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Eye-Gaze Estimation System for Multi-Application Purpose

A Dissertation
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بِسمِ ٱللَّهِ ٱلرَّحمنِ ٱلرَّحِيمِ

﴿ نَرْفَعُ دَرَجَاتٍ مَّن نَّشَآءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ

عَلِيمٌ ﴾

صَدَقَ ٱللَّهُ العَظِيم

سورة يوسف

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I would like to express my gratitude to my family.

Qutaiba Kadhim Abed

Dedication

To...

My family

My dear parents

My friends

All our distinguished teachers those who paved the way for our science and knowledge

Qutaiba Kadhim Abed

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This is to certify that this thesis entitled **"Eye-Gaze Estimation System for Multi-Application Purpose"** was prepared under my linguistic supervision. It was amended to meet the style of English language.

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Abstract

Eye-gaze is the mirror of speech, the language of nonverbal communication. The research investigations in eye-gaze estimation systems may reveal what persons think about on the basis of where they are looking. An eye-gaze estimation system can be built to operate the communication system that will help those kinds of people by depending on their gazes estimating.

The major applications for eye-gaze estimating is in Human-Computer Interaction (HCI) empowering impaired users with the ability to control the pointing and/or selection of components in a user interface, typically done by mouse and keyboard. With eye movement the eye-gaze is useful for many other purposes also in life such as offering new attributes to the e-readers, helping the handicapped individuals to run the automated appliances, alerting the drivers when their eye-gaze moves away from the path, controlling the instruments by the surgeons, allowing to control the smart home appliances like smart TV, controlling the video games, assisting the marketers to detect which a product the persons view at most, detecting the eye-gaze movement for the simulation of pilots in flight, non intrusive controlling for drones and monitoring the unusual eye-gaze movement in divers which may refer to narcosis nitrogen or deprivation of oxygen.

This thesis presents an implementation of a low cost, a passive and an appearance-based eye-gaze estimation system based on Laptop Webcam. The proposed approach consists of four fundamental parts: Firstly, the image pre-processing; Secondly, the face detection part; thirdly, the eye region detection part, and finally, the eye-gaze estimation part. This approach is more comfortable since it is based-unwearable devices, so there is no need to wear any sensor or camera to the user's body. This proposed system provides a suitable average of accuracy and reliability which make it applicable for multi-purposes.

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
Avg	Average
BMP	Bitmap Image
CD	Circular Distribution
EGE	Eye Gaze Estimation
HSV	Hue, Saturation, Value
HCI	Human Computer Interface
PC	Personal Computer
2D	Two Dimension

SYMBOLS TABLE

Symbol	Meaning
*	Multiplication operation
+	Addition operation
/	Division operation
-	Subtraction operation
=	Equality sign
θ	Theta
∑	Summation - sum of all values in range of series
|X|	The absolute value bars
σ	Sigma
%	Percent sign
Sin	Sin function
Cos	Cos function
√	Square root
(*a*,*b*)	Ordered pair, collection of 2 elements
( )	Parentheses, calculate expression inside first
º	Degree, 1 turn = 360º

Chapter One

General Introduction

Chapter One
General Introduction

The eyes are a basic piece of the people bodies. They expect a huge part in ordinary regular days during lifetime, granting a person's needs, social relationship and a broad type of psychological procedures. The eye is a means over with whom person chats to outside visional world. The same way, a capability for estimating someone's gaze without an invasive style looks very important to design efficacious human PC interfaces and for perfect human recognition comprehending. This chapter presents an introduction to the human eye, eye gaze estimation techniques and its classifications, related works, an expansion in the recently existing applications based on the eye-gaze estimation systems, and research objectives.

1.1 Introduction

Day to day in the life, the majority of people use their eyes strongly to perceive, learn, read, watch, navigate etc. In spite of the seemingly easy with how we comprehend the world surrounding us, visional understanding is, in reality, a complex operation that happens at a level under consciously attentive. The structure of light seen by the eyes is constantly testing because the eye moves in order of making the next essential structure of the light sample. The mind tries to comprehend the information that has been understood. So that way, we comprehend the scene. The movements of the eyes throughout reading and picture's identification supply beneficial information on the operations by which people comprehend visional insert and combine it with knowledge and memory [1].

