Preface

The scope of the book falls within a fairly narrow Human-Computer Interaction domain (i.e., describing a particular input modality), however, it spans a broad range of inter-disciplinary research and application topics. There are at least three domains that stand to benefit from eye tracking research: visual perception, human-computer interaction, and computer graphics. The amalgamation of these topics forms a symbiotic relationship. Graphical techniques provide a means of generating rich sets of visual stimuli ranging from 2D imagery to 3D immersive virtual worlds while research exploring visual attention and perception in turn influences the generation of artificial scenes and worlds. Applications derived from these disciplines create a powerful Human-Computer Interaction modality, namely interaction based on knowledge of the user's gaze.

Recent advancements in eye tracking technology, specifically the availability of cheaper, faster, more accurate and easier to use trackers, have inspired increased eye movement and eye tracking research efforts. However, although eye trackers offer a uniquely objective view of overt human visual and attentional processes, eye trackers have not yet gained widespread use beyond work conducted at various research laboratories. This lack of acceptance is due in part to two reasons: first, the use of an eye tracker in an applied experimental setting is not a widely taught subject. Hence, there is a need for a book that may help in providing training. It is not uncommon for enthusiastic purchasers of eye tracking equipment to become discouraged with their newly bought equipment when they find it difficult to set up and operate. Only a few academic departments (e.g., Psychology, Computer Science) offer any kind of instruction in the use of eye tracking devices. Second, to exacerbate the lack of training in eye tracking methodology, even fewer sources of instruction exist for system development. Setting up an eye tracking lab and integrating the eye tracker into an available computer system for development of *gaze-contingent* applications is a fairly complicated endeavor, similar to the development and

integration of Virtual Reality programs. Thus far, it appears no textbook other than this one exists providing this type of low-level information.

The goal of this book is to provide technical details for implementation of a gaze-contingent system, couched in the theoretical context of eye movements, visual perception, and visual attention. The text started out as the author's personal notes on the integration of a commercial eye tracker into a Virtual Reality graphics system. These technical considerations comprise the middle chapters of the book and include details of integrating a commercial eye tracker into both a 3D Virtual Environment, and a 2D image display application. The surrounding theoretical review chapters grew from notes developed for an interdisciplinary Eye Tracking Methodology course offered to both undergraduates and graduates from four disciplines: Psychology, Marketing, Industrial Engineering, and Computer Science. An early form of these notes was presented as a short course at the Association for Computing Machinery (ACM) Special Interest Group on Graphics' SIGGRAPH conference, 23-28 July 2000, New Orleans, LA.

Overview

The book is divided into three parts, presented thematically in a top-down fashion, providing first an Introduction to the Human Visual System (Part I), then briefly surveying Eye Tracking Systems (Part II), and finally ending by summarizing a number of Eye Tracking Applications (Part III).

In the first part, Introduction to the Human Visual System (HVS), the book covers the concept of visual attention, mainly from a historical perspective. The first chapter focuses on the dichotomy of foveal and peripheral vision (the "what" vs. the "where"). While this chapter covers easily observable attentional phenomena, the next chapter covers the neurological substrate of the HVS presenting the low-level neurological elements implicated in dynamic human vision. This chapter discusses the primary dual pathways, the parvo- and magno-cellular channels, which loosely correspond to the flow of visual information permitted by the retinal fovea and periphery. Following this description of the visual "hardware", observable characteristics of human vision are summarized in the following chapter on visual perception. Here, results obtained mainly from psychophysics are summarized, distinguishing foveal and peripheral visual perception. The first part ends by discussing the mechanism responsible for shifting the fovea, namely eye movements. Having established the neurological and psychophysical context for eye movements, the follow-

ing chapter on the taxonomy and models of eye movements gives the common terms for the most basic of eye movements along with a signal-analytic description of recordable eye movement waveforms.

The second part of the book, Eye Tracking Systems, presents a brief survey of the main types of available eye tracking devices, followed by a detailed technical description of the requirements for system installation and application program development. These details are mainly applicable to video-based, corneal-reflection eye trackers, the most widely available and most affordable type of eye trackers. This part of the book offers information for the development of two general systems: one for binocular 3D eye tracking in Virtual Reality, and one for monocular 2D eye tracking over a 2D display (e.g., a television monitor on which graphical information can be displayed). This part of the book ends with a description of system calibration, data collection, and analysis.

The third part of the book surveys a number of interesting and challenging eye tracking applications. Applications identified in this part are drawn from Psychology, Human Factors, Marketing and Advertising, Human-Computer Interaction and Collaborative Systems, and Computer Graphics and Virtual Reality.

How to Read this Book

The intended audience for this book is an inter-disciplinary one, aimed particularly at those interested in Psychology, Marketing, Industrial Engineering, and Computer Science. Indeed, this text is meant for undergraduates and graduates from these disciplines enrolled in a course dealing with eye tracking, such as the Eye Tracking Methodology course developed by the author at Clemson University. In this course, typically all chapters are covered, but not necessarily in the order presented in the text. In such a course, the order of chapters may be as follows.

First, Part III is presented outlining various eye tracking applications. Normally, this part should give the reader motivation for design and implementation of a one-semester eye tracking project. Coverage of this part of the book is usually supplanted by readings of research papers from various sources. For example, papers may be selected from the following conferences: The Computer Graphics Proceedings, the proceedings of the annual Association for Computing Machinery (ACM) Special Interest Group on Graphics and In-

teractive Techniques (SIGGRAPH) conference series, the proceedings of the ACM Special Interest Group on Human-Computer Interaction (SIGCHI), the proceedings of the Human Factors and Ergonomics Society, and the Eye Tracking Research & Applications (ETRA) conference.

To speed up development of a gaze-contingent application, Part II follows the presentation of Part III, dealing in the technical details of eye tracker application development. The types of applications that can be expected of students will depend mainly on the programming expertise represented by members of inter-disciplinary student teams. For example, in the Eye Tracking Methodology course at Clemson, teams are formed by joining Computer Science students with one or more of the other representatives enrolled in the class, i.e., from Marketing, Psychology, or Industrial Engineering. While all group members decide on a project, students studying the latter subjects are mainly responsible for the design and analysis of the eventual eye tracking experiment.

Once implementation of an eye tracking application has commenced, Part I of the text is covered, giving students the necessary theoretical context for the eye tracking pilot study. Thus, although the book is arranged “top-down”, the course proceeds “bottom-up”.

The book is also suitable for researchers interested in setting up an eye tracking laboratory and/or using eye trackers for conducting experiments. Since members with these goals may also come from diverse disciplines such as Marketing, Psychology, Industrial Engineering, and Computer Science, not all parts of the book may be suitable for all readers. More technically oriented readers will want to pay particular attention to the middle sections of the book which detail system installation and implementation of eye tracking application software. Readers not directly involved with such low-level details may wish to omit these sections and concentrate more on the theoretical and historical aspects given in the front sections of the book. The latter part of the book, dealing with eye tracking applications, should be suitable for all readers since it presents examples of current eye tracking research.

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I have gained considerable pleasure and enjoyment in putting the information I've gathered and learned on paper. I hope that readers of this text derive similar pleasure in exploring vision and eye movements as I have, and they go on to implementing ever interesting and fascinating projects—have fun!

Clemson, SC, June 2002 *Andrew T. Duchowski*

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