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An Expansion in Classification of Eye Gaze Detection Methods

[1]Jumana Waleed, [2]Ahmed Brisam and [1]Taha Mohammed Hasan
[1]Department of Computer Science, College of Science, University of Diyala, Baqubah, Iraq
[2]College of Agriculture, University of Al-Qadisiyah, Diwaniyah, Iraq

Abstract: Eye gaze, often regarded as a language of non-verbal communication can be studied and estimated using scientific detection methods and contains a tremendous scope of applications in daily lives. Investigations in eye gaze detection can give ideas about what a person is thinking about based on how and where he is looking. Nowadays, the eye gaze detection methods utilize an incorporation of convenient hardware and affined software to detect the gaze direction for providing new applications ranges. In this study, the objective is to provide an inclusive expansion in classifying the recently existing methods based on the eye gaze detection by considering various paradigms such as wearable and unwearable devices, active and passive systems, feature and appearance approaches, the estimation of head movements and the used algorithm. This study includes the major preliminaries, usefulness and abuses as well as the necessities of future expansion in the domain.

Key words: Communication, inclusive, appearance, necessities, passive, preliminaries, scientific

INTRODUCTION

The eye gaze movements supply a fundamental interfacing with a person's purposes and thinking. A noticeable view of the psychology field is the capability of investigating the internal working of the brains via. computing how different muscles of the eye are contracted (Fig. 1).

The researches of eye gaze detection methods may expose what is the thinking of person about on the basis of where he/she is looking. Thus, the eye gaze detection allows various applications, like working as an alternate mechanism of input to make the users capable of doing different jobs such as utilizing a smartphone to determine the visual attention of the users providing a modern field of human interaction environment for a perfect life to the disabled and old people reducing the road accidents by alarming the drivers under various driving conditions; controlling the video games representing a helpful means for medical diagnostics like mental disease diagnostic as well as improving medical education and therapy controlling the humanoid robots removing the awkwardness related to industrialization of sports allowing an extra reliability with a strong performance for security and authentication purposes.

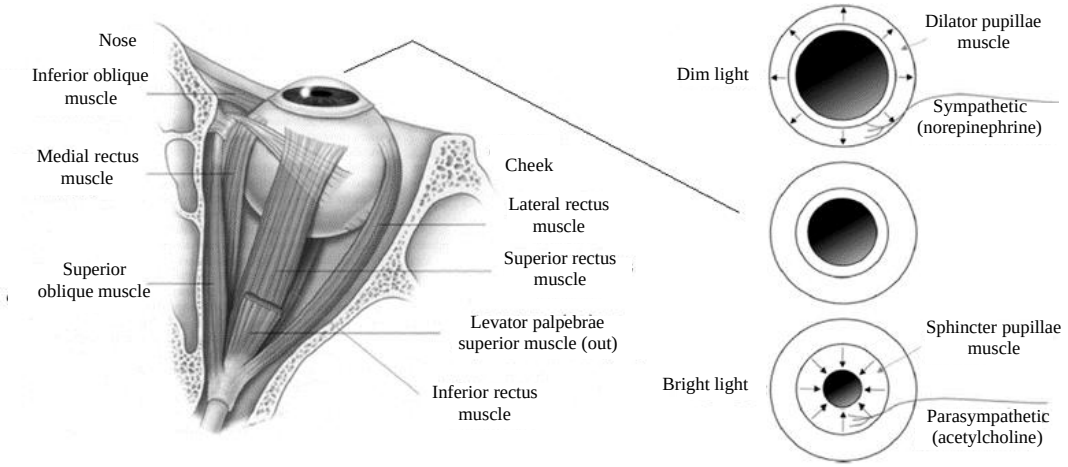

Fig. 1: Demonstrates the eye-muscles which are supply the eye gaze movement

Corresponding Author: Jumana Waleed, Department of Computer Science, College of Science, University of Diyala, Baqubah, Iraq

MATERIALS AND METHODS

Classification of eye gaze detection methods: The methods adopted for the detection of eye gaze can be classified into several types based on the perimeter chosen for classification. For instance, the classification differs when the physical proximity between the subject and the system is studied than when the algorithm used for gaze detection is studied. Further, new perimeters of classification of eye gaze detection systems are being introduced as new developments are being done rapidly in this field. In this study, different methods of eye gaze detection are classified under some broad criteria of differentiation.

