Chapter 5
2D and 3D Visual Attention for Computer Vision:
Concepts, Measurement, and Modeling

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ABSTRACT

Visual attention is one of the most important mechanisms deployed in the human visual system (HVS) to reduce the amount of information that our brain needs to process. An increasing amount of efforts has been dedicated to the study of visual attention, and this chapter proposes to clarify the advances achieved in computational modeling of visual attention. First the concepts of visual attention, including the links between visual salience and visual importance, are detailed. The main characteristics of the HVS involved in the process of visual perception are also explained. Next we focus on eye-tracking, because of its role in the evaluation of the performance of the models. A complete state of the art in computational modeling of visual attention is then presented. The research works that extend some visual attention models to 3D by taking into account of the impact of depth perception are finally explained and compared.

INTRODUCTION

In everyday life, we are constantly receiving an abundant amount of information through various senses. Among the senses, sight is considered to be the most dominant one (Wandell, 1995). However, our sensory system for vision, the human visual system (HVS), continually receives a really large amount of visual data and it is beyond our brain's capability to process all of them (Borji & Itti, 2013). To cope with this large amount of information, visual attention is one of the most important mechanisms deployed in the HVS to reduce the complexity of the analysis of visual scene (Wolfe, 2000). Driven by visual attention, viewers can selectively focus their attention on specific areas of interest in the scene.

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In the last decades, extensive efforts have been dedicated to the study of visual attention. Neurologists, psychologists, vision scientists, and computer scientists have taken part in, and contributed to various aspects of visual attention. These efforts from different disciplines made the research on visual attention become a highly interdisciplinary field; different relevant disciplines deal with the research on visual attention from different points of view, and profit from each other.

In recent years, the use of visual attention mechanisms in image processing systems has found increasing interest by computer scientists. Taking into account visual attention information becomes an effective way for improving various existing algorithms in image processing. A variety of areas, including compression (Parkhurst, Law, & Niebur, 2002), retargeting (D. Wang, Li, Jia, & Luo, 2011), image retrieval (Vu, Hua, & Tavanapong, 2003), quality assessment (H. Liu & Heynderickx, 2011), have been benefiting of being provided information about the locations that attracts viewer's attention in the visual scene.

When visual attention is taken into account by the signal-processing community, the two terms, "salience" and "importance", have traditionally been considered synonymous. It is true that both of visual salience and visual importance denote the most visually "relevant" parts of the scene. However, from the vision scientist's point of view, they are two different concepts, since they come from two different mechanisms of visual attention: bottom-up and top-down. The two mechanisms are driven by different types of stimuli, and are formed in different visual pathways that go through different areas of the brain. Therefore, it would be worth identifying the two terms in the context of image processing.

In recent years, another problem faced by researchers in the field of visual attention is the impact of 3D. During the viewing of 3D content, depth perception of the scene is enhanced. This change of depth perception also largely changes human viewing behavior (Hakkinen, Kawai, Takatalo, Mitsuya, & Nyman, 2010; Huynh-Thu, Barkowsky, Le Callet, & others, 2011). Because of the emergence of 3D content and recent availability of 3D-capable display equipments, studies related to 3D visual attention have been gaining an increasing amount of attention in the last few years.

In this chapter we propose to clarify the last advancements in computational modeling of visual attention.

The first section details the concepts of visual attention including the latest research results linking visual salience and visual importance. The main characteristics of the human visual system involved in the process of visual perception are explained in section 2. Because of their substantial role in the evaluation of the performances of the models, eye-tracking systems are presented in section 3. A complete state of the art in computational modeling of visual attention is then presented in section 4. The research works that extend some visual attention models to 3D by taking into account of the impact of depth perception are finally explained in section 5.

1. VISUAL ATTENTION

It would be difficult to go directly into specific studies without a general introduction of some background knowledge on visual attention. So in this section, we first introduce concepts of visual attention as well as various mechanisms of attention. Secondly, we present a brief introduction of the HVS and of different types of eye movements as well as the technique for measuring eye movements, i.e. eye-tracking. Finally, we introduce some typical state-of-the-art computational models of visual attention.

The oldest and most famous definition of attention, which is provided by the psychologist William James (James, Burkhardt, & Skrupskelis, 1980), dates back to year 1890: "Everyone knows what atten-