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EYE TRACKING AND VOICE INTERFACES FOR IOT SMART HOME

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ABSTRACT

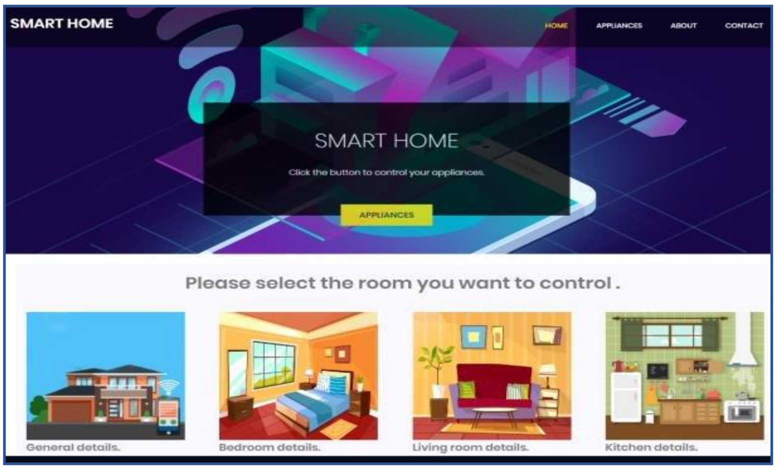
In recent days, Eye tracking in home appliances is the booming sector because of its ability to facilitate users with the special needs. Eye tracking facilitates interactions to control home appliances when the user cannot or does not wish to use their hands by means of the IoT and cloud Technologies. It has great impact in countless fields such as neurology, cognition, communication and security of different categories. To tackle similar issues, we propose a model that utilizes Video Oculography approach through Tobii technology with added voice interfaces using Azure cloud to help control home appliances. This model traces the user via reflected infrared light patterns and calculates the gaze position automatically. This method uses no wearable technology through Video Oculography with multiple cameras which deliver several advantages. It provides accurate gaze which estimates the portability of the video recording system and fully remote recordings. Focus groups and usability tests show that many users were satisfied with the straight forward use of the model, flexibility and reliability in interacting with the system, and accuracy in the movement of the pointer, make this model a reliable solution to simplifying some daily tasks.

***Index Terms* - Azure cloud, eye tracking, IoT, smart home, Tobii, video oscillography, elderly and special needs people.**

I. INTRODUCTION

Monitoring the activities of users and predicting their needs is possible with Smart technologies specifically Smart Home Wireless Sensor Networks, which offer elders and people with disabilities, personalized options in order to allow them to tune and adjust their environment to their specific needs from any smart phone, tablet, device or a computer application. Smart homes with hi-tech applications can be controlled remotely, are being heralded as the wave of the future.

Eye tracking is the process of measuring where one is looking (point of gaze) or the motion of an eye relative to the head. Researchers have developed different algorithms and techniques to automatically track the gaze position and direction, which are helpful in different applications. Research on eye tracking is increasing owing to its ability to facilitate many different tasks, particularly for the elderly or users with special needs. This study aims to explore and review eye tracking concepts, methods, and techniques by further elaborating on efficient and effective modern approaches such as machine learning (ML), Internet of Things (IoT), and cloud computing. These approaches have been in use for more than two decades and are heavily used in the development of recent eye tracking applications. The results of this study indicate that ML and IoT are important aspects in evolving eye tracking applications owing to their ability to learn from existing data, make better decisions, be flexible, and eliminate the need to manually re-calibrate the tracker during the eye tracking process. In addition, they show that eye tracking techniques have more accurate detection results compared with traditional event-detection methods. In addition, various motives and factors in the use of a specific eye tracking technique or application are explored and recommended. Finally, some future directions related to the use of eye tracking in several developed applications are described.



