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Virtual mouse control using Machine learning

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ABSTRACT

The current usability of eye-typing systems that rely on virtual keyboards is limited due to the lack of adaptive and user-centered approaches. This leads to low text entry rates and the need for frequent recalibration. In this study, we propose a set of methods to address these issues in gaze-based virtual keyboards. Our proposed methods focus on adapting the dwell time in asynchronous mode and the trial period in synchronous mode. We consider commands that allow for corrections within the application. The methods have been tested on a newly developed virtual keyboard designed for a structurally complex language. The keyboard incorporates a two- stage tree-based character selection arrangement. We introduce various mechanisms that are dwell-based or dwell-free, with the added feature of multimodal access. This means that the search for a target item is facilitated through gaze detection, while the selection can be made using dwell time, soft-switch, or gesture detection with surface electromyography in asynchronous mode. In synchronous mode, both the search and selection can be performed solely with the eye-tracker. To evaluate the performance of the system, we conducted experiments under 20 different conditions, measuring text entry rate and information transfer rate. Our adaptive strategy for parameter adaptation over time has demonstrated a significant improvement of over 40% compared to non-adaptive approaches, particularly for new users. The multimodal dwell-free mechanism, which combines eye-tracking and soft-switch, outperforms adaptive methods that rely solely on eye-tracking. Furthermore, we assessed the system's usability using the System Usability Scale and the NASA Task Load Index. The system received an excellent rating on the adjective rating scale, indicating its user-centered focus, while the weighted rating on the NASA Task Load Index was low.

Keywords: Gaze-Based Access Control · Adaptive Control · Multimodal Dwell-Free Control · Graphical User Interface · Virtual Keyboard · Eye-Typing · Human-Computer Interaction.

I. INTRODUCTION

Personal computers have evolved from being used primarily for mathematical problem-solving and word processing to becoming integral to various aspects of our daily activities, including professional applications, internet browsing, shopping, socializing, and entertainment. While computers are designed to be easily accessible for the general population, individuals with severe physical disabilities, such as cerebral palsy or amyotrophic lateral sclerosis, face significant challenges in using computers. Numerous research studies have focused on improving the interaction between users and computer systems through Human-Computer Interface (HCI) advancements. However, most of these methods are applicable only to able-bodied individuals and do not cater to the needs of disabled individuals. To address this gap, researchers have explored alternative methods that utilize signals such as electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG) for individuals with physical disabilities. These methods involve tracking various eye-related parameters such as limbus, pupil, eye/eyelid movement, and even head movement. However, many of these approaches require the use of attachments and electrodes on the head, making them impractical for everyday use. Additionally, high-end techniques based on expensive infrared tracking of eye and nose movements were not affordable for those who needed them. To make computer accessibility more feasible and cost-effective for disabled individuals, eye tracking and nose movement detection using a webcam and a PC or laptop have emerged as viable solutions. By utilizing eye tracking and nose movement detection, disabled individuals can access computer facilities and participate fully in this new technology. Various groups have explored the development of an "eye mouse," which allows users to perform computer operations using their eyes. This approach relies on well-designed virtual mouse systems that leverage the capabilities of a computer and a webcam, yielding promising results. Furthermore, an eye-control method based on electrooculography (EOG) has been investigated to create systems for assisted mobility. This method involves developing an eye model based on the electrooculographic signal, and its validity has been studied extensively. In conclusion, HCI research has made significant strides in providing computer accessibility for individuals with disabilities. By leveraging eye tracking, nose movement detection, and EOG-based approaches, these individuals can overcome barriers and participate actively in computer-based activities. The use of simple hardware setups, such as webcams and standard PCs or laptops, makes these solutions practical and affordable. Various modalities have recently been assessed for designing natural user interfaces that enable intuitive interaction with computers. These modalities include electroencephalogram (EEG)-based brain-computer interfaces (BCIs), eye-tracking- based human-computer interfaces (HCIs), electromyography (EMG)-based gesture recognition, speech recognition, and different input access switches. Eye-tracking, which involves tracking the position and orientation of the eyes or the point of regard, has gained significant attention in computer interaction for applications such as eye-typing interfaces, robotics control, web page behavior analysis, entertainment (e.g., video games), switch control, and virtual automobile control. In eye-tracking research, two primary methods have been used to measure eye movements. The first method involves wearable cameras that capture high- resolution images for gaze point calculation. However, wearing camera equipment can cause discomfort during eye-tracking interactions. The second method relies on remote cameras without additional equipment, capturing the gaze position. Although this method avoids discomfort, the lower image resolution of the eye can result in significant vibrations in the calculated gaze point due to pupil tremors. Additionally, the time-varying characteristics of remote-camera-based methods can lead to low accuracy and the need for frequent calibration. Like EEG-based BCIs, eye-tracking-based HCIs can be accessed in both synchronous (cue-paced) and asynchronous (self-paced) modes. In synchronous mode, user actions (e.g., click events) are performed after fixed intervals (trial periods), while in asynchronous mode, click events are performed using dwell time. Synchronous mode requires the user to focus on the target item for the maximum duration during a trial to select it, whereas in asynchronous mode, the user selects an item by fixating on it continuously for a specific predefined period. These methods effectively capture user intention but can be time-consuming when multiple selections need to be made.

