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# Techniques and Approaches of Eye Gaze and Eye Track System in Diverse Application

**Nandini V S[1], K. Bala Subramanyam Raju[2], M.E. Palanivel[3]**

*[1,2,3]Master of Computer Applications Department,*
*Sreenivasa Institute of Technology and Management Studies, Chittoor*
*Andhra Pradesh-517127,*
*[1]nandinivs2001@gmail.com, [2]raju.koti@gmail.com*

*Abstract* - **Eye gaze communication systems are assistive technologies designed to facilitate communication for abilities of individuals including, those with conditions such as cerebral palsy, spinal cord injuries, and neurodegenerative diseases. These systems utilize eye tracking technology to capture and interpret eye movements and gaze patterns as a means of communication systems, highlighting their significance in empowering individuals with disabilities to communicate effectively. Eye gaze system includes eye tracking, hardware, software interfaces, and communication modalities. Gaze system customized to suit the unique needs.**

Keywords - *eye gaze, eye tracking, eye blink sensor, gaze controllers, gaze communication.*

## 1. Introduction

Communication is crucial for all living beings. It helps us to express ourselves and connect with others. But people with paralysis or motor diseases may struggle to communicate because they cannot move their limbs or feel sensation. This loss of ability to express their needs and necessities can make them dependent on others for everything affecting their physical and mental health, as well as their quality of life. Providing a chance for people with severe disabilities, who can only move their eyes, to communicate gives them hope. An eye tracking system can be developed to detect the movement of the person's eye gaze for communication purposes. This low-cost system uses image processing techniques to track the position of the iris and interpret eye gestures in a graphical user interface to facilitate communication.

Eye tracking measures eye movement, while gaze tracking analyzes eye tracking information along with head movement information. Gaze tracking has applications in various fields such as robotics, psychological studies, cognitive science, computer vision, advertising, and neuroscience. In psychological studies, gaze tracking is used to measure behavioral responses, such as eye movements like saccades, fixations, and smooth pursuits, in order to understand visual processing, interaction between eye movements, vision, and performance tasks. In computer vision, eye tracking can be used as an input device, similar to a mouse, and can also be used to determine the optimal location for placing advertisements. In neuroscience, eye tracking is a cost-effective method for studying eye movement patterns, visual processing, object-by-object search mechanisms in attention studies, and neurological functions related to perception and decision making. The hierarchy of eye tracking applications includes interactive and diagnostic applications. Interactive applications are divided into two types: selective and gaze-contingent. Selective systems use the point of gaze as a pointing device, which can be useful for handicapped users. Gaze-contingent systems utilize knowledge of the user's gaze to facilitate rapid rendering of complex displays. Over all tracking and gaze tracking have applications in various fields, ranging from understanding human behavior in psychological studies to improving user interaction in computer vision and advertising and advancing research in neuroscience.

## 2. RELATED WORKS

Linda Sibert et al [3] compared the effectiveness of using eye gaze and the common mouse as computer input methods. They conducted two experiments to measure the time needed for completing tasks with both approaches. The first experiment required participants to quickly select highlighted circles from a grid. This aimed to showcase the advantages of human eye gaze over mouse interaction.

Kyung-Nam et al [1] delved into diverse techniques for estimating and monitoring eye movements. They spotlighted methods like longest line scanning, occluded circular edge matching, and eye lid tracking. The study employed computer vision and image processing to measure eye gaze.

The authors examined two routes to estimate eye gaze: geometry-based and adaptive-based. They explored nonintrusive vision-based tracking, successfully tracking eye gaze at an 8x10 screen resolution.

Manu Kumar [2] introduced a variety of techniques using gaze data for everyday tasks, aiming to offer alternative interaction methods based on users' physical capabilities and preferences. The author emphasized improving existing interaction techniques with gaze input. Contributions encompassed gaze-centric interaction techniques, gaze input technologies, and guidelines for effective gaze-based interactions. Various strategies for enhanced scrolling, off-screen gaze-triggered buttons, and switching between tasks were discussed. Moreover, the author proposed a gaze-based password entry approach for security and investigated methods to enhance gaze precision.