The eye gaze estimating term explains how it uses here to estimate the orientation of the person's gaze. Most scenarios of the estimating of the gaze orientation show the identifying of any thing on what the gaze has been falling [2]. Among the best tools that they utilized in order maintaining their livelihood is the communication between human in this world. Since the start with humankind, the aspect of some languages are constituted an advanced word, globally famous non-oral manner of articulation so far has a recognizable weighing for the human eye which is a typical perceptive that the eyes of human do the trick that requires for expressing thousands of the words which that pass on immense feelings and emotions. Regardless of this, there are situations when people experience the ill effects of a disability which makes them disable (paralyzed) for moving any organ of their body with the exception of their eyes. In that case, eye motions are crucial basic all together for the patient for communicating with this present reality and it is surrounded [3].

Improvement of fabulous eye gaze estimation techniques is wanted for a few fields, for example, for behavioral investigations or psychophysical and for man-machine interfaces. It is exceptionally helpful especially for a considerable lot of the physically distraught, for example, amyotrophic lateral sclerosis patients, whom cannot utilize the most important body motions precisely but do in fact have eyes motion capability. For instance, a person can control helpful gadgets or can communicate with other through a pointer with the PC displaying hierarchal basic menu choices on a PC screen [4].

The principal investigative instrument, over a long time ago, was the eye gaze estimating, which it is the points of the eyes gaze direction's measurement over the estimate of the eyes motion related to the head. In fact, that technique had used by clinicians such as a window to the human perceptive operations and

sensations. A large number of data mining needs explaining information abundance which it has given by gaze analyses, the researches have been centered on effective and application based feature picking. For example, eyes estimating could be utilized in order to assess the cognitive load of a subject, blinks number, the pupil diameters and the number of fixations. If in a granted quantity of time the blink declines whilst the other two parameters increase, person "confusion" is probably going to have happened. The outcomes could be utilized to automatically recognize fatigue in pilots and drivers, thus increase the safety of living and security. Through the numerous utilizations of gaze based analyses, either generally normal, in such a futuristic or soft biometrics, for instance, neuro advertising, a few scientific applications have arisen in recent years [5].

1.2 The Structure of Human Eyes

We can see the world around us by our eyes, which are next to each other in closeness. Both of our eyes can see the same thing in the world independently, any eye constructing a separated signal referring to the field of its visual. The human's mind on this point creates from these signs a uniform image [6]. Figure1.1 depicts the focal different modules for typical region to the eyes.

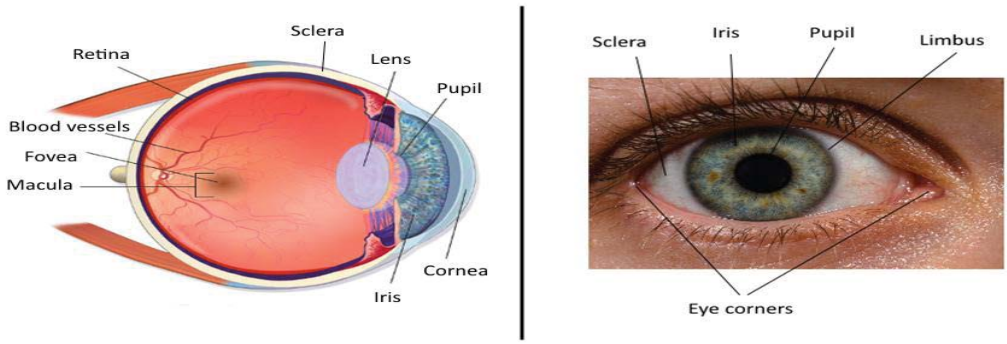


Figure1.1: The typical region to the eyes[7].

The eyes have a roughly round shape with a radius of almost 12 mm. The eyes outer portions which it is visible inside the eyes cavity are the iris (colorful piece of the eyes), the pupil in the middle of the iris, and the sclera (white piece within any eyes). The cornea is very beneficial part to protect the eye, which it is a transparent preventive membrane, in order to void of blood vessels that emerge in front of any eyes, and as well to cover the iris. The iris contains a spherical hole in the middle, titled pupil, which orders the quantity of light coming into the eyes by frequently altering its bulk. There is the lens beyond the iris, multilayered structure a convex on both sides[7].

