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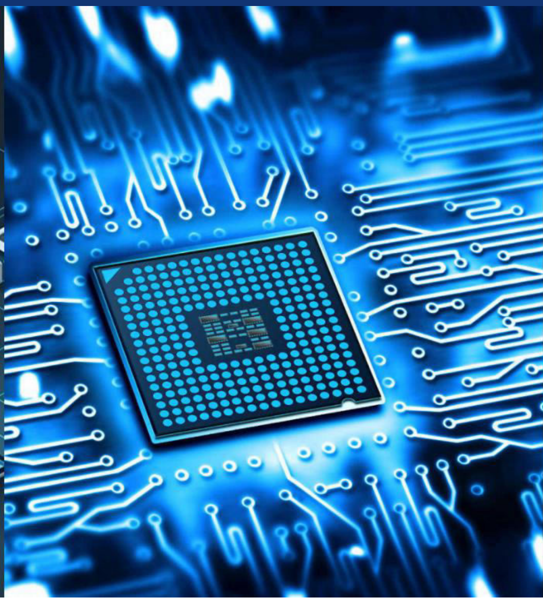


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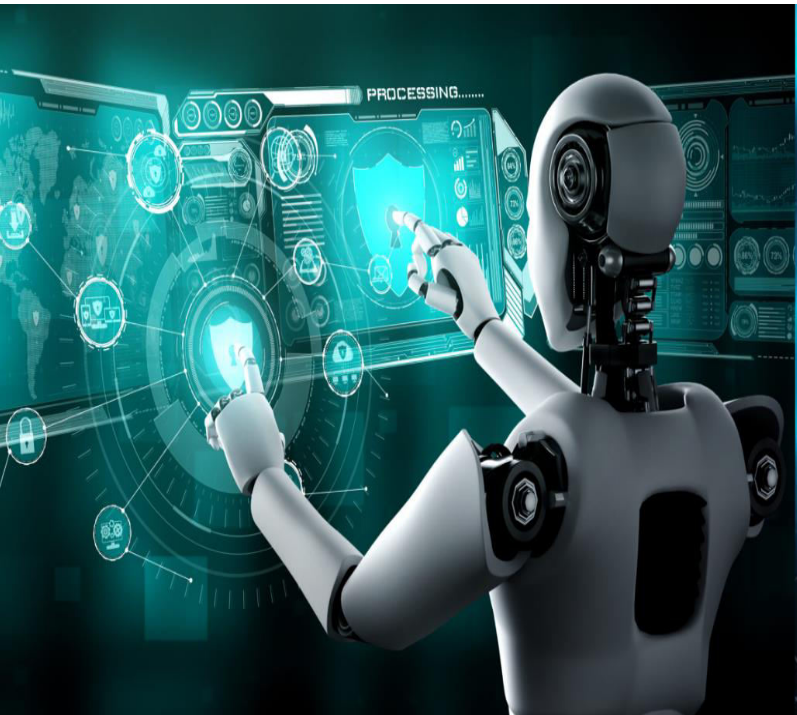

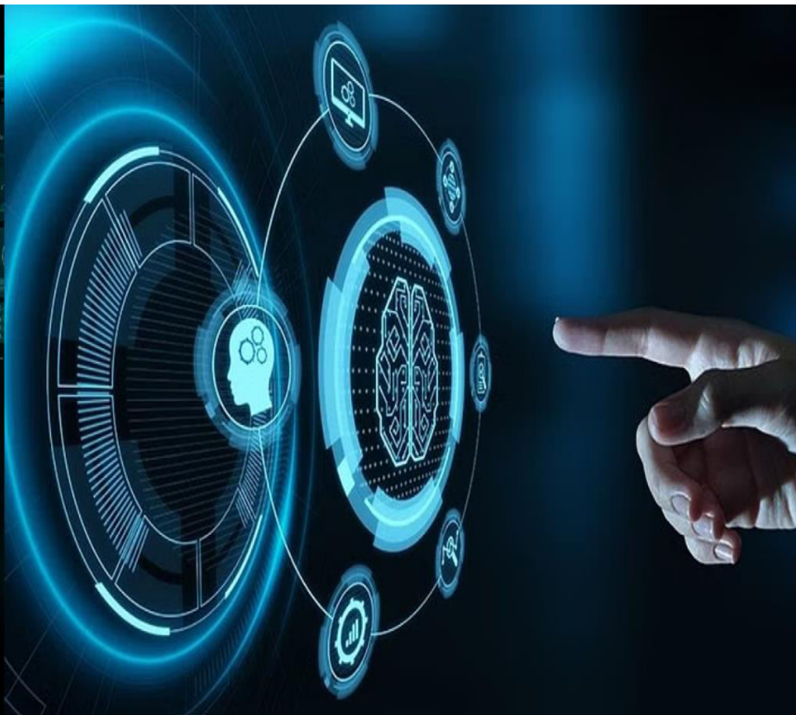

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Machine Learning-Based Eye Gaze Estimation for Precise Cursor Control

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ABSTRACT: Human–Computer Interaction (HCI) systems traditionally rely on input devices such as keyboards and mice; however, these devices are not accessible to individuals with physical disabilities or motor impairments. To overcome this limitation, this paper proposes an eye-controlled cursor system that enables users to operate a computer using only eye movements. The system utilizes a standard webcam to capture real-time eye images and detects iris position through image processing techniques such as edge and contour detection. Based on the detected eye movement, the cursor moves accordingly on the screen, allowing users to interact with the system without physical contact.

