Real-Time Eye Movement Tracking for Hands-Free Mouse Control using Deep Learning

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***Abstract*—The growing dependence on technology and virtual communication has created significant challenges for individuals with disabilities or limited mobility, who often struggle to use traditional input devices such as a mouse. This issue is exacerbated by the increasing need for digital inclusion, as many everyday activities, including education, work, and social interactions, now rely on the use of computers and mobile devices.**

Fortunately, the evolution of human-computer interaction (HCI) technologies has accelerated, particularly with the advent of low-cost solutions that have the potential to reach a large number of users, regardless of their physical limitations. Moreover, real-time systems are becoming increasingly accessible, allowing users to perform daily tasks without relying on traditional input devices like a mouse.

In this context, our work aims to explore an innovative approach for controlling the cursor through real-time eye movement tracking using deep learning. The proposed solution is based on using a common camera, without the need for expensive or specialized equipment. The system seeks not only to offer an alternative for individuals with disabilities but also to enhance the user interaction experience, making it more natural and intuitive.

***Index Terms*—Eye tracking, hands-free control, deep learning, assistive technology, real-time systems.**

I. Introduction

The growing dependence on technology and virtual communication has created significant challenges for individuals with disabilities or limited mobility, who often struggle to use traditional input devices such as a mouse. This issue is exacerbated by the increasing need for digital inclusion, as many everyday activities, including education, work, and social interactions, now rely on the use of computers and mobile devices.

Human-computer interaction (HCI) technologies have evolved significantly, particularly in the development of low-cost solutions that expand access to a larger number of users, including those with physical limitations. Additionally, real-time systems have become increasingly accessible, enabling users to perform everyday tasks without relying on traditional input devices, such as a mouse.

In this paper, we explore an innovative solution for hands-free mouse control using real-time eye movement tracking. The proposed approach utilizes a common camera, eliminating the need for expensive or specialized equipment. This system not only provides an alternative for individuals with disabilities but also improves the user interaction experience by making it more intuitive and natural.

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II. Related Works

Several methods for eye tracking have been developed over the years, including both hardware-based and computer vision-based solutions. Traditional eye tracking systems, such as those from Tobii and EyeTribe, use infrared technology to capture eye movements with high accuracy. However, these systems are expensive and not accessible to a large portion of the population.

In recent years, computer vision-based systems utilizing common webcams have gained popularity due to their accessibility and efficiency. One such example is GazePointer, which allows mouse control through eye tracking, using standard cameras and simple computer vision algorithms.

More recently, deep learning-based methods have been applied for gaze estimation with greater accuracy and real-time responsiveness. Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) have shown promise in this field, as demonstrated by systems like GazeML and RT-GENE, which exhibit high accuracy rates.

Additionally, blink detection has been explored as a means of emulating mouse clicks, with algorithms like dlib being used to detect blinks and enable cursor control without the use of hands.

III. System Overview

The system utilizes the 'GazeTracking' library by Antoine Lamé, which allows eye position detection using a common camera, making the system accessible without specialized hardware. The calibration process is carried out with five fixed points on the screen: top-left, top-right, center, bottom-left, and bottom-right corners. Calibration is performed in a **triple-loop**, meaning three consecutive calibrations are carried out to minimize errors and refine system parameters. This approach enhances the precision of eye movement tracking and ensures more accurate cursor control.

IV. Methodology

The system is implemented in Python using the ‘cv2‘ (OpenCV) library for video capture, ‘pyautogui‘ for mouse control, and the ‘GazeTracking‘ library for real-time eye tracking. The calibration process consists of three consecutive trials, where the five calibration points on the screen are used to adjust the cursor’s position. The data collected during calibration are analyzed to calculate the average eye position for each point, helping to improve the accuracy of the tracking system.

Once calibration is complete, the mouse is automatically controlled based on the user’s eye position. To further improve accuracy, a simple neural network model is incorporated. This model is trained using 2300 images and is applied to the real-time eye tracking data to enhance the accuracy of gaze estimation, ensuring more precise control of the mouse.

V. Neural Network Model and Learning

In addition to the eye tracking model provided by the ‘Gaze-Tracking‘ library, a simple fully connected neural network model was integrated to improve the system’s accuracy. The neural network consists of three fully connected layers and was trained with the following configuration:

- **Batch size**: 32 - **Epochs**: 150 - **Learning rate**: 10^{-4} (fixed learning rate) - **Validation split**: 20% of the data used for validation during training - **Target image size**: 224x224 pixels

The neural network was applied to real-time eye tracking, refining the eye position estimates and providing smoother and more precise cursor control.

VI. Evaluation and Results

The system’s performance was evaluated based on the accuracy of eye tracking and the responsiveness of mouse control. Accuracy was measured in angular degrees by comparing the actual position of the eye with the estimated position provided by the system. The sensitivity to movement and smoothing was also evaluated, with adjustments made to system parameters such as smoothing the movement and improving the sensitivity at the edges of the screen.

The results demonstrated that, with the calibration process and the neural network model, the system was able to effectively control the cursor, offering a viable alternative for individuals with disabilities or limited mobility.

VII. Conclusion and Future Work

This paper presented an innovative solution for hands-free mouse control using real-time eye tracking, with deep learning applied to improve gaze estimation accuracy. The system was designed to be accessible, using only a common camera and eliminating the need for specialized hardware.

Future work will focus on exploring more complex models, collecting additional data to increase the system’s precision, and implementing new features such as interaction through blinks or other eye gestures.

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