Susanna Nilsson et al [5] explored the integration of gaze-based interaction in an augmented reality (AR) system. Their objective was to evaluate the functionality of gaze control within AR applications. They devised an eye gaze control tool to create interfaces and interaction approaches for the AR system, incorporating an integrated eye tracker. The paper provided specifications for the system, including screen resolutions, field of view, and gaze tracking technologies like displays, optical components, image sensors, and real-time signal processing.

## 3. METHODOLOGIES

### *A. Working Procedure of Eye Gaze System*

- The eye gaze system uses the pupil central corneal reflection method.
- Video camera mounted below the monitor. It takes 60 pictures per seconds.
- Infra-red.
- Reflected from eye.
- Sensor records where the reflected light is moving.
- Computer calculated the person gaze point.

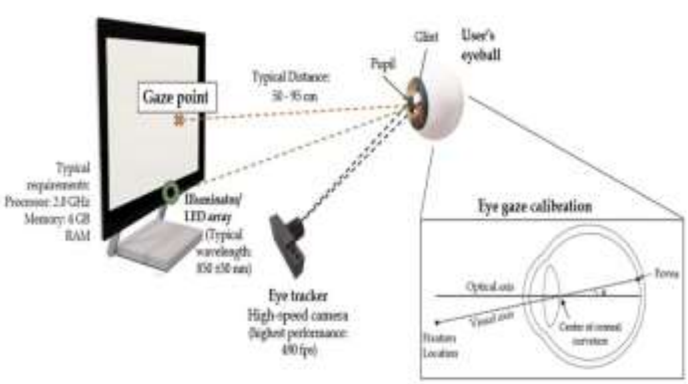


Figure 1 Eye Gaze System

Before using eye-tracking applications, the eye gaze system needs to calibrate by learning several physiological properties of the user's eye. This is done by having the user focus their gaze on a small yellow circle on the screen and following it as it moves around. Calibration usually takes about 15 seconds and does not need to be repeated if the user moves away and returns later. To help with accurate tracking, the system uses an LED to illuminate the eye, which reflects light off the cornea and retina, making the pupil appear white. This bright-pupil effect enhances the camera's image of the pupil and helps locate its center. Based on the position of the pupil center and corneal reflection within the video image of the eye, the computer calculates the users gaze point on the screen. Typically, the eye gaze system predicts the gaze point with an average accuracy of a quarter inch or better. The eye gaze system uses a specialized video camera mounted below the monitor to observe one of the user's eyes. This camera captures infrared-sensitive images of the eye at a rate of 60 pictures per second. The camera is equipped with a low power infrared LED that is mounted in the center of the camera's lens.

Sophisticated image-processing software in the eye gaze system's computer analyzes the video images of the eye in real-time. The software uses the pupil-center/corneal reflection method to determine where the user is looking on the screen. It calculates the position of the pupil center and the corneal reflection within the video image to accurately determine the user's gaze point on the screen.

Importantly, no attachments or sensors are required on the user's head or body for this process. The eye gaze system solely relies on the video images captured by the camera and the processing done by the software to determine the Users gaze point on the screen.

