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# Survey of Eye Tracking Methods and Gaze Techniques

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**Abstract:** ***In Investigation of eye-development is being utilized in Human Computer Interaction (HCI) inquire about. Eye - look following is one among the premier testing issues inside the territory of Computer vision. The aim of this paper is to sitting a review of latest research during this continued development of eye gaze tracking. This overview includes the fundamental definitions and terminologies, recent advances within the field and at last the requirement of future development within the field.***

**Keywords:** "eye-gaze tracking, single and Multi-camera eye tracker, Video oculography"

## 1. Introduction

Eye tracking may be a technique whereby the position of the attention is employed to determine gaze direction of an individual at a given time and also the sequence in which there are moved (Poole & Ball, 2006). That's useful for scientists who try to understand movements of the attention while an individual is involved in several activities. Different techniques where developed over the years consistent with technology available at that point.

Emile Java (French ophthalmologist, 1839 - 1907) was among the primary who describe in 1879 the movements of the attention during text reading He observes with a the assist of a mirror, that the notice movements aren't continuously along the phrase but composed from rapid movements named saccades combined with short stops named fixing.

Later, Edmund Huey (the author of The Psychology and Pedagogy of Reading published in 1908) built an eye fixed tracker device using small contact provided with a hole for pupil. An aluminium pointer was connected to lens in order to watch the gaze direction during reading (Edmund Huey, 1908).

(Dodge and Cline) achieved the speed of eye movements and spread the first accurate and non-invasive eye tracking device supported corneal reflexion (Dodge 1901), named photocronograph.The system recorded only horizontal movements of the attention employing a plate (Jacob and Karn, 2003). Four years later (1905), Charles H. Judd (an American psychologist and education reformer) developed a photograph device that allowed recording the attention movements in both directions, horizontally and vertically (Shahzad & Mehmood, 2010).

In 1930, Miles Tinker worried about how print influenced reading, made a string of studies using eye tracking technology about eye movement in reading (Tinker, 1963).

Paul Fitts, authenticated for improving wing safety, decided in 1947 some relation between person's eye movement and his cognitive activity.He appliedvideo camera to take and survey ocular action of airplanes pilots during flights. He concluded that the fixing were associated with the importance of the control while the duration of fixing were concerning on how easy the information is interpreted (Russell, 2005). Next year, Hartridge and Thompson invented the primary head mounted eye tracker (Hartridge, 1948).Thus force of head movement were eliminated (Eachus, 2009).

Alfred Yarbus progressing eight small suction devices attached to eye.Some of them are covering completely corneal area leaving only a small rectangle window for subject. Some of them are attached only to sclera leaving the visual field unobstructed (Yarbus, 1967). Both types reflect light onto photosensitive surface.Using these devices, Yarbus defines five sort of eye movement: fixation, saccades, tremor, drift, pursuit (Kassner & Patera, 2012).

In the '70s pains were focused on study about human eye procedure and what are often revealing from perceptual and cognitive processes (Jacob and Karn, 2003). Also the amount of scientific publications decrease compare with previous periods due to the methods used and energy involved in processind data.

The occurrence of personal computer in the '80s was compared with a breath of air for eye tracking researches. Now, scientists have an important instrument for high speed data processing. They also start to investigate how eye tracking ability, be used for interaction between human and computer. At first this was done to help disabled people to have access to the new technology (Levine, 1981; Hutchinson, 1989). Then marketing groups saw an opportunity in using eye tracking to enhance their announcement in magazines by observing what pages are actually read and afferent times. In the same context, in the early '90s, eye tracking was employed by NFL (National Football Ligue) analyst Joe Theismann and a series of football fans to work out what parts of the screen was most viewed and what parts less (Leggett, 2010). Because of success of this approach, eye tracking technology was employed by EURO RSCG, the most important advertising and marketing agency, to guage and measure the reactions to information on websites (Leggett, 2010).

