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A non-contact device for tracking gaze in a human computer interface☆

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Abstract

This paper presents a novel design for a non-contact eye detection and gaze tracking device. It uses two cameras to maintain real-time tracking of a person's eye in the presence of head motion. Image analysis techniques are used to obtain accurate locations of the pupil and corneal reflections. All the computations are performed in software and the device only requires simple, compact optics and electronics attached to the user's computer. Three methods of estimating the user's point of gaze on a computer monitor are evaluated. The camera motion system is capable of tracking the user's eye in real-time (9 fps) in the presence of natural head movements as fast as 100°/s horizontally and 77°/s vertically. Experiments using synthetic images have shown its ability to track the location of the eye in an image to within 0.758 pixels horizontally and 0.492 pixels vertically. The system has also been tested with users with different eye colors and shapes, different ambient lighting conditions and the use of eyeglasses. A gaze accuracy of 2.9° was observed.

Keywords: Eye tracking; Gaze estimation; HCI

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1. Introduction

Tracking and recording a person's eye movements has been shown to be useful in diverse applications [1–5]. However, speed, accuracy, cost, and ease of use have so far limited its widespread use in a human computer interface beyond narrow research markets. The research reported in this paper attempts to overcome these limitations.

Background physiology and neurology of eye movements used to define design specifications are covered in [1,6,7]. Useful characteristics of the eye include corneal reflections (*glint*) [6] and the maximum angular velocity of head movement (100°/s). While physiologically, fixations during reading are about 200 ms long, a *fixation* as defined here extends that period to 350 ms to include tremors, microsaccades, and slow drifts. The 3D location of a point on the object that falls within the foveal center during this period is considered to be the *point of gaze* (POG). The *angle of gaze* (AOG) has been defined (see Fig. 1) as the angle between the line of sight and either the user's frontal plane (θ_1) or, as used here, the normal to the viewing plane (θ_2).

2. Previous work

Video-oculography (VOG) [6,8,9] is a minimally intrusive or completely non-contact technique commonly used for tracking and recording eye movements. In this paper, VOG is used to track the eyes and determine a user's gaze. In a complete VOG system that determines where an unconstrained user is looking, there are three basic tasks [10]. The *first task* is to compensate for natural head movements to ensure that the user's eye is always in the field of view of the camera(s) tracking the eye. The *second task* is to detect the features in each image and extract parameters (e.g., 2D or 3D pupil and glint locations) used by a tracking model. The *third task* involves mapping the derived parameters to a problem space (e.g., AOG or POG).

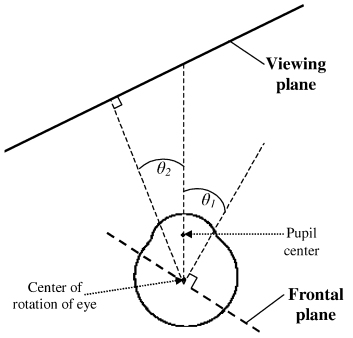

Fig. 1. Angle of gaze.