I. RELATED WORK

In recent years, there has been a significant increase in the development of assistive technology aimed at improving traditional systems for people with disabilities. This growth can be attributed to the widespread use of computers in both work and leisure activities, which has led to the creation of PC-associated handling applications that primarily rely on graphic interfaces. These new methods of control and communication between humans and machines supplement traditional input devices like joysticks, mice, and keyboards, which require a certain level of motor control from users. Instead, these new methods enable individuals with severe disabilities to interact with computers effectively. Two notable examples of these new methods are voice recognition and visual information. Voice recognition technology allows users to control instruments or applications through basic voice commands or write text using "speech and spell" applications. On the other hand, video oculography or infrared oculography can detect eye movements and gestures, while an infrared head-operated joystick detects head movements. Another approach involves using an electrooculographic mouse, which senses eye movements by recording the corneal-retinal potential generated by hyperpolarization’s and depolarizations between the cornea and retina. This recording is known as an electrooculogram (EOG). EOG-based systems utilize different guidance strategies such as direct access guidance, guidance by automatic or semiautomatic scanning techniques, and guidance by eye commands. These systems have been developed using efficient concepts and techniques, resulting in high processing performance and a better user experience. They have opened new possibilities for individuals with disabilities to interact with computers and perform various tasks effectively.

II. BACKGROUND

In general, most eye-tracking methods are developed in asynchronous mode to allow users to proceed at their own pace. However, in this mode, it is crucial to set an appropriate dwell time to ensure accurate selection of the intended item. Insufficient dwell time can lead to false selections, known as the Midas touch problem, which can frustrate users and delay the overall process. To address this issue, researchers have proposed adaptive strategies for choosing the dwell time. These enhancements enable users to select desired items more easily

and improve the overall performance of the system. Some studies have adjusted the dwell time based on exit time. However, this online adjustment suffers from delayed feedback and uncontrolled variations in exit time. Another approach involves tuning the dwell time by controlling the speed of control keys. One drawback of this method is the requirement of additional selection time. A recent study proposed a probabilistic model that adjusts the dwell time based on the probability of each letter's selection history, another approach dynamically adjusts the dwell time of keys based on their selection frequency and location on the keyboard. However, these studies often rely on manual selection of hyperparameter values and do not consider user variability, limiting their applicability to other scenarios. Consequently, the adjustment of dwell time depends heavily on the application and parameter choices, with little attention given to typing errors and correction commands in the automation of dwell time selection.

Othe other hand, online adjustment of a fixed interval time in synchronous mode has received less attention in eye-typing studies. This approach can be valuable for individuals who may not be able to maintain their gaze on a desired location continuously, such as those with nystagmus. However, they can still focus on the desired location more often than on undesired items. Synchronous mode also allows users to follow a tempo during typing tasks without requiring their complete attention. Thus, this mode can be useful for specific user groups, such as individuals with attention deficit hyperactivity disorder Dwell-free techniques have been implemented in virtual keyboard applications, where dwell-free eye-typing systems generally achieve a moderately higher text entry rate compared to dwell-based systems. The user interfaces of virtual keyboard systems have been designed to accommodate these dwell-free mechanisms.

I. PROPOSED METHODS

In this study, two methods for the adaptation (over time) of the dwell time in asynchronous mode and the trial period in synchronous mode are proposed for gaze-based access control and compared with non-adaptive methods. We have set a benchmark for several dwell-free mechanisms including several portable, non-invasive, and low-cost input devices. A multimodal dwell-free approach is presented to overcome the Midas touch problem of the eye-tracking system.