## 2. Methods of Eye Tracking

A method of recording eye position and movements is named oculography. There are four different ways to track eye movement [COGAIN (2005)].

### 2.1 Electro-Oculography

In this method, sensors are attached at the skin round the eyes to live an electrical field exists when eyes rotate. By recording small differences within the skin potential round the eye, the position of the attention are often estimated. By carefully placing electrodes, it's possible to separately record horizontal and vertical movements. However, the signal can change when there's no eye movement. This system isn't well-suited for everyday use, since it requires the close contact of electrodes to the user but remains frequently employed by clinicians. However, it's an inexpensive, easy and invasive method of recording large eye movements. The large advantage of this method is its ability to detect eye movements even when the attention is closed, e.g. while sleeping [Mazo et al. (2002)]. The projects called MONEOG, from Metro Vision Systems and Eagle Eyes from Opportunity Foundation of America have used the tactic of electro-oculography successfully for eye-gaze tracking. The Eagle Eyes are helping people with severe physical disabilities to regulate the pc by moving only their eyes.

### 2.2. Sceleral Search Coils

When a coil of wire moves during a magnetic flux, the sector induces a voltage within the coil. If the coil is attached to the eye, then a sign of eye position are going to be produced. So as to live human eye movements, small coils of wire are embedded during a modified contact. This is often inserted into the attention after local anesthetics has been introduced. An integrated mirror within the contact allows measuring reflected light. Alternatively, an integrated coil within the contact allows detecting the coil's orientation during a magnetic flux. The advantage of such a method is that the high accuracy and therefore the nearly unlimited resolution in time. Its disadvantage is that it's an invasive method, requiring something to be placed into the eyes. To the simplest of our knowledge, this method of eye tracking has not been used for HCI by gaze, so far. This method is usually utilized in medical and psychological research. Chronos Vision and Skalar Medical have used scleral search coils method for eye tracking relative to the head position.

### 2.3. Infrared Oculography

The infrared oculography gauge density of reflected infrared during this eye tracking method, eye is illuminated by infrared which is reflected by the scelera. The difference between the amounts of IR light reflected back from the attention surface carries the knowledge about the attention position changes. The sunshine source and sensors are often placed on spherical glasses. Hence it's an invasive method. The infrared oculography has minus noise than electro-oculography, however is more critical on changes of external light tension the of this method is that it can measure eye motion just for about ±35 degrees along the horizontal axis and ±20 degrees along the vertical. These systems are designed to live eye movements during resonance Imaging (MRI) examination. The benefits include ability to live eye movements darkly. Infrared oculography is getting used in gaze interaction by making use of image processing software. There are three categories of infrared oculography which use: the corneal reflection, the Purkinje images and therefore the track of the pupil. These principles are exploited during a number of commercially available eye trackers viz. Intelligaze IG-30, EyeMax System, EyeTech Digital Systems and SeeTech.

### 2.4 Video Oculography

Video-based eye tracking is that the most generally used method in commercial eye trackers. Until recently, the eyegaze tracking was a really complex and expensive task limited for less than laboratory research. However, quick technological progress (increased processor speed, advanced digital video processing).Video oculography make use of single or multiple cameras to work out the movement of eye using the knowledge obtained from the pictures captured. Video-based eye tracking systems could also be invasive or non-invasive. Each category again splits into two other categories counting on the type of sunshine used: light or infrared. Invasive systems or head mounted systems are commonly composed of 1 or more cameras [Duchowsky (2007)]. Non-invasive or remote systems are the foremost exciting subject of Human Computer Interactions (HCI) [Huchuan et al. (2012); Morimoto and Mimica (2005)]. During this paper, we are concentrating on video-based remote eye tracking systems. It is surprising to seek out the big variety of gaze tracking systems which are used with an equivalent purpose, that is, to detect the purpose of gaze [Hansen and Ji. (2010); Böhme et al. (2006); Orman et al. (2011); Černy, M. (2011); Mohamed et al. (2008)]. In any case, their premise is by all accounts the equivalent; the picture of the consideration caught by the camera will change when eye pivots or deciphers in 3D space. The remote eye following frameworks that showed up in the writing are frequently gathered into; single-camera eye tracker and multi-camera eye tracker. The subsequent section specialise in hardware setup of the attention tracker system instead of some cumbersome mathematical details.

