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A bioinspired model of early visual processing with hue-feature saliency for a cognitive architecture

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Abstract

We present a computational model that describes the early stages of visual processing with selective attention mechanisms to generate feature-based (hue or color) activations of salient localizations, based on neurophysiology evidence of activations and inhibitions in visual pathway: photoreceptors in retina, simple opponent cells in thalamus with increases by top-down spatial-related signals, double opponent cells in and its lateral inhibitions to determine salient regions. The model is part of the selective attention aspect for a broader cognitive architecture, which focus in the identification of related brain areas, the likely operations of each one, and the type of data generated and shared among the components. Such approach aims to develop a system able to grow as more components and operations from other cognitive functions will be integrated, keeping its biological and computational feasibility.

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1 Introduction

With vision, we could perceive a great diversity of features (e.i. color, movement, distance) from our environment. A huge quantity of neurons is needed to acquire and process the visible light, however not all the information is completely processed: we can only notice the prominent parts of a scene, what we *pay attention* to them in a selective manner.

Selective attention involves allocation of processing resources to the most relevant or salient sensory events. Concurrent mechanisms in the brain may help to perform the whole process. They could be *bottom-up* inhibition of neural activity based on purely physical peculiarities (stimulus-driven), which makes it salient; *top-down* enhancement of neural activity based on the congruence of the stimulus with current task-related information (goal-driven), which makes it relevant; or even motivational or emotional values related to the stimuli (value-driven) could make a stimulus more salient. Also, attention could be oriented to specific visual properties, such color or motion (feature-based); to spatial regions, like left or right (space-based); and to the regions which compound a perceptible object (object-based). It is possible that the final

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deployment of attention is achieved by integrations among all of them during different stages of visual processing.

Biological evidence along with theoretical and computational models agreed that early stages of visual processing (from the entry of information in the retina to first layers in the occipital cortex) works in a bottom-up manner to extract salient features, enhanced by top-down signals for feature-based and space-based processing. Some models of visual processing, like [1, 2], focus on energy transduction as realistically as possible for the preservation of chromatic luminosity but appear to be isolated from attentive mechanisms. Itti & Koch model [3] is a relevant reference related with salient areas detection, specifically to generate bottom-up saliency map using low-level features (color, intensity, and orientation), although it leaves aside top-down influences on space and features, besides other interactions with more mental processes. Some approaches use and extend that model to include or improve other untreated aspects of attention[4]. Even so, their approach is more computational-oriented than bio-inspired modeling.

In our perspective, it is needed a model that gathers biological and computational plausible operations in the visual processing pathway along with more *cognitive functions* to deploy realistic behaviors, and at the same time, be flexible enough to add more mechanisms which may help to achieve a system alike cognition. The idea is in line with our central work on the creation of a cognitive architecture for virtual creatures. Our approach is to develop and integrate diverse cognitive functions, such as attention, sensory processing, perception, decision making, planning, emotions, or motivations. Each cognitive function is designed as the conjunction of operations in specific components (brain areas), which could be organized in various intra-functions, sub-functions or aspects.

In this paper, we present the first stages of sensory processing along with part of a selective aspect of attention, modeled in a way that it is flexible enough to continue growing to higher visual stages and other aspects of attention. We relay in that possibility because our method comprises the identification and implementation of independent modular components (in a computational distributed system) that interact with each other (and not a global neural network), so more modules could be included as needed. In previous works, we present a model that describes the interaction between visual processing, attention and novelty detection in semantic memory[5], but we did not include detailed information about in the plausible computations of each component that we describe now.

2 Model of early visual processing with attention

In the beginning stages of visual processing, inputs (stimulus intensity sensed by the receptors) are acquired and transformed into an internal representation. Afterward, during later phases, the internal representation is treated to extract the features that are used to describe the environmental objects. Since this model is part of a broader cognitive architecture, figure 1 shows the components and connections described in this paper, as well as other parts of the system beyond the current scope. As seen, visual processing starts with activation of receptors in the retina, then information passes through the thalamus and ascends to visual areas in the occipital cortex. Besides this feedforward connections, there are feedback projections which may help to modulate the activity across areas.

Next, we will describe the computation done in each brain area and its correspondence in our model, which is summarized in figure 2 using a representation similar to activity diagrams defined in UML 2.0.