II. DISCUSSION

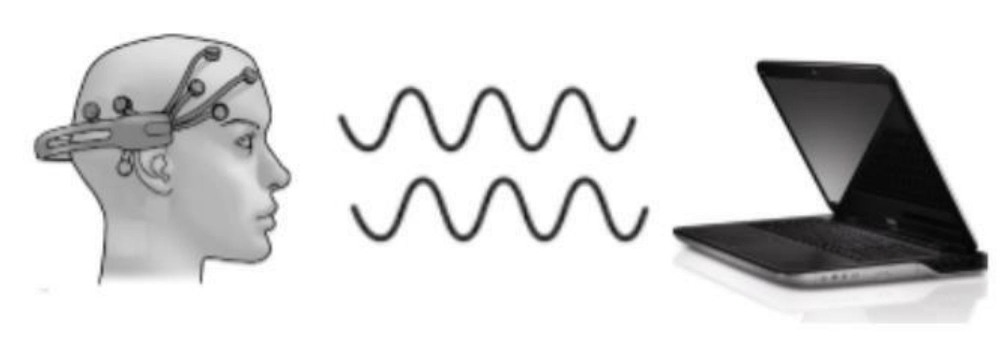
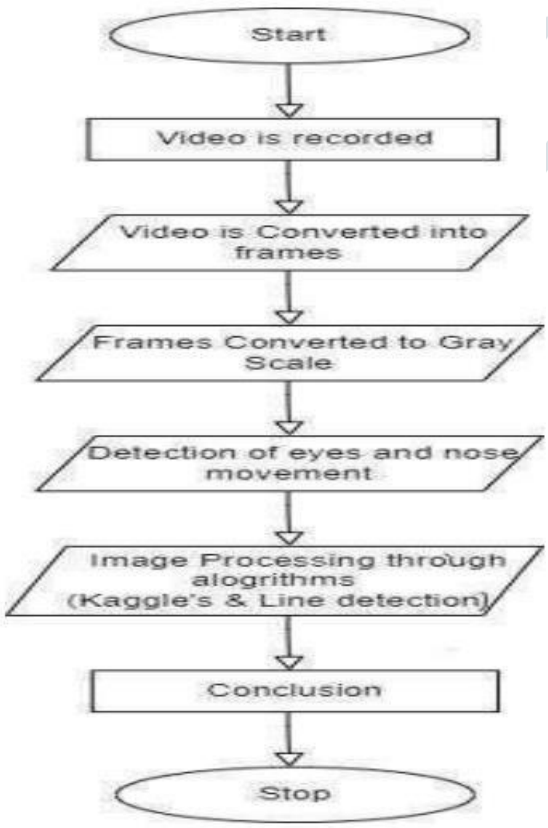


Fig. 1: Block Diagram

This study is unique in that it offers multiple levels of comparisons to assess the performance of proposed approaches for beginner users. The proposed time-adaptive methods demonstrated a higher average text entry rate in both synchronous (17.06 ± 3.06 letters/min) and asynchronous (16.10 ± 3.36 letters/min) modes with new users. Additionally, the multimodal dwell-free mechanism using a combination of eye-tracking and soft- switch (21.83 ± 6.58 letters/min) outperformed eye-tracker with sEMG based hand gestures and adaptive methods with eye-tracking only. The study focused on users' initial adaptation to a new system rather than learning over a longer period. The proposed algorithms suggest the beneficial impact of an adaptive approach in both synchronous and asynchronous modes, which needs to be confirmed over long sessions as performance is expected to improve over time. This study provides comprehensive insights into the potential benefits of adaptive methods for improving text entry rate for beginner users in gaze-based virtual keyboard systems

II. METHODOLOGY



The image processing operations carried out in this system includes,

- Firstly, using the webcam the video is recorded.
- Then all the frames are extracted from the captured video.
- From the collected frames, it is furthermore changed over into grayscale images and processes the values obtained from the Grayscale.

- After processing, the edges of the face are detected with the help of Line detection algorithm.
- From these edges, it detects eyes and nose in the frame and the aspect ratio of the eye.
- Finally, eye blink and nose movement are detected by Kaggle's Algorithm.

III. EXPERIMENTAL RESULTS

The main objective of our project is to develop a user-friendly human-computer interaction system by detecting eye and nose movements and mapping them to the computer cursor. The project involves accessing the webcam to capture video images, which are then processed to extract the desired features. The process starts by initializing the webcam and capturing the video stream. Each frame of the video is then extracted for further analysis. To prepare the frame for feature detection, it is converted into grayscale. Next, facial landmarks are detected within the frame, which provides crucial information about the position and structure of the face. These facial landmarks are utilized to determine the edges of the face, enabling precise tracking of eye and nose movements.

The eye aspect ratio and nose movement features are then calculated based on the detected landmarks. These features are used to identify blink patterns and nose movements. The resulting data is mapped to the computer cursor, allowing users to control the cursor with their eye and nose movements. This entire process is repeated continuously in a loop for every frame of the video, ensuring real-time tracking and updating of the cursor position based on the user's eye and nose movements.