Methods based on wearable/non-wearable devices: One of the most popular classification of eye gaze detection methods is based on the wearability and non-wearability concepts. Based on these concepts, the methods of eye gaze detection are classified in to attached and remote methods (Al-Rahayfeh and Faezipour, 2013). The attached (wearable) gaze detection methods generally consist of a single/multiple lenses attached to a device, generally glasses in order to detect the gaze coordinates of the eyes. In this methods, the person requires to lay glasses frames on the helmets or cameras. Helmets provide good solutions for detecting the eye gaze, none the less, there is a limitation in expanding the use of such methods because of their heavy weight. As an example for using helmets in detecting of eye gaze (Pires *et al*., 2013). present a method can be successfully implemented in sport applications with a fast computing and handling of the eye location changes. While the spectacles or glasses can achieve a high publicity, since, they are not heavy and accurate as in the work in which McMurrough *et al*. (2013) use a wearable eye gaze glasses (Fig. 2) for monitoring the right eye equipped with an infrared-monocular camera in addition to the used of reflective markers to detect the head movements and this resrearch provides a high degree of accuracy.

Another arrangement of wearable eye gaze glasses with a low-cost webcam was introduced by Jen *et al*. (2016) for detecting the region of interest and this work also provides high degrees of accuracy and robustness. Depending on the recently existing eye gaze detection methods, the wearable based classification methods are implemented in various applications. Kim *et al*. (2012) present a monitoring system for both eyes equipped with three mini cameras and two mirrors for extracting the regions of interest depending on the detection of binocular gaze. Yip *et al*. (2016) present a controlling interface for surgical manipulators based on wearable

Fig. 2: Represents the wearable eye gaze device (McMurrough *et al*., 2013)

eye gaze detection method. And with application of virtual reality, Tripathi and Guenter (2017) propose a method based a wearable device to detect an eye gaze with a relatively good degree of accuracy. The remote (non-wearable) methods of eye gaze detection do not require any attachment to the subject's body. Rather, the hardware in this system can be assembled in a close proximity to the subject in order to feed the necessary data to the software involved. This type of methods can be particularly beneficial to operate machineries and equipment's remotely, allowing the controller to be at a safe distance while performing tasks that are risky. Also such mothed can be applicable for people with motor disorders to control appliances that input eye signals to perform tasks. An application of remote based methods is proposed by Ebisawa and Fukumoto (2013). Another application is the concept of a tele operative mobile robot has been proposed by Gego *et al*. (2017).

There are different fields of both attached and remote eye gaze detection methods because of both types of detection methods have unrivaled usable benefits. But comparing with other methods based on wearable devices, the methods based on non-wearable devices are widely applied, gratitude for their convenience and easy utilization.

Methods based on active/passive systems: The eye gaze detection methods can be categorized into active and passive systems. Active detectors use infrared illuminants, a light emitting diode and cameras for adding lighting to obtain a suitable recognition for the eye. they are a less effectiveness at more distances and in the daybreak. The passive systems are operating in visual light. These systems are so, natural yet, they are very sensitive to lighting condition. The most present eye gaze

detection methods necessitate somewhat a high cost and employment of infrared illuminators and a light emitting diode techniques that affect the user eyes (Palinko *et al*., 2016). For this reason, it is quite necessary to design a low cost eye gaze detection method based on a software.

Recently, a lot of researches have been worked with the active and passive eye gaze detection methods. Hughes *et al*. (2017) proposed an accurate active detection method under the perfect script of lighting environment (32 light emitting diodes) and a fixed head movement but when moving the head, the detection of eye gaze will be very difficult. Findings by Smith *et al*. (2013) show that, while the active systems of gaze detection were generally more accurate, the passive system is better in terms of distance sensitivity and pose variation. Further, the efficiency of the passive system can be increased by feeding the system with more memory (the number and variations of pictures of different faces in different poses and gazes) that are used as reference to detect the gaze of the subject. As a passive based method in the application of driver assistance, Maralappanavar *et al*. (2016) decide if the drivers are distracted or not via estimating their gaze directions.