Through the accommodation the form of the lens is changeable, a procedure that permits to convey the picture of an object for a sharp concentration in the retina, that is a level having photosensitive cells placed at the rear of the eyes. The anterior chamber lies between the cornea and the lens that is full of with the aquatic humor and in the space between the retina and the lens is the clear jellied hyaline body. The lights that infiltrate the retina have crossed the entire eyes optic media, enduring reflection, and refraction at every media border. The retina has a small but special area, called the fovea that focuses extreme of the color sensitive cells and is accountable for the comprehension of the scene's well details. The fovea does not be precisely in the optic axis of the eyes explained by the middle of the middle of the pupil and the middle of the eyeball [8].

1.3 Categorization of The Eye Gaze Estimation Systems

There are a number of various types of eye-gaze estimation systems that can be classified along various ranges.

1.3.1 Wearable and Unwearable of Eye Gaze Estimating Systems

There are two distinct types of the eye-gaze estimation systems, which are the systems based-wearable devices (head mounted systems) and based-unwearable devices (remote systems). In head mounted systems, the people need to put cameras on the helmets or the glasses frames. Helmets offer good results for eye-gaze estimation; nonetheless, their heaviness makes them unpractical for expanding utilization. Spectacles have been achieving a good popularity because they are accurate and not heavy. With remote systems, there is no need to wear any sensor or camera to the human's body, and this may lead to increase the user's convenience, essentially in long term utilization. But, this type of systems provides a low accurate as well as it is unsuitable for the applications that needed mobility [9]. As compared with various systems based-wearable devices [10,11], the systems based-unwearable devices are extensively utilized thankfulness to its ease of use and convenience[12,13].

1.3.2 Active and Passive Techniques of Eye Gaze Estimating Systems

Eye-gaze estimation systems can be classified into active and passive systems. In Active systems, the estimators require the use of cameras, infrared illuminants (IR) and A light emitting diode (LED) to add lighting to get a preferable look for the eye. These systems have a lower efficiency at big distances and in the daytime. The passive systems are working in visual light. These systems are very natural; however, they are more sensitive to lighting cases [14]. The most existing eye-gaze estimation systems require to some extent a high cost and utilization of near IR and LED technologies [15] in which the user's eyes may sense uncomfortable. In spite of the use of invisible IR illumination, it is still possible for the IR illuminator to affects the users’ eyes

and this affects the applicability. For these reasons, a design of a low cost based a software eye-gaze estimation system is very necessary. With this context, some researchers use a low cost single camera and others use low cost devices like high definition (HD) web camera and Kinect [16].

1.3.3 Feature-Based Method and Appearance-Based Systems

Another significant classification is between feature-based and appearance-based systems. Feature-based systems are developed to be the highest popularity for the eye-gaze estimation that detects the local attributes from the images of the eye, like eye corners, reflections, and contours. In appearance-based systems, the eye-gaze estimation does not obviously detect the attributes; but it utilizes the contents of the image as an input and maps them directly to screen coordinates. The major disadvantages of this type of systems are; firstly, it has a low-accuracy typically between 2º and 3º with a fixed head movement, on the contrary, the feature-based system has a higher accuracy (less than 2º); secondly, it is difficult to merge the information of head pose with appearance in a strong manner when involving the head movements [9].

Anyone can turn the eye-gaze to a proper location after moving the head. Therefore, head pose estimation systems must be integrated with the eye-gaze estimation systems. There are many researches for head pose estimation such as [17] that can be utilized for eye-gaze estimation systems. Therefore, a lot of systems have been developed for robustly combining the head pose estimation with the eye-gaze estimation[17].

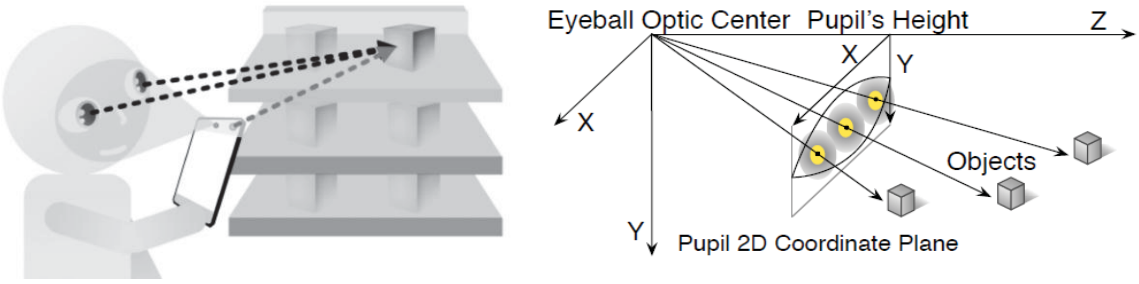
1.4 Related Works of Eye-Gaze Estimation Systems in Multi-Applications

