An Intelligent Human-Machine Interface Based on Eye Tracking for Communication of Patients with Locked in Syndrome

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ABSTRACT:

Paralyzed people lack the ability to control muscle function in one or more muscle groups. The condition can be caused by stroke, ALS, multiple sclerosis, and many other diseases. Locked in Syndrome (LIS) is a form of paralysis where patients have lost control of nearly all voluntary muscles. These people are unable to control any part of their body, besides eye movement and blinking. Due to their condition, these people are unable to talk, text, and communicate in general. Even though people that have LIS are cognitively aware, their thoughts and ideas are locked inside of them. These people depend on eye blinks to communicate. They rely on nurses and caretakers to interpret and decode their blinking. Whenever LIS patients do not have a person to read their eye blinks available, they have no means of self-expression. Our project Blink to Text offers a form of independence to paralyzed people. The software platform converts eye blinks to text. Every feature of the software can be controlled by eye movement. Thus, the software can be independently operated by paralyzed people. The software can be run on any low-end computer. The software uses computer vision and Haar cascades to detect eye blinking and convert the motion into text. The program uses language modelling to predict the next words that the user might blink.

INDEX TERMS: Eye-tracking, Deep learning, human machine interface.

I. INTRODUCTION:

In our research, we found that most of the previous studies focused on various physiological and behavioural indicators using eye tracking. Common parameters included eye gaze patterns, blink rate, pupil dilation, and fixation duration. When focused specifically on patients with syndromes, researchers typically considered cognitive load, visual attention span, and response time to stimuli. In studies related to specific conditions such as autism spectrum disorder, Locked In Syndrome, Down syndrome, or Rett syndrome, the use of eye tracking emphasized understanding social gaze behaviour, attention to facial features, and response to visual cues.

Injuries to the brain stem, resulting from factors like stroke, trauma, anoxia, or neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS), can give rise to a condition known as Locked-In Syndrome (LIS). Coined by Plum and Posner in 1966, LIS describes a state where an individual experiences severe paralysis while retaining intact cognitive abilities.

This syndrome stems from traumatic or vascular damage that bilaterally severs the corticospinal and corticobulbar tracts, presenting in various forms based on the extent of motor output impairment. The classification of LIS is contingent on the degree of motor functionality affected. In the total form, no voluntary movement is possible. In the pure form, individuals can move their eyes and blink but are incapable of any other voluntary actions.

The incomplete form involves some residual voluntary movements beyond eye control. LIS typically exhibits minimal improvement and often follows a chronic course. A critical hurdle in managing LIS is communication, crucial for the individual's quality of life, emotional well-being, and overall sense of existence. Effective communication is essential not just for daily practical activities but also for fostering social participation.

Individuals with incomplete LIS can benefit from communication aids, although conventional augmentative and alternative communication (AAC) devices may not always suffice, especially when residual muscle activity is inadequate for device control.

Establishing a communication channel for individuals with LIS remains a persistent challenge. Embracing low-tech AAC methods, which are non-battery powered and cost-effective, becomes a primary approach for patients seeking to overcome communication barriers. Some studies have documented the use of Morse code (via eye blinking) or other eye-coded methods, enabling these individuals to convey messages letter by letter to their communicative counterparts.

Eye tracking systems enable the monitoring of eye movements across a range of activities, including emotional assessment, reading, recognition of human movements, advertisement viewing, website navigation, human-computer interaction (HCI), driver assistance systems, game perception, identification of driver fatigue, and more. They utilize an eye-tracking framework to create an "eye-mouse," improving computer accessibility for individuals with disabilities. This technology serves as a control interface, eliminating the need for a mouse or other input devices, and facilitates direct interaction with the user interface. The proposed framework aims to provide a straightforward and useful interactive mode using only the client's eye blinking to text conversion.