One complication for both the active and passive systems of eye gaze can arise when the subject is either far-sighted or near-sighted and wears glasses. It is because glasses often reflect environmental lights which makes detecting eye gaze more difficult. This problem can even combine with a difficulty to detect the pupil when using an active gaze detection method (Chinsatitf and Saitoh, 2016). However, one major advantage of active eye gaze system over the passive gaze system is former's usefulness to control robotics that require the input of a controller's facial and body gestures in order to perform.

Methods based on appearance/feature approaches: The eye gaze detection methods are divided into two categories appearance based methods and feature based methods. The appearance based eye gaze detection methods are the ones that treat the cropped eye images to be detected as points in a high dimensional space instead of treating them as a combination of certain geometrical figures like contours and corners (Zang and Liu, 2012). The core usefulness of appearance based methods is that they require low hardware and these methods can be implemented without using high resolution cameras or extra sources of light. While the core disadvantage of this classification is that it has low accuracy between 2-3° with a fixed head.

Feature based methods occupy into consideration different merits of the human eyes to detect a distinguishing set of features such as pupil contour, the corners of the eye and corneal reflections of near infrared light sources (Wang *et al*., 2016). These methods can be partition into regression based and model based methods. In the regression based methods, the vector between the pupil center and corneal reflections is detected and geometrically mapped via. a polynomial regression-function to gaze coordinates on the screen. While the model based methods utilize a geometrical pattern of the eye of human straight with near infrared illuminator and various cameras and mirrors for developing an accurate detecting of eye gaze directions. Comparing with the appearance based methods, this classification has a higher accuracy but it requires extra hardware like various sources of light or cameras. Also, there is a difficulty may cause method fail when the near infrared glints in the eye cornea are disappearing owing to the head movement or when more glints are appearing in the eye via. other near infrared sources of light (Bazrafkan *et al*., 2015).

There are many researchers are tried to fix the problems appeared in appearance and feature based methods. Wang *et al*. (2016, 2018) improve that appearance based methods can be very effective when training big amounts of data. Zhang *et al*. (2017) propose a full face appearance based trained architecture method to detect accurate and robust eye gaze directions under various challenges of light conditions and head poses. Without any extra hardware (only a webcam on the screen of the computer), Jariwala *et al*. (2016) presented a geometric feature based method to detect the eye gaze directions with a high degree of accuracy.

The methods based on head pose estimation: The estimation of the eye gaze of a human can also be made by analyzing the head pose instead of detecting for minute features like pupil or iris. Therefore, the head pose estimation system is more effective when the subject of study is not in a close proximity of the detection system to effectively detect the configuration of optical and facial muscles. The head pose method of eye gaze detection can be applied to study multiple subjects at the same time, thus, making it suitable for applications like studying the behavioral patterns of crowds for crowd management, searching for a particular person in a crowd and so on (Baxter *et al*., 2015). The head pose estimation systems are further studied under two different domains namely visual surveillance and human computer interactions (Mukherjee and Robertson, 2015). Both domains of head pose detection differ for one another in aspects of the quality of input and range of detection. The visual

surveillance system is the type of estimation system than can work from a fairly long range between the system taking the input and the subject. It is mostly applied to detect patterns and superficial details such as the speed and direction of a subject in motion, common gestures and patterns of crowd movement etc. (Chen and Odobez, 2012). Since, this domain only concerns with the superficial subjects and can work from a long range, it does not demand very high quality of images as input data. In contrast, Human Computer Interactions (HCI) is a detail-based domain of detection. This type of detection system applies the approach where facial landmark detection is performed (Fanelli *et al*., 2011). Therefore, this approach requires the input of high resolution images and can only work in a short range, i.e., generally, 1-2 m between the hardware and the subject. Further, unlike the visual surveillance methods, the human computer interaction methods are suitable for indoor applications where the subject in interest are static and facing directly towards the input mechanism. However, it is possible to combine the usefulness of both the domains and to avoid their limitations by combining the concepts of both the domains together in an applicable system as proposed by Mukherjee and Robertson (2015). Their approach involved the combination of two different networks, one trained to capture depth and detail and the other to capture RGB in order to unify the problems of both the domains. Their results further show that the combination of these two domains into one system opens up scope for faster and more reliable detection systems that are highly applicable. Valenti *et al*. (2012) provide a preferable visual eye gaze estimation via. joining the eye location with the information of the head movement. For smart interacting between the user and the smart TV, Nguyen *et al*. (2013) present an eye gaze detection method based on head pose estimation to control the smart TV. Another application of controlling various assistive technologies is proposed by Al-Rahayfeh and Faezipour (2014) in which several controlling signals are promoted via. the classification of eye gaze direction and the detection of head movement. In the application of the drossiness in the driving assistance systems, Choi and Kim (2014) propose a relatively fast calculation method for detecting the head pose and the eye gaze to reveal the drowsy driver.