Recently, the term of eye-gaze estimation systems in unlimited cases has become a modern research field in which various types of programs and related devices are improved over the multidisciplinary researches. In spite of the considerable achievements by the researchers in this domain, the ability to use eye-gaze movements in various application fields is still negligible in reliability and accuracy criteria [18]. Currently, the use of trained neural network can determine the eye-gaze estimation with high reliability and accuracy as in the works [19, 20]. Also, the utilization of optimization techniques like particle swarm optimization can improve the performance of eye-gaze estimation systems [21]. And to optimize the performance of the whole system, presents an optimized combination of neural network and particle swarm optimization. This section presents a summarized study about the highest representative works in eye-gaze estimation systems. Therefore, different applications have been considered[22].

1.4.1 Eye-Gaze Estimation as Input Mechanism with Smartphone

With the fast development of techniques, Smartphone is developed to be a ubiquitous device used by a large number of users. It is vastly utilized to control an extremely domain of commercial applications in daily lives because it is supplied perfectly with various equipment such as a high resolution camera, wireless connection, a considerable processing, large storage and etc. In order to deal with Smartphone without using the hand, eye-gaze estimation systems have been developed as an alternative input mechanism to allow the user to do many jobs at the same time. Different researchers utilize a Smartphone based eye-gaze

estimation to determine the visual attention of the users. [23] Proposes a low cost visual attention detection system based on a Smartphone which is able to compute the eye-gaze direction and the range toward the object (see figure 1.2). This system achieved high accuracy with low response time. A driver's visual attention system based on a Smartphone utilizing computer vision techniques is presented in [24], as a solution for driver monitoring with high convenience and low cost. Smartphone represents a dynamic platform in which the cases for fixed eye-gaze estimation are extremely challenged owing to changeable locations to the users with respect to Smartphone, the unusual hand movement and variable lighting [18].



(a) **(b)**

Figure 1.2: Explanation of the visual attention detection system based on a Smartphone. (a) Getting information about objects through an eye-gaze. (b) The computation of eye-gaze directions [23].

1.4.2 Eye-Gaze Estimation for Controlling Smart Homes/TV

Fundamental developments have been built in smart home appliances to support the disabled and regular persons in their daily life. The suitable design for the smart homes provides an unconventional free life for these persons to stay in their usual surroundings for a long time. Nowadays, Smartphones are utilized for a low cost and flexible home control and monitoring system. But, with daily workloads, the users are not in a situation to take out the Smartphone

to control their home devices. Several methods have been proposed in the design of such systems for estimating the user emotions by analyzing eye-gaze, nose and lips [25]. Eye-gaze estimation based smart homes are a new domain of human environment interaction which provides a perfect life for the old and disabled people. Recently, the Smart TV has been widely used by offering a smart interaction between system and user for controlling TV menus based on a remote controller, user's gestures and etc. With the appearing of different functions for the smart TV, it is difficult for a remote control to do these large functionalities. In addition to, the viewers need convenient input devices without moving their hands. Therefore, the eye-gaze estimation can be used for detecting the location where the users are looking at on television screen, and thus represents a substantial use in the situation of choosing a special television menu or monitoring if the user is watching television or not. [25] Proposes an eye-gaze estimation system based on head pose estimation in smart TV, and this work requires reducing the impact of lighting in the process of detecting the face contours. [27] Presents a wearable system based on internet protocol TV environment. This system still needs to improve its throughput to get a high reliability and convenience.