**Table 1:** Comparison between non-intrusive methods

| Video Camera | Infrared Camera |
|---|---|
| Suitable for miniaturization | Unsuitable for miniaturization |
| Only requires normal (visible –Light) Camera = low cost | Requires an infrared camera and an Infrared = High cost. |

#### 2.4.1. Single Camera Eye Tracker

Infrared light like the trackers from LC or ASL. Some systems incorporate a second lighting, because the one from Eyetech. Yasuk Sugano et al. proposed a look estimation framework with one camera mounted on the screen by utilizing gradual learning technique. This technique also estimates the top pose of an individual by employing a 3D rigid facial mesh [Sugano et al. (2008)]. Ohno et al developed one camera system with one glint [Ohno et al.(2002)]. Matsumoto et al. proposed a system which uses one stereo to compute the 3D head pose and estimate the 3D position of the eyeball [Matsumoto et al. (2000)]. An identical approach is additionally proposed by Wang and Sung (2002). Nitschke et al. proposed an eye fixed pose estimation model by using single camera and display monitor is employed as a light-weight source [Christian et al. (2011)]. Paul Smith et al. described a system for monitoring head/eye motion for driver alertness with one camera [Paul Smith et al. (2000)]. Hirotake et al. proposed a remote gaze estimation method supported facial-feature tracking employing a single video camera [Yamazoe et al. (2008)]. Wang et al. introduced eye-gaze estimation method just by using one camera supported iris detection [Wang et al. (2003)]. Chi Jian-nan et al proposed a pupil tracking method supported particle filtering [Chi et al. (2011)]. Laura Sesma et al. proposed a gaze tracking system based on an internet cam and without infrared may be a searched goal to broaden the applications of eye tracking systems [Sesma et al. (2012)]. Xiao-Hui Yang et al. employed just one camera and 4 IR light sources and used the grey distribution of the video frame to get the corneal glints and pupil centre [Yang et al. (2012)].

The primary trouble with the above fixed single camera frameworks is that the restricted field of view required to catch adequately high goals pictures. By adding different light sources to the arrangement will give preferred outcomes over the only source. The primary single camera remote eye tracker with high accuracy (about 1 degree) and good tolerance to user movement was a billboard system &; Tobii] but implementation details have not been available. A few scholarly gatherings have fabricated single camera frameworks [Hennessey et al. (2006; Guestrin what's more, Eizenman (2006); Meyer et al. (2006)]. Ohno et al. improved their framework with two light sources and one camera [Ohno (2006)]. Morimoto et al. introduced a way for computing the 3D position of an eye and its gaze direction from one camera and a minimum of two light sources [Morimoto et al. (2002)]. The authors argue that it allows for free of charge head motion. Tomono et al. developed a true time imaging systems composed of one camera with 3 CCDs and two light sources [Tomono et al. (1989)]. A camera is found slightly below the centre of the screen. Four light sources are placed at the corners of a planar surface (screen) to be ready to compare and cross-ratio methods [Hansen et al. (2010); Flavio et al. (2012)]. Xiaohui et al. proposed an intelligent control scheme for remote gaze tracking which incorporates a standard resolution camera and 4 near infrared sources [Xiaohui et al. (2010)].