In this paper, a model of a smart home using eye tracking and voice interfaces is developed to help solving significant elderly needs and disabilities by giving them a chance to live more independently and have the ability to regulate different home appliances to their needs, such as unlocking doors, turning the TV ON or OFF as well as lights, air-condition, heater, fan, electric curtains, etc.

The rest of the paper is organized as follows: 1) The eye tracking techniques 2) The research methodology 3) Finally, the conclusion and future work of this paper.

I. The Eye Tracking Techniques

A large number of different techniques that track eye movements have been investigated previously; four eye tracking techniques have been shown to be the major methods and are commonly used in research and commercial applications today. These techniques are described in detail as follows

i) Scleral Search Coil Approach

The Scleral Search Coil method is based on the recording of small electric currents induced by a magnetic field in a coil of very narrow-gauge wire embedded in a pliable donut-shaped plastic ring that is placed on the eye. The scleral search coil method has emerged as the “gold standard” for the accurate recording of eye movements; however, it is an invasive technique that may cause discomfort for the patient. Also, recording time is limited to approximately 30 minutes. The scleral search coil technique generally is confined to research purposes. In this method, eye trackers use a contact lens with mirrors. As soon as a coil of wire shifts in a magnetic field, a voltage induces in the coil. If the coil is attached to the eye, then a signal of eye position will be produced. To measure human eye shifts, compact coils of wire are inserted in an altered contact lens. An embedded mirror in the lens is used to measure the light replication. Alternatively, an injected coil in the lens will enable sensing the coil's location in a magnetic field.

ii) Infrared Oculography Approach

Infrared Oculography (IROG) is a non-invasive method validated to define time of foveation, an indirect measure of visual acuity. This system measures the force of an infrared light which is replicated from the sclera of the eye. The sclera reflects infrared light and collecting information about the eye position, this information will vary reliant on the eye position. The light source and sensors can be positioned on spherical glasses. IROG has a lesser amount of noise than electrooculography. As this method rests on perceptible light and pupil tracing, head movement might be a delicate issue.

iii) Electro-Oculography Approach

Electro-Oculography (EOG) is used to record eye movements during electronystagmography testing. It is based on the corneoretinal potential (difference in electrical charge between the cornea and the retina), with the long axis of the eye acting as a dipole. Movements of the eye relative to the surface electrodes placed around the eye produce an electrical signal that corresponds to eye position. Recordings of eye movement are accurate to about 0.5 degree, but it is still less sensitive than visual inspection, which can perceive movements of about 0.1 degree. Therefore, visual inspection with Frenzel lenses is sometimes still necessary to document nystagmus of low amplitude. Another limitation of electro-oculography is that torsional eye movements cannot be monitored. Again, visual inspection with Frenzel lenses is sometimes necessary to document torsional nystagmus. Fortunately, new techniques have been developed to provide greater accuracy and breadth for oculomotor testing. The most clinically useful technique that has been developed is the infrared video electronystagmography system. Here, the patient wears goggles that illuminate the eyes with infrared light (invisible to the patient), allowing a small video camera to pick up and project an image of the eyes onto a monitor. This can also assess eye movement in horizontal, vertical, and torsional directions and is more accurate than electro-oculography.

EOG is human-computer interaction method where sensors are connected at the skin that is around the eyes to measure an electric field that happens when the eyes rotate, by logging the small variations in the skin that surrounds the eye, the location of the eye can be predicted by cautiously inserting electrodes. Parallel and perpendicular shifting of the eyes is logged in disjointedly by the insertion of electrodes. However, the signal can vary when there is no shifting of the eye. This method is both practical and low cost.