1.4.3 Eye-Gaze Estimation in Driver Assistance Systems

It is necessary for developing robust safety systems, which can reduce the road accidents via alerting the drivers under different bad driving conditions. Eye-gaze estimation systems are one of the essential techniques for the future of driving assistance systems. A lot of researchers recorded the driver assistance systems based eye-gaze estimation in which the eye-gaze movements for the drivers are estimated as a point of their attention [28,29]. The ability to use this

kind of applications include difficulties in eye-gaze estimation owing to unstable lighting, the blurred area of the eye due to shade or wearing glasses, fake warning, and the ability to operate in real time. [30] Presented a low cost system capable of detecting the direction of the eye-gaze when it is out of the road along the day under different conditions such as age or wearing glasses. In addition to eye-gaze estimation, this feature-based assistance system contains a robust facial feature and head pose estimations for detecting the eye-gaze out of the road. Another system is proposed to detect the driver distraction by using the eye-gaze estimation [31]. But, this system requires handling head movement and detecting the facial directions. The navigation systems in cars can supply the drivers with information about the traffic in the complex roads or strange regions. Explores eye-gaze behavior for providing a vision about the performance of drivers through the use of mobile navigation systems in a civilized region. Eventually, most existing driving assistance systems require special devices which restrict their ability to access[32].

1.4.4 Eye-Gaze Estimation in Virtual Space and Entertainment

In the past few years, the virtual reality systems have been utilized in different applications and research domains by using conventional devices such as joysticks for an interacting user with the system. Even though these means are able to control the video games, they are still unnatural interfaces. Playing the virtual reality game with unnatural interfaces hinders the users from fully immersive experiences. It is necessary to develop natural interfaces for controlling the virtual space and environment based on eye-gaze estimation systems. [33] Presents a natural interaction system through an improved gaming experience, and the user can be interacting with this system based on eye-gaze

movement. Increasing the utilization of stereoscopic 3D technologies in virtual space, video game, and entertainment put attention for developing interaction based on eye-gaze. Researchers in eye-gaze estimation systems and virtual space have shown up the necessity for a suitable valuation system that can be applied in stereoscopic 3D environments. The computer graphic technologies have made it possible to improve a valuation system for 3D eye-gaze estimator [34,35].

1.4.5 Eye-Gaze Estimation in Medicine

The benefit of using eye-gaze estimation systems in medical applications has been presented by various researches. Most of the existing researches are used for multi-purposes such as exploring different kinds of diseases, improving medical education and therapy and etc. Moreover, the eye-gaze estimation systems represent a useful means in medical diagnostics like mental disease diagnostic. Although there are a reasonable number of new researches in this area, there are still unexplored fields which may lead to a diagnostic revolution. Also, the utilization of eye-gaze estimation systems in therapy remains nearly unexplored[36].

Proposed a system for eye cancer therapy that is the critical stage for making the proton treatment of the eye completely noninvasive. Recently, utilizing robots in the operating theater has become very popular. Various interfaces to surgeon robot interactions have been improved for controlling the tools in operating theater like hand controlled and eye-gaze controlled interfaces [37, 38].

With the progress of the diseases, people may suffer from the inability of communicating with their environment. Those disabled may be become incapable of moving their hands or legs, walk or moving the objects, and may be

they are incapable of speaking. Nevertheless, in most of these conditions, their cognition capabilities are still robust. Currently, improving tools to aid those people in communicating is the main difficulty which scientific communities are facing. Eye-gaze estimation systems as an assistive tool can help the disabled who can use only their eyes in different fields [39,40] such as to control the computer effectively [42]; and to select objects (home appliances) [41].

1.4.6 Eye-Gaze Estimation for Human Robot Interaction

With nearby future, the Robot will become the best companion. For achieving this aim, still different difficulties required to be removed. One of these difficulties is the ability of robot for perceiving some fundamental communication signals utilized by the users. In the recent years, the significance of communication via eye-gaze has been recognized in the robots, even beyond the limits of social applications. In spite of the chance of utilizing the robot's eyes for communicating has been already implemented in markets, the ability of robots to understand the user’s eye-gaze for anticipating their requirements and objectives has not been exceedingly utilized until now. A lot of researchers are looking forward to utilizing remote eye-gaze estimation systems built in a humanoid robot. The researchers in [14] and [43] provide an effective utilization of eye-gaze information to communicate with the users. And with the context of a low cost Human Robot Interaction, a Tele robotic scheme based on eye-gaze estimation system is proposed, in which the user is capable of controlling the navigation of a Tele-operated portable robot using eye-gaze as input to the scheme. But this scheme contains some difficulties that must be resolved such as the relatively low performance of the eye-gaze interface [44].