., integrate-and-fire, integrate-and-fire with leakage, spike response model, Izhikevich model (Gerstner & Kistler, 2002; Izhikevich, 2003). In the majority of models, a neuron is represented with three parts: dendrites, responsible for collecting signals from other neurons; soma, the summation unit, and axon, from which signals are released. Most of these attempts model information processing at a somatic level and consider the spiking characteristic as a means of communication between neurons (Gerstner & Kistler, 2002). These neuron models come in opposition to the perceptron model (Rumelhart & McClelland, 1996), which enables input/output communication using real numbers (Figure 1C).

While the perceptron enables the units to process only rate-based information, spiking neurons enable richer processing patterns. A sequence (train) of spikes emitted by a given neuron in response to stimulus may contain information based on different coding schemes. Frequency or rate coding is a traditional coding scheme assuming that information about the stimulus is contained in the output firing rate of the neuron. This has led to the idea that a neuron transforms information about a single input variable (the stimulus strength) into a single continuous output variable (the firing rate) as in the perceptron. Many artificial neural network models use this idea. However, a number of neurobiological studies have found that the temporal resolution of the neural code is on a millisecond time scale (Abeles & Gat, 2001; Hopfield, 1995; Izhikevich, 2006; Reece, 2001; Thorpe, Fize, & Marlot, 1996; Villa, Tetko, Hyland, & Najem, 1999). This indicates that precise spike timing is a significant element in neural coding. For example, time to first spike after the stimulus onset, or precisely timed temporal patterns of spikes or the relative timing of

Figure 1. Neuron and its basic input-output behaviour. (A) Incoming pulses evoke the postsynaptic potential (PSP), which is the sum (Σ) of many (thousands) of synaptic PSPs. (B) Output pulses are released when the total PSP reaches the firing threshold ϑ. (C) Perceptron model. Note the innovations proposed over the years: changeable input weights **W**, *different activation functions f, and inputs/outputs with real numbers representing mean firing frequencies of spike trains.*



Related Content