iv) Video Oculography Approach

Video-oculography (VOG) is a non-invasive, video-based method of measuring horizontal, vertical and torsional position components of the movements of both eyes (eye tracking) using a head-mounted mask that is equipped with small cameras. VOG is usually employed for medical purposes. An eye tracking system that relies on video can be either applied remotely through positioning a camera ahead of the user or put up where the camera is located below in visual axis of the eye, usually on the frame of eyeglasses. Head-mounted systems regularly contain a scene camera for taking footage of the user's view. Through directing infrared light on the eye, in which the light makes a spark on the cornea of the eye. It can be applied to discover the user's gaze through using single or two cameras. The problem with single camera models is that it can take images with restricted range in taking high resolution images. On the other hand, dual cameras are operated to gain wider view high-resolution images to offer precise gaze approximations. In this method, head moment is taken into perspective. by using one camera for the head location and another camera is used for the eye. Calculation of the pupil centre is accomplished by 3D coordinates. The video cameras are placed on the monitor screen whereas the infrared light is situated before the other camera to capture the flash in the image.

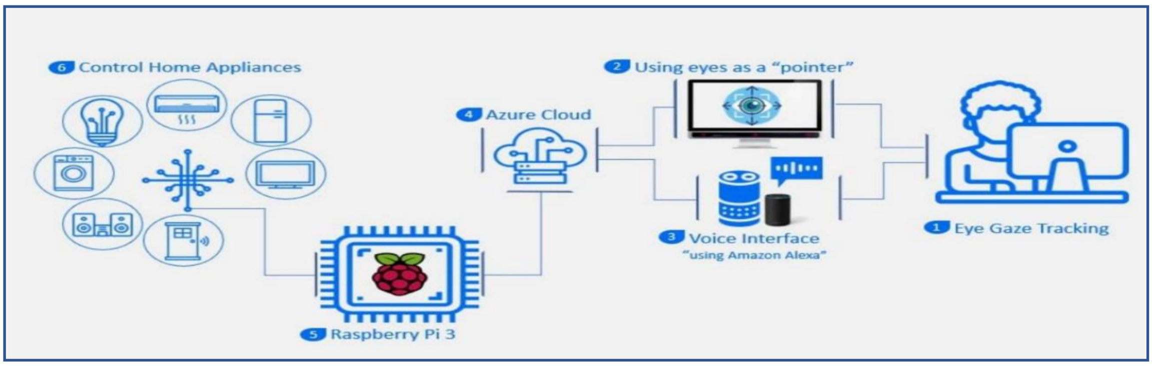
v) Selection of Tobii Tracking System

According to the comparisons between the popular eye tracking techniques as shown in Table, it is concluded that there is no optimum method that can resolve all the problems in different life sectors and environments; each method has its limitations and advantages based on the problem specification, environment, cost, usability and etc. But in general, it is noticed that the last technique, the video oculography has many advantages and fewer limitation comparing to other techniques and has been integrated into a variety of devices. The Tobii eye tracking system is an example of video Oculography that uses multi cameras to detect and collect eye gaze data. It contains head movement compensation and low deflection effects, with dual-eye tracking, which gives higher resolution. In addition, if user keeps moving, especially the head, the system can continue tracking even if only one eye is tracked during the movement.

Tobii provides a natural eye gaze interface with objects and devices, where the user is not required to be constrained with wearables, or health care gadgets such as Head-Mounted Displays, smart jewellery, smart clothing, or smart glasses, that might limit the ease of movement for this segment of users. Therefore, we have selected the Tobii tracking system to convert the user's eyes gaze into a pointer in order to help the elderly and special needs people to control home appliances as explained in methodology.

II. METHODOLOGY

The multiple cameras of Tobii technology are adopted in this framework as they serve several advantages over other methods in delivering accurate gaze estimates, portability of the video recording system, and fully remote recordings. Thus, the video oculography approach is the ideal choice in this model. The following framework in figure presents the proposed eye tracking system using IoT and cloud technologies.



