Computational Modeling of Visual Selective Attention

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Abstract

An overview of a nerocomputational model of visual selective attention that has been properly implemented is presented in this abstract.

Visual selective attention is a fundamental function of human cognition and a highly important brain mechanism, essential for the functioning of the human brain as a system. A comprehensive example of the role of human attention can be seen by noting that at each instant of conscious life, each person receives millions of external stimulations from his/her sensory systems, while only a limited amount is selected by attention for further processing that leads to conscious perception. If every stimulus was allowed to pass into perception, one would have been soon overflowed and in constant distraction. Adding to external stimulation all internal stimuli (e.g., thoughts), a person would end up in a totally unstable state. Selective attention is thus regarded as the main control mechanism, necessary for keeping the brain system in stability. It does so by filtering out any irrelevant information while at the same time advancing any vital stimulation to higher cortical areas for further processing.

Attention can be oriented towards object or empty space either in a voluntary or an automatic manner. That is, attention can be guided by top-down and bottom-up processing as cognition can be regarded as a balance between internal motivations and external stimulations. Top-down or endogenous attention refers to the volitional modulation of neural activity that corresponds to an object or a location in space, and it functions in response to signals initiated by internal goals, that most likely originate in the parietal and frontal lobes of the brain (Buschman & Miller, 2007). Bottom-up or exogenous attention on the other hand is a faster and more automatic process that relies on the sensory saliency of stimuli registered by sub cortical structures and the primary sensory cortices (Corbetta & Shulman, 2002).

Studying the brain from the computer scientists’ perspective has always being a great challenge, and is usually divided under two main paths within the computational intelligence (CI) field. On one, to understand and mimic in a sense the functionality of the human brain has triggered the design and implementation of artificial intelligent systems such as robotics, expert systems etc. On the other, the understanding of certain brain functions can be facilitated with the implementation of relevant cognitive computational models.

Our objective is to develop a plausible and biologically realistic computational model of visual selective attention using tools from the field of computational intelligence and use it in engineering and other applications. In recent years, an increased interest in developing cognitive models for a variety of technology and engineering applications has been observed and more specifically, there has been much interest in the development of systems capable of simulating users’ attention and how these systems could be practically and effectively used.

For example, a tendency towards practical systems that are based on human attention has been observed (Horvitz et al., 2003) while research on computer vision is as well heavily dependent on the principles of human attention (Sun & Fisher, 2003). To apply ideas and concepts of human attention in the Computational Intelligence area, it is necessary to develop relevant computational models that will allow pinpoint the functional details of this brain mechanism.

In line with the above, we present here a brief description of a computational model of visual selective attention that we have designed and implemented.

Keywords: Attention; Computational Modeling; Spiking Neural Networks
1. Main

The proposed computational model was built through an appropriate system of dynamical equations that were implemented and simulated in the MATLAB/SIMULINK environment. The model has two stages of processing implemented with spiking neural networks (SNN). The first stage simulates the initial bottom-up competitive neural interactions among visual stimuli, while the second stage involves modulations of neural activity based on the semantics of the stimulus. During the progression of the neural activity in the two stages of processing, the encoded stimuli will compete for access to working memory (WM) through forward, backward and lateral inhibitory interactions which influence the strength of their neural response. At the same time, top down interactions can influence the overall processing in both stages, depending on their nature. For instance if the top-down signals contain information regarding the spatial location of a brief visual stimulus (i.e. spatial cues), they will influence the first stage of processing, while if perceptual cues contain information about the semantics of a stimulus, they will manipulate the processing in the second stage.

The basic functionality of the model relies on the assumption that an incoming visual stimulus will be processed by the model based on the rate and temporal coding of its associated neural activity. The rate associated with a visual stimulus is crucial in the case of exogenous attention as this has been originally proposed by relevant models. These models are based on the presence of a saliency map, according to which, an image is initially analyzed by distinct characteristic maps and then is processed by specific operands inspired by the functionality of the brain (e.g. Treisman & Gelade, 1980; Koch & Ullman, 1985). The overall process is completed in the saliency map and a winner-take-all neural network selects the area of the image to which attention is oriented. Endogenous attention is believed to be affected by the synchronization of incoming stimuli with the goals that guide the execution of a task. The presence of a closed link between endogenous attention and synchronization is supported by many recent studies (Gregoriou et al., 2009).

The developed model was used for simulating the findings from several behavioral experiments that are well-known in the scientific literature of visual selective attention. More details about the mathematical representation of the model and the specific experiments that have been simulated, along with the model’s fit to experimental data can be found in Neokleous et al., 2009a, 2009b, 2009c, 2010.

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References