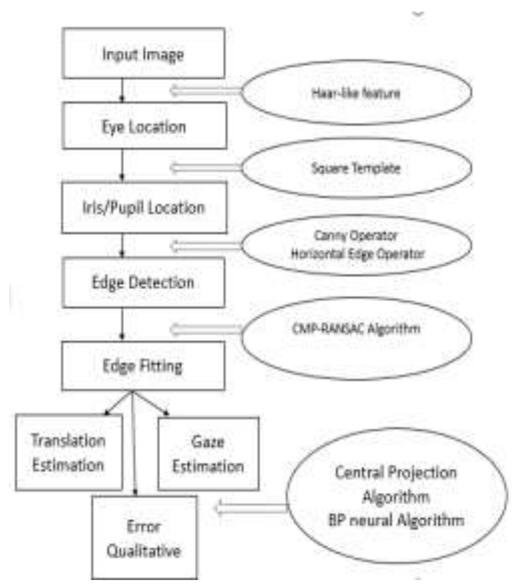


Figure 2 Flow diagram for Eye Gaze System

*B. Methods of Eye Tracking*

EOG(Electro-oculography): Electro-oculography (EOG) is a technique used to measure the electrical potential difference (voltage) generated by the movement of the eyes. It is commonly used in ophthalmology and neurophysiology to study eye movements and diagnose various eye conditions. EOG involves placing electrodes on the skin around the eyes to measure the electrical activity of the muscles that control eye movements. These electrodes detect changes in voltage that occur when the eye moves in different directions, such as up, down, left, or right. By analyzing these electrical signals, eye movement patterns can be studied and analyzed. EOG is a noninvasive and relatively simple technique that provides information about eye movements, including saccades (rapid eye movements), smooth pursuit (tracking moving objects with the eyes), and fixation (maintaining gaze on a stationary object). It can be used to diagnose and monitor eye conditions such as nystagmus (involuntary eye movements), strabismus (misalignment of the eyes), and other disorders that affect eye movements. In addition to clinical applications, EOG is also used in research to study various aspects of eye movements, visual perception, and cognitive processing. It is a valuable tool in understanding the physiology and mechanics of eye movements, as well as their relationship to higher brain functions.

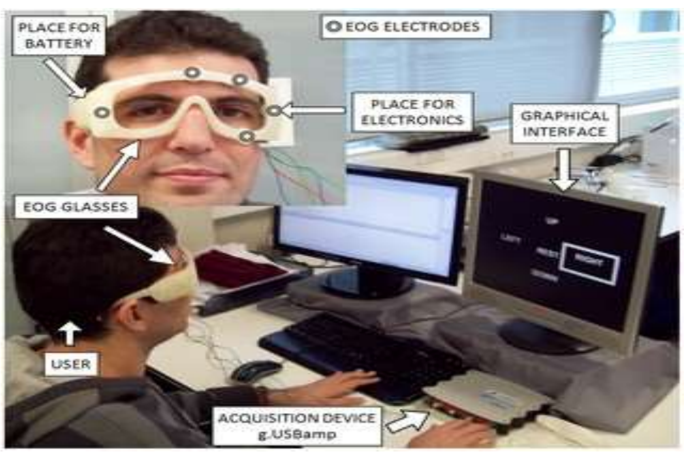


Figure 3 Electro-oculography

INFRARED OCULOGRAPY: Infrared oculography, also known as infrared eye tracking or infrared eye movement recording, is a technique used to measure and analyze eye movements by utilizing infrared light. It involves the use of specialized cameras or sensors that can detect the reflection or absorption of infrared light by the eyes, allowing for non-invasive tracking and recording of eye movements. Infrared oculography typically uses infrared light-emitting diodes (LEDs) that emit infrared light towards the eyes, and infrared-sensitive cameras or sensors that capture the reflected or absorbed infrared light. The position and movement of the eyes can be determined by analyzing the changes in the reflected or absorbed infrared light, which are correlated to the movement of the eyes. Infrared oculography is commonly used in research and clinical settings for studying various aspects of eye movements, such as saccades, smooth pursuit, and fixation. It can provide quantitative data on eye movements, including metrics such as gaze position, velocity, and acceleration. Infrared oculography has applications in fields such as ophthalmology, neurophysiology, psychology, human-computer interaction, and virtual reality, among others. One of the advantages of infrared oculography is its non-invasiveness, as it does not require any physical contact with the eyes. It is also relatively easy to set up and can be used in a wide range of environments. However, it does have some limitations, such as potential accuracy and precision issues, sensitivity to ambient lighting conditions, and potential interference from reflective surfaces. Calibration is also an important step in the process to ensure accurate and reliable eye movement measurements