In addition to cursor movement, eye blinking is used as an input mechanism to perform actions such as clicking, opening and closing applications, and scrolling through pages. The proposed system is implemented using Python and does not require any additional hardware, making it cost-effective and accessible. This approach provides an intuitive and efficient solution for physically challenged individuals, especially those without hand mobility, thereby enhancing independence, usability, and accessibility in human–computer interaction.

KEYWORDS: Human–Computer Interaction (HCI), Eye Tracking, Eye Gaze Control, Cursor Control, Iris Detection, Assistive Technology, Computer Vision, Accessibility

I. INTRODUCTION

Eye tracking technology, which involves measuring eye movements and gaze positions using specialized devices, has gained significant importance in fields such as psychology, marketing, and human–computer interaction (HCI). In the beginning, eye trackers were mainly used in controlled laboratory environments to study how people see and process visual information, rather than being used as practical input devices for everyday computer systems [1].

One of the major limitations in the early adoption of eye tracking systems was their high cost, which was approximately $30,000 a decade ago. This made them unrealistic for widespread, real-world applications. However, with advancements in technology and the availability of more affordable components, low-cost eye tracking devices have now emerged, making them accessible to a wider audience. Because of this, gaze-based interaction has grown rapidly, leading to many new and innovative applications in HCI systems [3][6].

Traditional user interfaces are very effective at sending information from the computer to the user through multimedia outputs like images, animations, and videos. However, they provide limited bandwidth when it comes to user input. Improving communication from the user to the computer in a way that feels natural and intuitive is a major goal in HCI. The human eye plays a key role here, as it captures around 80–90% of external information. This makes eye movement a powerful and efficient real-time input method, especially for individuals with motor disabilities such as Amyotrophic Lateral Sclerosis (ALS) [7].

A common approach in gaze-based systems is to use eye trackers as a replacement for traditional input devices like the mouse, where gaze coordinates are used to control cursor movement. However, natural eye movement is very different from hand-controlled mouse interaction, which creates challenges in system design. These include issues with accuracy, stability, and unintended cursor movements [1][4].

To address these challenges, several improved eye tracking systems have been proposed. For example, Murthy et al. developed a system that uses eye gestures to control the cursor [2]. Bharath proposed a system that combines eye tracking

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with a virtual keyboard using computer vision techniques [6]. In addition, Kanakaprabha et al. designed an eye-controlled cursor system specifically for individuals with disabilities, helping to improve both accessibility and usability [7]. More advanced approaches, such as gaze-assisted pointing like the MagCursor technique, further improve interaction by combining eye and hand coordination to achieve better precision and efficiency [5].

Overall, these developments highlight the growing potential of eye tracking technology in creating more efficient, accessible, and natural ways for users to interact with computers, especially in assistive technologies and next-generation human–computer interfaces.