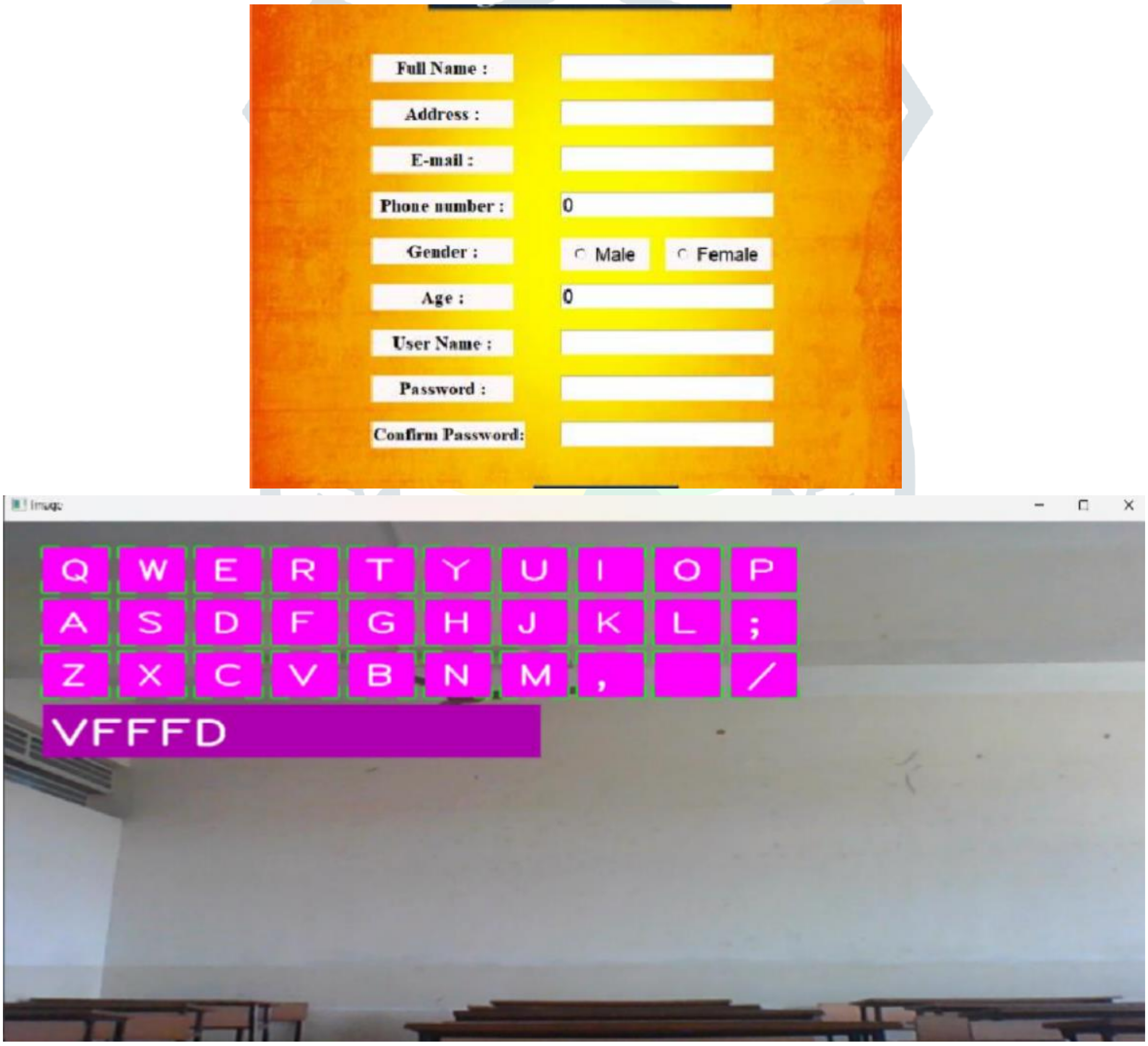


Figure 2. Output

IV. CONCLUSION

The primary objective of this project is to create a hand-free cursor control system that reduces the reliance on a mouse. Our focus is on individuals with physical disabilities who are unable to use their hands to operate a computer system, especially in poor lighting conditions. The proposed model serves as a viable solution for both physically disabled individuals and those without disabilities, enabling them to use the computer effortlessly. Furthermore, the project has the potential to evolve into an operating system that utilizes multiple threads to efficiently run various applications simultaneously. This system will significantly benefit people with physical challenges by providing access to mouse functions and actions. Through experimental results, we aim to demonstrate that the proposed system surpasses the existing systems and consistently improves over time.

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