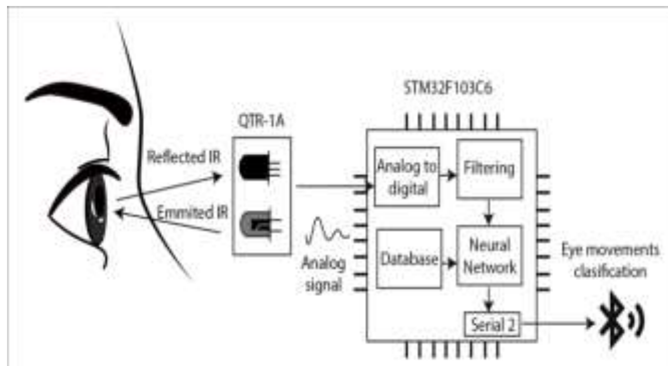


Figure 4 Infrared Oculography

SCLERAL SEARCH COIL: Scleral search coils are tiny coils of wire that are implanted into the sclera, the outer white part of the eye, of an experimental subject, typically an animal such as a primate or a rabbit. The coils are usually made of biocompatible materials, such as platinum or stainless steel, and are typically less than a millimeter in size. The principle behind scleral search coils is based on electromagnetic induction. When an electrical current is passed through the coil, it generates a magnetic field. When the eye moves, the magnetic field generated by the coil changes, and this change can be detected by external sensors, typically placed near the eye, to precisely measure the eye's movement in three dimensions (horizontal, vertical, and torsional). Scleral search coils are considered a gold standard for measuring eye movements with high spatial and temporal resolution, making them a valuable tool in oculomotor research. They are used in a wide range of experiments to study various aspects of eye movements, such as saccades, smooth pursuit, vergence, and nystagmus. Scleral search coil recordings are used in research to investigate the neural mechanisms underlying eye movements, perception, and cognition, as well as in clinical studies to assess eye movement abnormalities in patients with oculomotor disorders or other neurological conditions. However, due to their invasive nature and technical complexity, scleral search coil recordings are typically limited to search setting and are not routinely used in clinical practice.

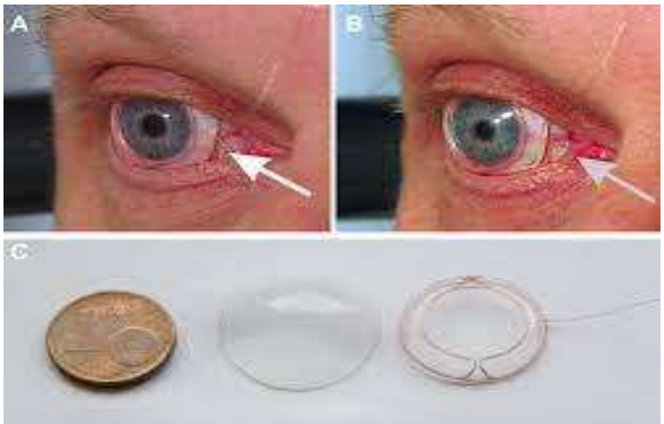


Figure 5- Scleral search coils

VIDEO-BASED OCULOGRAPY: Video-based oculography, also known as video eye tracking, is a technique that uses video cameras to track and record eye movements. It involves the use of specialized cameras or recording devices that capture video images of the eyes and then analyze these images to determine the position and movement of the eyes. Video-based oculography typically uses high-resolution cameras that are capable of capturing the movement of the eyes in real-time or at a high frame rate. These cameras can be positioned in front of the eyes or integrated into other devices, such as computer monitors or virtual reality headsets. The recorded video images are then processed using specialized software to extract eye movement data, such as gaze position, velocity, and acceleration.