### 2.4.2. Multi-camera Eye Tracker

A large field of view is required to permit for free of charge head motion, but a limited field of view is required to capture sufficiently high-resolution eye images to supply reliable gaze estimates. Multiple cameras are utilized to achieve these goals either through fisheye lens cameras or movable narrow-angle lens cameras. Multiple camera systems within the literature use either separate cameras for every eye or use one camera for head location tracking to catch up on head pose changes. Then combine the knowledge of all the cameras to estimate gaze point. Zhu et al. proposed an eye fixed gaze tracking system during which two video cameras are mounted under the monitor screen and an IR illuminator is mounted within the front of 1 camera to supply the glint within the eye image. Therefore, the pupil-glint vector are often extracted from the captured eye images. additionally, both cameras are calibrated to make a stereo vision system in order that the 3D coordinate of the pupil center are often computed. The computed 3D pupil center will concatenate with the extracted 2D pupil-glint vector to function [Zhu et al. (2006)].

Baymer and Flickner present a system with four cameras: two stereo wide angle cameras and two stereo narrow field of view cameras. Two narrow field cameras that are positioned near the lower monitor corners capture high resolution images of the attention for gaze tracking. Thanks to the narrow field of view, quick head motions would outpace pan-tilt heads. Thus, pan and tilt are controlled using rotating mirrors on high performance galvos. Two wide angle systems are located just below the middle bottom of the monitor screen. The stereo baseline is oriented vertically since this optimizes stereo matching on the central countenance , which are predominantly horizontal edges [Beymer and Flickner (2003)]. Similar system was proposed by Brolly et al, but unlike their system, they use one narrow field eye camera rather than two [Brolly and Mulligan (2004)]. Ohno and Mukawa implemented a free-head gaze tracking system. The attention positioning unit features a stereo camera set which consists of two NTSC cameras. They're placed on a display monitor. The gaze tracking unit features a near-infrared sensitive NTSC camera placed on a pan-tilt stand. A near-infrared LED array is additionally placed under the camera. However, the measurable area are often expanded by changing the stereo cameras' focal lengths and therefore the convergence angle [Ohno. and Mukawa (2004)]. Shih et al.

**Table 2:** Comparison between three intrusive methods

| *Electro-oscillography (EOG)* | *Eye Gaze Input and BCI* | *coil-eye tracking* |
|---|---|---|
| Able to detect the movement of the eye when the person is asleep or closed eyes. | Results indicated that the spatial accuracy and speed were a good reflection of targeted tracking of errors. | Wearing the lenses before the start. |
| This technique has limited use because it requires electrode contact. | Enabled faster communication, which can dramatically improve People's quality of life. | High accuracy. |
| Still used by clinicians. | BCIs will help creating a direct communication between a human or animal brain and computers. | These prone to noise, the coil is not solid. |
| It is inexpensive. | It is inexpensive. | It is inexpensive. |

## 3. Methods of Gaze Tracking

Video oculography systems take information from one or more cameras. The primary step is to detect the attention location within the image. Supported the knowledge obtained from the attention region and possibly head pose, the direction of gaze are often estimated. The foremost important parts of human eye are: the pupil – the aperture that lets light into the attention, the iris – the coloured muscle group that controls the diameter of the pupil and therefore the scelera – the white protective tissue that covers the rest of the attention. Eye detection and tracking remains a very challenging task thanks to several unique issues, including illumination, viewing angle, occlusion of the attention, head pose etc. Two sorts of imaging processes are commonly utilized in video-based eye tracking: visible and infrared spectrum imaging. Infrared eye tracking typically use every bright pupil or dingy-pupil technique [Morimoto et al. (2002)]. During this paper, we specialise in gaze estimation methods supported analysis of the image data.

### 3.1 Feature-based Gaze Estimation

Feature-based methods explore the characteristics of the human eye to spot a group of distinctive features of the eyes like poorness (limbus and pupil contour), eye come and cornea reflex are the common features used for gaze estimation. The aim of feature-based methods is to spot informative local features of the attention that are generally less sensitive to difference in lighting and viewpoint [Iannizzotto and La Rosa (2011)]. These systems have execution issues in outdoors or under strong ambient light. Additionally, the accuracy of gaze estimation decreases when accurate iris and pupil features aren't available. There are two sorts of featurebased accession exists [Hansen and Ji (2010)]: model-based (geometric) and fulfilment-based (regression based).