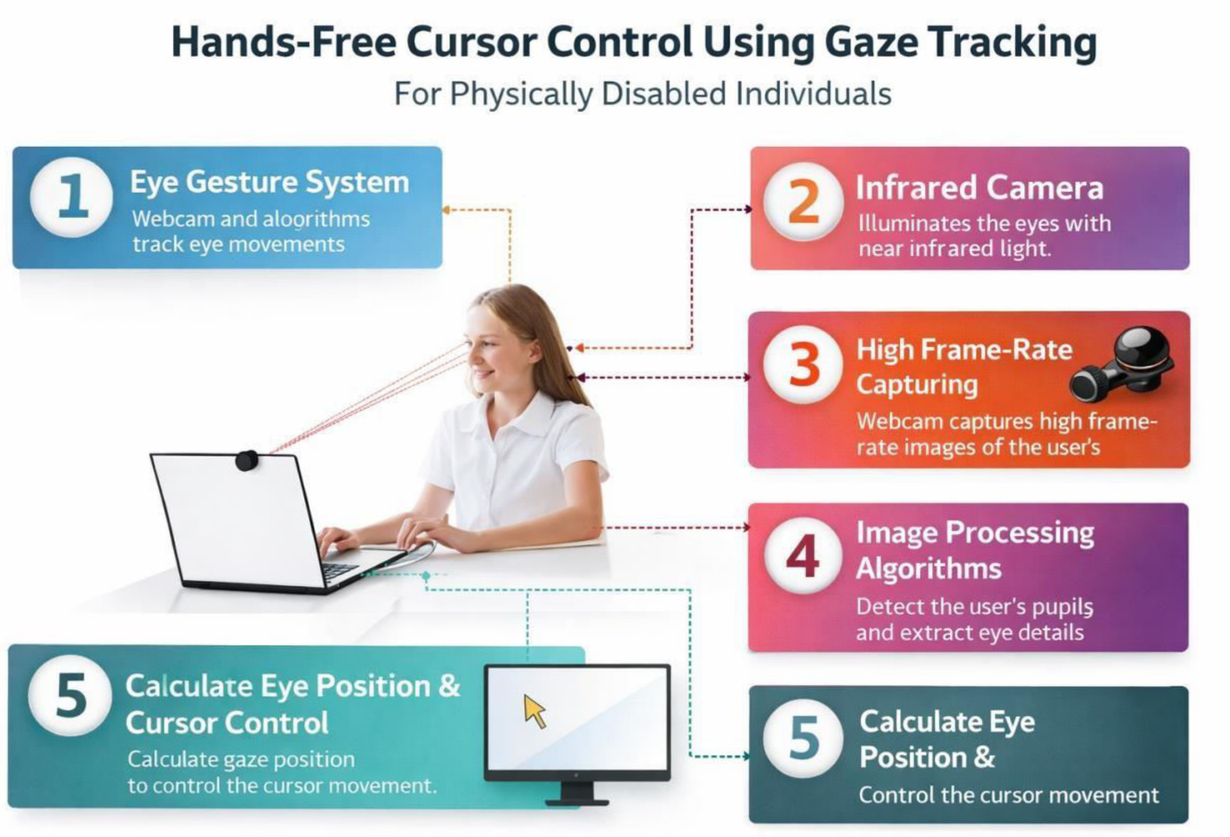

Fig.1 System Functionality Diagram

II. RELATED WORK

In [1], Murata carried out a comparative study between eye-gaze input and traditional mouse control, looking at how cursor performance varies across different age groups. The study found that while eye-gaze input feels more natural to use, it still has some drawbacks, such as lower accuracy and slower response times when compared to a regular mouse. In [2], Murthy et al. introduced a system that allows users to control the mouse cursor using eye gestures. Their method relies on computer vision techniques to track eye movements and convert them into cursor actions, making hands-free interaction possible. The system showed noticeable improvements in usability, especially for basic cursor tasks.

Hegde et al. in [3] worked on developing a low-cost eye-based human–computer interface system intended to replace traditional input devices. Their main focus was on making the technology affordable and accessible by using simple hardware and image processing methods, which makes it more practical for widespread adoption.

In [4], Reddy et al. proposed a method for controlling the mouse cursor through eye movements. Their approach focused on real-time tracking and accurately mapping gaze positions to screen coordinates. This helped improve interaction efficiency while also addressing common issues like jitter and unintended cursor movements.

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Cai et al. in [5] presented the MagCursor technique, which is a gaze-assisted manual pointing system that combines eye tracking with hand coordination. This hybrid method improves cursor precision and reduces user effort by taking advantage of the natural coordination between the eyes and hands, leading to better pointing performance.

In [6], Bharath developed a system that combines eye tracking with a virtual keyboard using computer vision. This setup allows users to control the cursor and type text, making it especially useful for individuals with severe motor impairments. Kanakaprabha et al. in [7] designed an eye-controlled mouse system specifically for people with disabilities. Their work focused on enhancing both accessibility and reliability, enabling users to carry out essential computer functions using only their eye movements.

Overall, these studies show how eye tracking technology has advanced in terms of accuracy, affordability, and usability. At the same time, there are still some challenges to overcome, such as sensitivity to lighting conditions, the complexity of calibration, and unintended cursor movements, which highlights the need for further improvement and research.

III. PROPOSED ALGORITHM

The **modules** that are used in this project are as follows

Facial Features Extraction:

This module is used to process the presence of an eye gaze tracking algorithm and facial features detection, which includes mouth and eye extraction.

Point of Gaze Calculation:

PoG can be calculated by the extraction of an eye patch and other crucial eye features. When the person uses this mechanism. Their eyes are focused on the screen. We first detect the face and extract the midpoint between the two eyes, which can be used as the centre point. This is done by converting the image into 2D.

Gradient Boosting:

In machine learning, gradient boosting is a method that gives a prediction model for learning an ensemble of regression trees that optimises the sum of squared error loss and naturally handles missing or partially labelled data.

IV. FUNCTIONAL REQIREMENT

Functional requirements describe the specific behaviour and functionality that a system or program must exhibit in order to meet its intended purpose.