Video-based oculography has several advantages, including its non-invasiveness, ease of use, and relatively low cost compared to other eye tracking methods. It is widely used in research and clinical settings to study various aspects of eye movements, including saccades, smooth pursuit, and fixations. It has applications in fields such as psychology, neuroscience, human-computer interaction, and marketing research, among others. However, video-based oculography also has limitations, such as potential accuracy and precision issues, sensitivity to lighting conditions, and the need for proper calibration to ensure accurate measurements. Nevertheless, with advancements in camera technology and image processing algorithms, video-based oculography has become a popular and widely used method for studying eye movements in both research and clinical application


Figure 6 Video-based oculography

Benefits:

Eye tracking increase computing and resource efficiency.
It helps to access human conditions and behaviors.
It helps to learn from expert delivering skills.
It makes technology more intuitive.
It helps to communicate machines in ordered to automate manual tasks.
It increases user experience performance in playing games.

Limitations:

It is expensive technology due to costly hardware requirements.
It does not work with few users who were contact lenses or having long eye lashes.
It requires some calibration time before it gives satisfactory results.
Eye movement of some users are often un-intentional. This results into unwanted responses by the system.
It is difficult to control eye position accurately all the times unlike mouse. Eye tracker provides instable output when it does not get appropriate image of the eye in consecutive frames.

*C. Methods Of Gaze Tracking*

PUPIL: pupil is the circular opening at the center of the iris in the eye. It regulates the amount of light that enters the eye and reaches the retina, which is responsible for vision. The size of the pupil changes in response to various factors, such as lighting conditions and emotional states.

IRIS: is the colored part of the eye that you can see when you look at someone's eye. It's the part that gives your eye its unique color, whether it's blue, brown, green, or any other color. The iris acts like a "shutter" that controls the amount of light that enters the eye by changing the size of the pupil, which is the small black hole in the center of the iris. When there is bright light, the iris makes the pupil smaller to let in less light, and when it's dark, the iris makes the pupil bigger to let in more light. So, the iris and the pupil work together to regulate the amount of light that enters the eye and helps you see clearly in different lighting conditions.

SCELERA: sclera is the tough, white outer covering of the eye that you can see when you look at someone's eye. It's often referred to as the "white of the eye." The sclera provides protection and structural support to the eye, helping to maintain its shape and integrity. It covers most of the eyeball except for the front part, which is covered by the transparent cornea. The sclera is made up of dense connective tissue and serves as an attachment site for the muscles that move the eye. It also helps to maintain the intraocular pressure, which is important for the proper functioning of the eye. In summary, the sclera is the tough, white outer covering of the eye that helps protect and support the eyeball.

FEATURE BASED ESTIMATION: Feature-based gaze estimation is a technique used to estimate the direction of a person's gaze, or where they are looking, based on the features or characteristics of their eyes or face. In simple words, it involves using specific visual cues or markers, such as the position or movement of the eyes, eyelids, or other facial features, to determine the direction in which a person is looking for example, the position of the pupils in relation to the irises (the colored part of the eyes) can be used as a feature for gaze estimation. By tracking the position of the pupils over time, a computer or a device can estimate the direction of gaze. Other facial features, such as the position of the eyelids or the relative positions of the eyes in the eye sockets, can also be used as features for gaze estimation. Feature-based gaze estimation can be used in various applications, such as human-computer interaction, virtual reality, and augmented reality. It can enable devices or systems to respond to a person's gaze, such as adjusting the display or content based on where the person is looking, or controlling a cursor or pointer on a screen. Feature-based gaze estimation techniques typically rely on computer vision algorithm and machine learning to analyze and interpret the visual cues or, markers from the eyes or face to estimate gaze direction.