#### 3.1.1. Model-based approaches

Model-based approaches use a particular geometric model of the attention to estimate 3D gaze direction vector. Most 3D model-based (or geometric) approaches believe metric information and thus require camera calibration and a global geometric model (external to the eye) of sunshine sources, camera and monitor position and orientation. Most of the model-based method follows a standard strategy: first the optical axis of the attention is reconstructed in 3D: the visual axis is reconstructed next: finally the purpose of gaze is estimated by intersecting the visual axis with the scene geometry. Reconstruction of the optical axis is completed by estimation of the cornea and pupil centre. By defining the gaze direction vector and integrating it with information about the objects within the scene, the purpose of gaze is estimated [Hansen and Ji. (2010)].For 3D model based approaches, glimpse directions are predestined as a vector from the eye-ball centre to the iris centre [Yamazoe et al (2008); Taba (2012); Sigut and Sidha (2011); Yang et al. (2012); Hung and Yin (2010); Nagamatsu, et al. (2010); Model and Eizenman (2010)].

#### 3.1.2. Interpolation-based approaches

These methods assume the mapping from image features to gaze co-ordinates (2D or 3D) have a specific parametric form like a polynomial or a nonparametric form as in neural networks. Since the utilization of an easy linear mapping function within the first video-based eye tracker [Merchant et al. (1974)], polynomial expressions have become one among the foremost popular mapping techniques [Brolly and Mulligan (2004); Cerrolaza et al. (2012); Morimoto and Mimica (2005); Cerrolaza, et al. (2012)]. Interpolation-based methods avoid explicitly modelling the geometry and physiology of the human eye but in-state depict the gazed point as a public function of image features. Calibration data are wont to calculate the unknown coefficients of the mapping function by means of a numerical fitting process, like multiple linear regressions. As an alternate to parametric term, neural network-based eye stalker [Baluja and Pomerleau (1994); Demjen et al.Torricelli et al. (2008)] suppose a non-parametric form to perform, the mapping from image features to gaze assortment. In these approaches, the gaze tracking is completed by extracting the coordinates of certain facial points and sending them through a trained neural network, whose output is coordinates of the purpose where the user is watching.

### 3.2. Appearance-based Gaze Estimation

Appearance-based methods detect and track eyes directly supported the photometric appearance. Appearance based techniques utilize image content to rating gaze trend by chart image data to screen coordinates [Javier et al. (2009); Lu et al. (2011)]. The main appearance-based methods [Sheela and Vijaya (2011)] are supported morphable model [Rikert and Jones (1998)], gray scale unit images [Yang (2012)], appearance manifold [Kar-Han et al. (2002)], Gaussian interpolation [Sugano et al. (2012)] and cross-ratio [Flavio et al. (2012)]. Appearance-based methods typically don't require calibration of cameras and geometry data since the mapping is formed directly on the image contents.

## 4. Summary and Conclusion

With the introduction of various methods of eye tracking, we've presented a review of non-contacting video based gaze tracking. The most intention of this paper is to offer a review of latest growth in non-contacting video-based gaze tracking. Albeit, the eye-gaze tracking features a history of 100 years of research, it's not been standardized. Future developments in eye tracking got to centre on standardizing what eye movement metrics are used, how they're mentioned, and the way they ought to be interpreted within the context of interface design [Poole et al. (2004)]. For instance, no standard yet exists for the minimum duration of a fixation. The intrusiveness of kit should be decreased to form users feel easier. The robustness and accuracy of knowledge capture must be increased and eye-gaze tracking systems got to become cheaper so as to produce them a viable usability tool for smaller commercial procuration and research labs.

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