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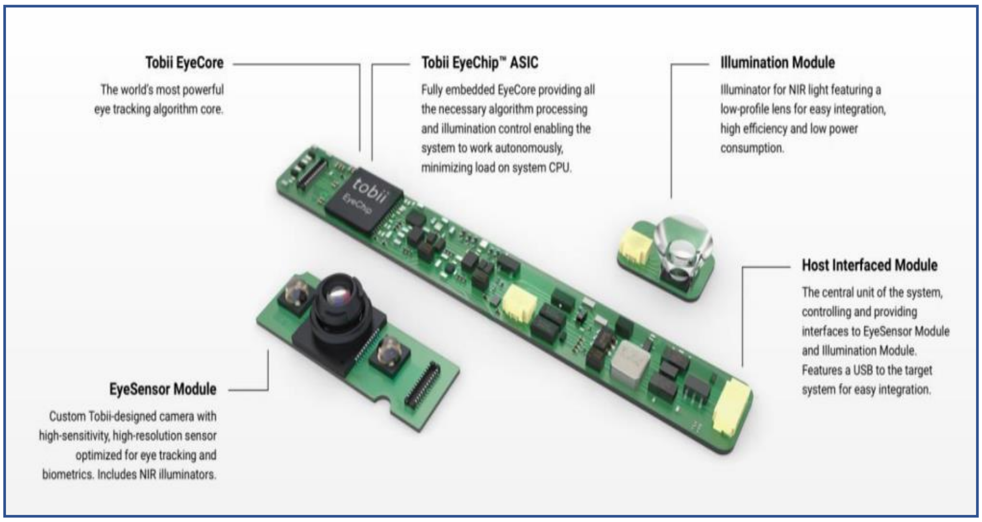
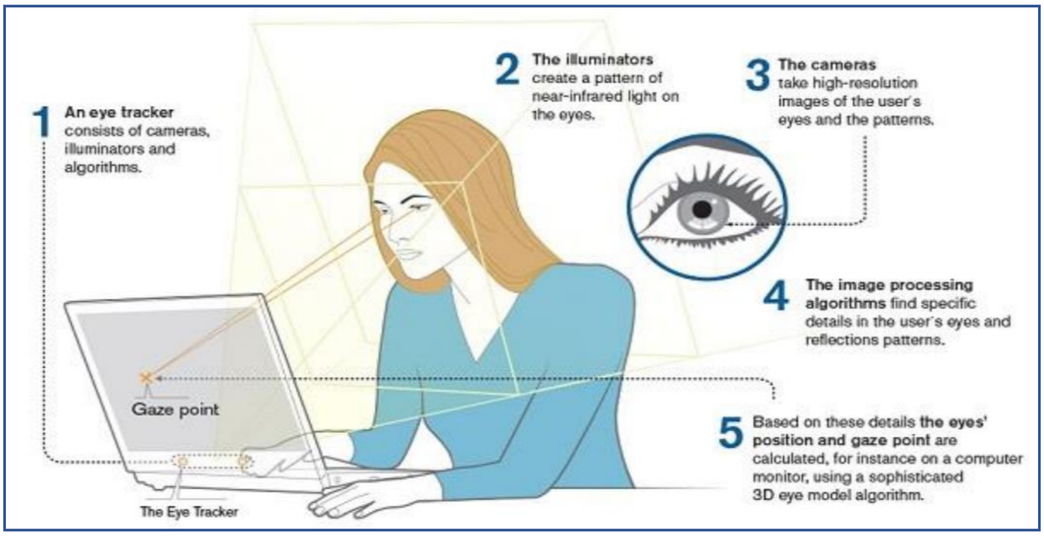
i) Tobii Eye Tracking

The Tobii as shown in figure is un-wearable eye tracking device includes sensors that consists of cameras that capture high-speed images to display the user's eye, and projectors that make a pattern of infrared light on the user's eyes.