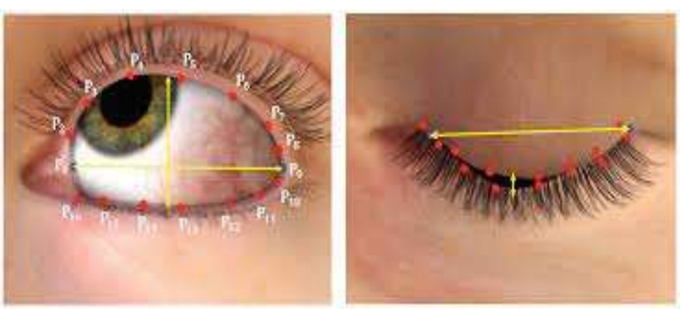

Figure 7- Feature Based Estimation using position of Pupils

APPEARANCE BASED METHOD: an appearance-based method in eye tracking uses the visual appearance of the eyes, such as their shape, color, or texture, to estimate where a person is looking. This method involves capturing images or videos of the eyes and analyzing their visual features to determine gaze direction. For example, by tracking the positions or movements of the pupils and irises, or by analyzing the shape or color of the eyes, a computer can estimate the direction in which the eyes are looking. Appearance-based eye tracking is commonly used in applications like human-computer interaction, psychology, and healthcare to understand visual attention and user behavior. However, conditions and eye movements.

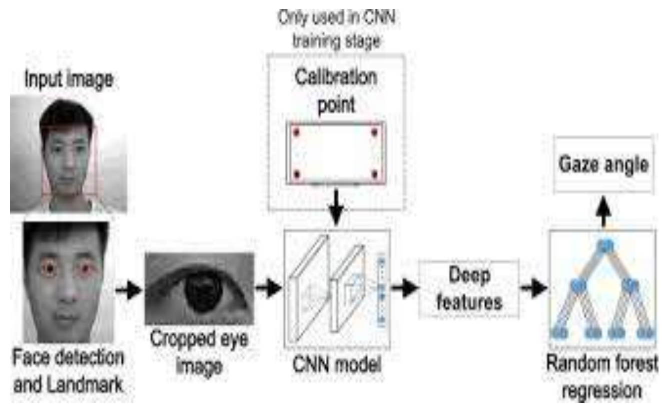


Figure 8 Appearance-based method in eye tracking

Benefits:

Gaze tracking can help improve the user experience of various applications, such as virtual reality or video games, by allowing users to interact with the system using their eyes.

Gaze tracking provides insight into how people interact with different stimuli, allowing researchers to better understand user behavior and preferences.

Gaze tracking can be used to detect driver drowsiness, distraction, and other safety-critical events, potentially preventing accidents.

Gaze tracking can be used to diagnose and monitor various medical conditions, such as autism, Parkinson's disease, and multiple sclerosis.

Gaze tracking can be used as an assistive technology for people with disabilities, allowing them to control devices and interact with their environment using their eyes.

Limitations:

Gaze tracking technology can be expensive, especially for high-end systems that require specialized equipment.

Gaze tracking systems require regular calibration to maintain accuracy, which can be time-consuming and may require specialized training.

Gaze tracking can be affected by environmental factors such as lighting, reflections, and head movement, which can reduce the accuracy of the system.

Gaze tracking involves collecting data about a person's eye movements, which can raise privacy concerns, especially if the data is not properly secured or anonymized.

While gaze tracking technology has improved significantly over the years, it is still not perfect and may have limitations in certain situations, such as detecting eye movements in people with certain eye conditions or when wearing glasses.

### *D. RUN GAZE SYSTEM*

Running an eye gaze system typically involves several steps, which can be simplified into the following:

Set up the hardware: Depending on the type of eye gaze system you are using; you may need to connect and configure the hardware components. This could include an eye tracking device, such as an eye tracker camera or sensor, and a computer or other device that will process the eye gaze data.

Install software: You may need to install software or drivers provided by the eye gaze system manufacturer on your computer or device. This software will allow you to interact with the eye gaze system and perform tasks such as calibrating the eye tracker and collecting gaze data.

Calibrate the system: Calibration is a crucial step in setting up an eye gaze system. It involves having the user look at specific targets or points on the screen while the system records their gaze data. This helps the system learn the user's eye movements and establish accurate gaze estimates for their specific eyes.