Methods based on used algorithm: The used algorithm based eye gaze detection methods, rather than detecting for certain facial reference points or analyzing images for certain facial features and poses, uses a set of calculable rules in order to determine the eye gaze of an individual. Already, this classification of eye gaze detection methods can be utilized in the field of driver fatigue monitoring, since, the past few years. Lopar and Ribariæ (2013) suggest two different bases of eye gaze detection, one for eye detection and the other for face detection further, both the types of detection methods contained further divisions of detection types in practice. George and Aurobinda (2016) have provided fast and reliable detection algorithm for eye localization using low resolution images which searches for the center of the iris using the geometrical features. Besides, several other algorithmic techniques for eye gaze detection are being introduced in researches these days, expanding the field and introducing new approaches all the time.

RESULTS AND DISCUSSION

The performance analysis: The previously presented classifications are briefly given in Table 1. This table introduces a comparison that is based on the following criteria: the application domain, wearable and unwearable devices, active and passive systems, feature and appearance based systems and the head movements detection.

Table 1: A comparison between different classifications of eye gaze detection methods

Researchers (years)	Field of application	Attached methods	Remote methods	Active system	Passive system	Feature based system	Appearance based system	Head poses
Pires (2013)	Motor sports application	✓		✓		✓		
McMurrough *et al.* (2013)	Educational and research purposes	✓		✓		✓		✓
Jen (2016)	Driver assistance systems and assistive techniques	✓			✓		✓	
Kim *et al.* (2012)	Psychology and robot utilization	✓		✓			✓	
Yip *et al.* (2016)	Surgical manipulator	✓			✓		✓	
Tripathi and Guenter (2017)	Virtual reality	✓		✓		✓		✓
Ebisawa and Fukumoto (2013)	-		✓	✓		✓		✓
Gego *et al.* (2017)	Human robot interaction		✓		✓		✓	
Hughes *et al.* (2017)	Input device for computer interaction		✓	✓		✓		
Smith *et al.* (2013)	Human object interaction							

Table 1: Continue

Researchers years	Field of application	Attached methods	Remote methods	Active system	Passive system	Feature based system	Appearance based system	Head poses
Shweta *et al.* (2016)	Driver assistance system		✓		✓		✓	
Wang *et al.* (2016)	Human attention understanding		✓		✓		✓	
Wang *et al.* (2018)	-		✓		✓		✓	✓
Zhang *et al.*(2017)	Computer vision tasks		✓		✓		✓	✓
Jariwala *et al.* (2016)	Commercial gaze estimation systems with simple webcams		✓		✓		✓	✓
Mukherjee and Robertson (2015)	Scene interaction detection		✓		✓		✓	✓
Valenti *et al.* (2012)	-		✓		✓		✓	✓
Nguyen *et al.* (2013)	Smart TV controlling		✓		✓		✓	✓
Al-Rahayfeh and Faezipour (2014)	Various assistive techniques		✓		✓		✓	✓
Choi and Kim (2014)	Driver assistance systems		✓		✓		✓	✓
George and Routray (2016)	-		✓		✓		✓	

CONCLUSION

To conclude, the classifications and applications of eye gaze detection methods are diverse and expanding. Each classification of the methods has its own usefulness and abuses. Unfortunately, these methods based classification cannot provide entirely exhaustive objectives. In the previous sections, a representative insight for classifying the eye gaze detection methods in various applications is presented. The need to find a beneficial eye gaze detection method includes high degrees of reliability and accuracy, robust head movements detection and robustness to spacious varied lighting conditions. In addition to the necessity for increasing the performance of the method and decreasing the cost.

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