Based on the code snippet provided, here are some possible functional requirements for the program:

1. The program must be able to capture live video input from a camera.
2. The program must be able to detect faces in the video input using the Media pipe Face-Mesh library.
3. The program must be able to extract facial landmarks from the detected faces.
4. The program must be able to determine the position of the user's eyes based on the facial landmarks.
5. The program must be able to map the position of the user's eyes to the position of the mouse cursor on the screen.
6. The program must be able to recognize when the user blinks or closes their eyes.
7. The program must be able to simulate a mouse click when the user blinks or closes their eyes in a specific pattern.
8. The program must be able to adjust the sensitivity of the eye tracking and blinking detection to accommodate different users and lighting conditions.
9. The program must be able to handle errors and exceptions gracefully, such as when the camera or eye tracking library fail to function properly.
10. The program must provide a user-friendly interface to configure and customize the eye tracking and clicking behaviour, if applicable.

These are just some examples of potential functional requirements based on the code snippet provided. Depending on the intended purpose and scope of the program, there may be additional or different functional requirements that need to be defined.

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V. SIMULATION RESULTS

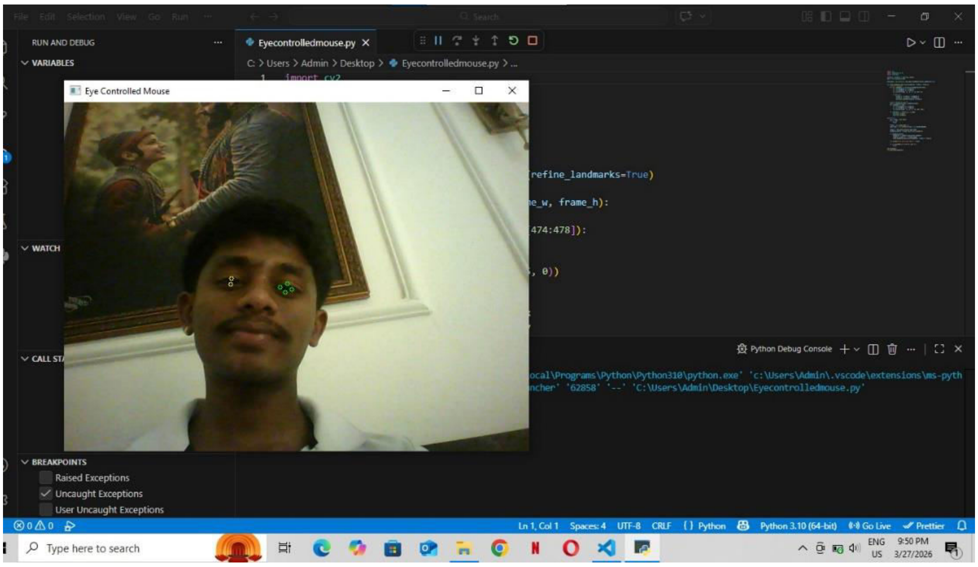

Fig.1. Capture user eyes

Fig. 2. Clicking using eye sensor

VI. CONCLUSION

This paper presents a hands-free cursor control system based on eye gaze tracking, aimed at helping physically disabled individuals who are unable to use traditional input devices like a mouse. The system uses computer vision techniques to detect and track eye movements through a standard webcam and then translates those movements into cursor actions. This allows users to interact with a computer in a more natural and intuitive way. Since it relies on common hardware, the approach is low-cost, practical, and accessible, making it suitable for wider use.

However, the system's performance is influenced by environmental conditions, especially lighting and camera quality. In low-light or unstable environments, the accuracy of eye detection and feature extraction tends to decrease, which can affect the system's overall reliability and precision. There are also challenges like unintended cursor movements and the need for proper calibration to ensure smooth operation.

Even with these limitations, the system shows strong potential as an alternative input method. It serves as a useful assistive technology for individuals with limited mobility and contributes to the development of more accessible and natural human–computer interaction systems. Future improvements could focus on making the system more robust under different lighting conditions, increasing accuracy, and incorporating advanced algorithms to deliver a smoother and more reliable user experience.

VII. FUTURE WORK

Future improvements can focus on making the system more robust and user-friendly. For example, advanced image preprocessing techniques can be used to handle different lighting conditions and improve the accuracy of eye detection. Using high-resolution cameras can also enhance overall performance by providing clearer images and allowing more precise cursor control. In addition, adding head posture detection would give users more freedom to move naturally while interacting with the system.

Further enhancements could include integrating gaze estimation and gaze projection methods to improve cursor precision. Machine learning-based approaches can also be explored so the system can adapt to individual user behavior over time. Techniques like Particle Filters are particularly useful for efficient gaze estimation, as they work well in dynamic tracking scenarios. Altogether, these improvements can lead to a more accurate, adaptive, and user-friendly eye-controlled interface system.

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