The system tracks the user's eye gaze at a frequency of 50 observes each second. In combination of scene camera and advanced image processing algorithms the eye movement system monitors the person’s eyes based on reflected infrared illumination patterns and calculates gaze conditions automatically. According to these mathematical algorithms, it figures out the eye’s position (x and y) and gaze point for example on tablet, mobile or laptop's monitor. Figure shows the Tobii eye tracking techniques.



ii) Website Interface

Using eyes as a "pointer" on a screen, simplify communication with household appliances especially when the user can't or does not wish to use their hands. The Tobii eye tracking techniques, converts user's eye gaze into pointer on a laptop's monitor that contains the developed website interface using HTML, JavaScript and PHP. The user holds three seconds on requested household appliance in order to send the request to Azure cloud.

iii) Voice Interface

Moreover, a voice interface is presented to help users with special needs and disabilities who find it difficult to use the interface of the website. Voice assistants, for example Microsoft's Cortana, Google's Assistant, or Amazon's Alexa are software's that have the ability to understand human speech as well as reply through synthesized speech. Amazon's Alexa is a smart speaker which supports smart home devices, its configurability and personalized aspects allow it to be personalized to users' specific requirements. Machine learning is the basis of Amazon Alexa's rising success; it is the reason behind the fast improvement in the abilities of voice-activated user interface and continuously working on resolving mistakes and decreasing the error rates. It has been used in the proposed system to receive user's verbal commands and then send the request to Azure cloud to help them control home appliances.

iv) Azure Function and Raspberry Pi

After receiving the users' request from API gateway to control a certain appliance by either turning it ON or OFF as described in the Azure function reflect the request on SQL database. Then the Raspberry Pi microcomputer reads from SQL database and controls the appliance.

III. EVALUATION AND TESTING

An evaluation was performed to confirm and validate the execution and performance of our system. We have tested the proposed system with the help of 20 volunteers of elders (age between 55 and 70) and special needs users. We distributed a sheet to each volunteer contains four questions. We allowed each volunteer to interface with the system and use it to control all the appliances for at least two times for each appliance. Then, each volunteer filled the sheet with a satisfaction rate (i.e., a number between 0 and 100, the higher is better). We collected these rates and calculated the average. Based on the evaluation results, we can conclude the followings

- The eye gaze was very accurate and can track the eye movement efficiently.
- The pointer on the interface was easily controlled, where users could select what they require in a straightforward manner.
- The response time had an acceptable delay.
- The speech commands to control home appliances were simple and effective.
- Generally, our initial system achieves high satisfaction rate.

IV. CONCLUSION AND FUTURE WORK

We described a method of smart home for elderly and special we described a method of smart home for elderly and special needs users through the Internet of Things technology to control the home appliances by using either a web page, mobile application. as well as using the added voice and eye tracking interfaces that accept voice commands and eye movement tracking sent to Azure cloud where Raspberry Pi microcomputer reads from SQL database to help control the appliance. A comparison was performed describing the four major techniques used in eye tracking methodologies: Electro-Oculography, Scleral Search Coil, Infrared Oculography, and Video Oculography. In this paper Tobii eye tracking system was chosen to develop the prototype due to the use of multiple cameras which capture high-speed images to display the user's eye, and projectors that make a pattern of infrared light on the user's eyes. Also, this system delivers higher resolution as it contains head movement compensation and low deflection effects, with dual-eye tracking. Results shows how users found accuracy in tracking the eye gaze and movement through how responsive the pointer on the interface was. The response time of the system had an acceptable delay. Furthermore, the model shows simplicity of the voice interface option which shows that speech commands to regulate home appliances. Although multiple camera eye trackers are rather costly and lack capability to measure with eye torsion. It provides the ability to clinically observe and measure eye movement disorders, they can allow head free movement and fully remote recording. The goal is to make the system as reliable and useful as elders and users with special needs require in accomplishing their tasks.

For future studies in this field, the prototype can be added as a new feature in any existing system in homes for the elders and hospitals, as required for users with special needs. Different techniques and comparisons between Tobii system and other eye tracking techniques could be performed to see if development is possible on the algorithm with Artificial Intelligence. As well as integrating the ability to track the user’s behavioral aspects and patterns automatically to the system.

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