Run the eye gaze application: Once the system is calibrated, you can start running the eye gaze application or software that you want to use. This could be a communication tool, a game, or any other application that utilizes eye gaze input. The application will interpret the gaze data from the eye tracker and respond accordingly based on where the user is looking.

Fine-tune and troubleshoot: During actual usage, you may need to fine-tune the eye gaze system settings to optimize accuracy and performance. You may also encounter issues such as drift (where gaze estimates may shift over time), occlusions (where the eyes are partially obstructed from view), or other technical challenges that may require troubleshooting.

It's important to follow the instructions provided by the eye gaze system manufacturer and consult any user manuals or guides for specific guidance on how to run their system. Additionally, it may be beneficial to seek assistance from experts or technical support If needed to ensure proper operation and accurate eye gaze tracking.

### *E. SKILLS REQUIRED FOR USER*

Using an eye gaze system typically requires certain skills to ensure effective and accurate interaction. These skills may include:

Eye control: Users need to have the ability to control their eye movements and fixate their gaze on specific targets or points on the screen, as eye gaze systems rely on tracking the movements of the eyes to determine gaze direction. This may involve maintaining steady gaze, focusing on targets, and coordinating eye movements to perform tasks.

Calibration: Users may need to participate in the calibration process, which involves looking at specific targets or points on the screen to allow the eye gaze system to establish accurate gaze estimates for their specific eyes. Users need to follow instructions and cooperate during the calibration process to ensure accurate eye tracking.

Motor skills: Depending on the specific eye gaze system and application, users may need to possess certain motor skills to perform actions such as selecting targets, navigating menus, or interacting with virtual objects using eye gaze input. This may involve precise eye movements, blinking, or other eye-related actions.

Run the eye gaze application: Once the system is calibrated, you can start running the eye gaze application or software that you want to use. This could be a communication tool, a game, or any other application that utilizes eye gaze input. The application will interpret the gaze data from the eye tracker and respond accordingly based on where the user is looking.

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It's important to follow the instructions provided by the eye gaze system manufacturer and consult any user manuals or guides for specific guidance on how to run their system. Additionally, it may be beneficial to seek assistance from experts or technical support if needed to ensure proper operation and accurate eye gaze tracking.

## 4. RESULT AND DISCUSSION

Eye gaze and eye tracking systems have proven to be transformative technologies with diverse applications in various fields. In the realm of assistive technology, these systems have empowered individuals with disabilities, such as those with motor impairments, to communicate effectively and regain control over their environment. By capturing and interpreting eye movements, eye gaze systems allow users to interact with computers, control assistive devices, and even operate wheelchairs, significantly enhancing their independence and quality of life. Additionally, eye tracking's applications extend to medical diagnosis and research, as it offers valuable insights into neurological disorders, eye conditions, and cognitive impairments. In fields like user experience research, advertising, gaming, and simulation, eye tracking provides invaluable data for understanding human behavior, improving product design, and creating more immersive and engaging experiences. Moreover, in areas like psychological studies and automotive safety, eye tracking helps researchers and industries gain deeper insights into cognitive processes, attention, and driver monitoring, contributing to safer and more efficient practices. As technology continues to advance, the possibilities for eye gaze and eye tracking systems in diverse applications are likely to expand even further, positively impacting various aspects of human life and interaction.

## 5. CONCLUSION

Eye gaze communication systems offer a promising way for people with limited mobility or communication abilities to interact with computers or other devices using their eye movements. Techniques such as longest line scanning (LLS), occluded circular edge matching (OCEM), and eye lid tracking are used to estimate and track eye gaze. These systems use computer vision and image processing methods, and there are two main approaches: geometry-based and adaptive-based estimation. Non-intrusive tracking type is preferred, and higher screen resolutions tend to be more successful. Further research in this field may lead to improved accuracy and usability, providing new communication and interaction possibilities for individuals with diverse needs.

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