Chapter 4
Main Retina Information Processing Pathways Modeling

Hui Wei
Fudan University, China

Qingsong Zuo
Fudan University, China

XuDong Guan
Fudan University, China

ABSTRACT

In many fields including digital image processing and artificial retina design, they always confront a balance issue among real-time, accuracy, computing load, power consumption, and other factors. It is difficult to achieve an optimal balance among these conflicting requirements. However, human retina can balance these conflicting requirements very well. It can efficiently and economically accomplish almost all the visual tasks. This paper presents a bio-inspired model of the retina, not only to simulate various types of retina cells but also to simulate complex structure of retina. The model covers main information processing pathways of retina so that it is much closer to the real retina. In this paper, the authors did some research on various characteristics of retina via large-scale statistical experiments, and further analyzed the relationship between retina's structure and functions. The model can be used in bionic chip design, physiological assumptions verification, image processing and computer vision.

INTRODUCTION

Understanding how biological visual systems cognize and represent the outside world is one of the important and intricate issues in many disciplines, such as physiology, neuroscience, cognitive informatics and artificial intelligence. As a kind of classical natural intelligences, the human visual system can easily and effortlessly handle many visual tasks that are very difficult to accomplish for contemporary computer vision and artificial cognitive model. Many investigations into the internal information processing mechanisms of visual system have shown that the visual natural

DOI: 10.4018/978-1-4666-2476-4.ch004

intelligence originates from the complex structure and parallel computation (Edelman, 1999; Grimson & Grimson, 1981). Therefore, modeling and simulating the human visual system becomes a good solution for some traditional tasks, such as cognition, object recognition and image representation (Palmeri & Gauthier, 2004; Riesenhuber & Poggio, 2000; Wang, 2009). In the human visual system, information is processed along the pathway from the retina through the lateral geniculate nucleus to the visual cortex. Not surprisingly, even in the early visual system, the retina, possessing intricate and delicate hierarchies, transforms and transmits visual information accurately and in real time.

In recent decades, computer vision has been widely applied to target tracking, object detection, position estimation, visual navigation, even missile guidance, and many other fields. However, many computer vision applications are still far from meeting all the requirements especially in real-time and accuracy balance. Meanwhile, artificial retina design confronts the similar balance issue that the chip must be capable of computing very quickly but still maintaining low power consumption and keeping enough accuracy in a limited space. For this issue, nature gives us a good solution. That's our visual system, which not only can meet real-time of information processing but also can ensure high precision of processing, not only can satisfy the different computing load requirements under various environments, but also can maintain low power consumption, not only can deal with a variety of visual tasks, but also can keep a relatively fixed structure. It might be an effective way to model retina's structure to try to solve the problem.

Actually, there have been a number of simulation models of retina structure and function. Since the retina is at the intersection of several subjects, different models may focus on different aspects and applications. These models can broadly be divided into three categories according to their fields and goal. The first category is for neuroscience. These retina models try to establish a model to analyze a number of physiological data to explain some physiological phenomena and verify some assumptions. These models must strictly consist with physiological data and fact; they even simulate ion channels and chemical regulation mechanism (Casti, Hayot, Xiao, & Kaplan, 2008; Dunn, Doan, Sampath, & Rieke, 2006; Niu & Yuan, 2007; Publio, Oliveira, & Roquea, 2006; Roska, Molnar, & Werblin, 2006; Schiller, Slocum, & Weiner, 2007; Shah & Levine, 1996a, 1996b). These models are often too detailed to show the whole retina information processing. The second category is for computer applications. The structure and characteristics of the retina are utilized in computer science fields such as edge detection (Niu & Yuan, 2008; Rong, Yi, & Qiang, 2004; Tang, Sang, & Zhang, 2005), image segmentation (Giorgio, Guido, & Francesco, 1997; Reddick, Glass, Cook, Elkin, & Deaton, 1997; Wu, McGinnity, Maguire, Valderrama-Gonzalez, & Dempster, 2010), motion detection and object tracking (Ishii, Deguchi, & Sasaki, 2004; Lee, Chae, Kim, Kim, & Cho, 2001; Risinger & Kaikhah, 2008), the depth calculation (Shimonomura, Kushima, & Yagi, 2008)and some other applications. Such models try to introduce the physiology idea to solve computer-related issues, not necessarily loyal to the physical structure and information processing of real retina. The third category is for the electronic engineering hardware design. The purpose of these retina models is to design artificial retina chips which can eventually replace real retina (Ahuja, Behrend, Kuroda, Humayun, & Weiland, 2008; Behrend, Ahuja, Humayun, Weiland, & Chowe, 2009; Caspi et al., 2009; Morillas et al., 2007; Wu, Yang, Basham, & Liu, 2008), but as mentioned, they face many problems such as power consumption, real-time, accuracy, compatibility, eyeball movement control, chip size, energy supply, and so on.

This paper presents a simulation retina model, not only simulating various types and distribution of retina cells, but also simulating the different

Related Content