II. LITERATURE SURVEY:

EMBEDDED SYSTEM FOR EYE BLINK DETECTION USING MACHINE LEARNING TECHNIQUE:

Bishar R. Ibrahim; Farhad M. Khalifa; Subhi R. M. Zeebaree; Nashwan A. Othman; Ahmed Alkhayyat

Nowadays, eye tracking and blink detection are increasingly popular among researchers and have the potential to become a more important component of future perceptual user interfaces. The real-time eye-tracking system has been a fundamental and challenging problem for machine learning problems. The main purpose of this paper is to propose a new method to design an embedded eye blink detection system that can be used for various applications with the lowest cost. This study presents an efficient technique to determine the level of eyes that are closed and opened. We offered a real-time blink detection method by using machine learning and computer vision libraries. The proposed method consists of four phases: (1) taking frame by employing a raspberry pi camera that slotted to the raspberry pi 3 platform, (2) utilizing haar cascade algorithm to identify faces in the captured frames, (3) find facial landmarks by utilizing facial landmark detector algorithm, (4) detect the eyes' region and calculate the eye aspect ratio. The proposed method obtained a high accuracy to indicate eye closing or opening. In this study, an aspect ratio method was used to implement a robust and low-cost embedded eye blink detection system on the raspberry pi platform. This method is exact resourceful, fast, and easy to perform eye blink detection.

DEEPVISION:

DEEPFAKES DETECTION USING HUMAN EYE BLINKING PATTERN:

Tackhyun Jung; Sangwon Kim; Keecheon Kim

In this paper, we propose a new approach to detect Deepfakes generated through the generative adversarial network (GANs) model via an algorithm called Deep Vision to analyse a significant change in the pattern of blinking, which is a voluntary and spontaneous action that does not require conscious effort. Human eye blinking pattern has been known to significantly change according to the person's overall physical conditions, cognitive activities, biological factors, and information processing level. For example, an individual's gender or age, the time of day, or the person's emotional state or degree of alertness can all influence the pattern. As a result, Deepfakes can be determined through integrity verification by tracking significant changes in the eye blinking patterns in deepfakes by means of a heuristic method based on the results of medicine, biology, and brain engineering research, as well as machine learning and various algorithms based on engineering and statistical knowledge. This means we can perform integrity verification through tracking significant changes in the eye blinking pattern of a subject in a video. The proposed method called Deep Vision is implemented as a measure to verify an anomaly based on the period, repeated number, and elapsed eye blink time when eye blinks were continuously repeated within a very short period of time. Deep Vision accurately detected Deepfakes in seven out of eight types of videos (87.5% accuracy rate), suggesting we can overcome the limitations of integrity verification algorithms performed only on the basis of pixels.

IDENTIFICATION OF SIGNIFICANT EYE BLINK FOR TANGIBLE HUMAN COMPUTER INTERACTION:

JashaswimalyaAcharjee; Suman Deb

This paper introduces a mode of interaction with computers through Visual Tracking Technique (VTT) along with robust Eye Blink Detection (EBD). The visible facial rigid movements of human eye blinks, lip movement etc. and nonrigid movements including head rotation and orientations are combined together to infer significant and precise interaction order with consumer grade devices. The conjugate machine learning and heuristic approach involving cascades of regressors with accurate calibrations have been established successfully to transform facial movements into a meaningful interaction cues to navigate or trigger events as of any conventional input devices. The optimized implementation of the close loop interaction cycle is accomplished within 400 ms, making the system as natural as the traditional keyboard or mouse input. The proposed interaction has a spectrum of application areas including assistive technology, augmented interaction, gaming and entertainment.

EYE-BLINK DETECTION UNDER LOW-LIGHT CONDITIONS BASED ON ZERO DCE:

Xiaolin Zhou

Eye-blink is an effective tool for human-computer interaction, and it could be a physiological index to judge human activities. Nonetheless, eye-blink reactions not only happen during the daytime, but also blink a lot during nighttime, as blink can moisten the eye when people feel fatigued. In this paper, eye-blink detection under a low-light environment is proposed, improving the success rate of detecting blinks in an insufficient light environment. After comparing two face meshes, which are generated by Dlib and Media Pipe can yield an abundant and precise face landmark. Even without applying some methods of low-light image enhancement (LLIE), the method of Media Pipe can locate an approximate area of eyes in a nighttime environment. For the problem of detecting blink under a low-light environment, Zero Reference Deep Curve Estimation (Zero-DCE), a deep learning-based method, is applied. Zero DCE is used to improve the details of dark blurry images, the advantage of which is zero-reference, i.e., no paired or unpaired data are needed in the training process. Also, Zero-DCE can yield a pleasing result in the aspects of brightness, colour, contrast, and naturalness, the details of which will be shown in the following images. When under sufficient light environment, the average success rate of detecting right eye blink is 95.9%, and for left eye blink is 91.2%; when under insufficient light environment without enhancing the image, the average success rate of detecting right eye blink is only 39.7%, and for left eye blink is only 48.8%; when under an insufficient light environment with Zero-DCE, enhancing the quality of image, the average success rate of detecting right eye blink raise to 84%, and for left eye blink raises to 92.7%.

lll. RELATED WORK:

Several studies have explored the integration of eye tracking and machine learning to better understand the cognitive and behavioural characteristics of patients with neurological syndromes. Researchers have primarily focused on syndromes such as autism spectrum disorder (ASD), Down syndrome, and Rett syndrome, where visual attention and gaze behaviour are key indicators of cognitive development.

In the context of ASD, Loth et al. (2017) and Wang et al. (2019) applied machine learning classifiers like SVM and Random Forests to distinguish between neurotypical and ASD children based on gaze fixation on facial features and social stimuli. Their results demonstrated that children with ASD show reduced fixation on eyes and faces, which could be detected with high accuracy using eye tracking data.

Yu et al. (2020) used deep learning models such as CNNs and LSTMs to analyse dynamic gaze patterns in individuals with Rett syndrome, helping to identify periods of attention lapse and stereotypical behaviours. These models enabled automatic feature extraction from raw gaze data, improving classification performance and reducing the need for manual labelling.

In studies involving Down syndrome, Johnston et al. (2018) employed clustering algorithms to categorize visual scanning strategies, showing that children with Down syndrome exhibit unique gaze sequences during reading or image exploration tasks.

Moreover, hybrid systems combining eye tracking with emotion recognition (e.g., using facial expressions or EEG data) have been explored to provide a more holistic view of patient behaviour. These multi-modal systems, enhanced with ML, offer improved accuracy in detecting emotional responses and attention deficits.

While promising, existing studies are often limited by small datasets, variability in eye tracking equipment, and lack of standardized protocols, indicating a need for larger-scale, longitudinal research using consistent ML frameworks.

IV. EXISTING SYSTEM:

In the current scenario, individuals with Locked-in Syndrome (LIS) depend heavily on human assistance for communication. The most common method involves interpreting eye blinks or gaze patterns manually by nurses or caretakers. Some advanced systems use expensive eye tracking hardware or Brain-Computer Interface (BCI) devices, which are often costly, complex to operate, and not widely accessible. These systems, while functional, are not user-friendly for those who wish to operate them independently. The lack of affordable, autonomous solutions leaves many LIS patients with limited or no means of expressing their thoughts when human interpreters are not available.

Disadvantages of the Existing System:

➢ Requires constant human assistance to interpret eye blinks.

➢ Eye-tracking hardware and BCI systems are expensive and not widely available.

➢ Not accessible for individuals in low-resource settings.

➢ Complex to set up and operate without technical expertise.

➢ Limited communication speed and autonomy for users.

V. PROPOSED SYSTEM:

The proposed "Blink to Text" system introduces an affordable and independent communication solution for paralyzed individuals, particularly those with LIS. It uses a standard webcam and computer vision techniques to detect and interpret eye blinks. Haar cascade classifiers are employed to recognize eye movements, which are then translated into text using a predefined blink pattern scheme. To enhance the efficiency of communication, the system includes a language model that predicts and autocompletes words based on input. This blink-based interface allows full control over the software, enabling users to compose text, navigate options, and send messages—all through eye blinks. The system is lightweight, cost-effective, and designed to run on low-end computers, making it highly accessible.

Advantages of the Proposed System:

➢ Fully independent operation using only eye blinks.

➢ No need for expensive or specialized hardware—only a webcam is required.

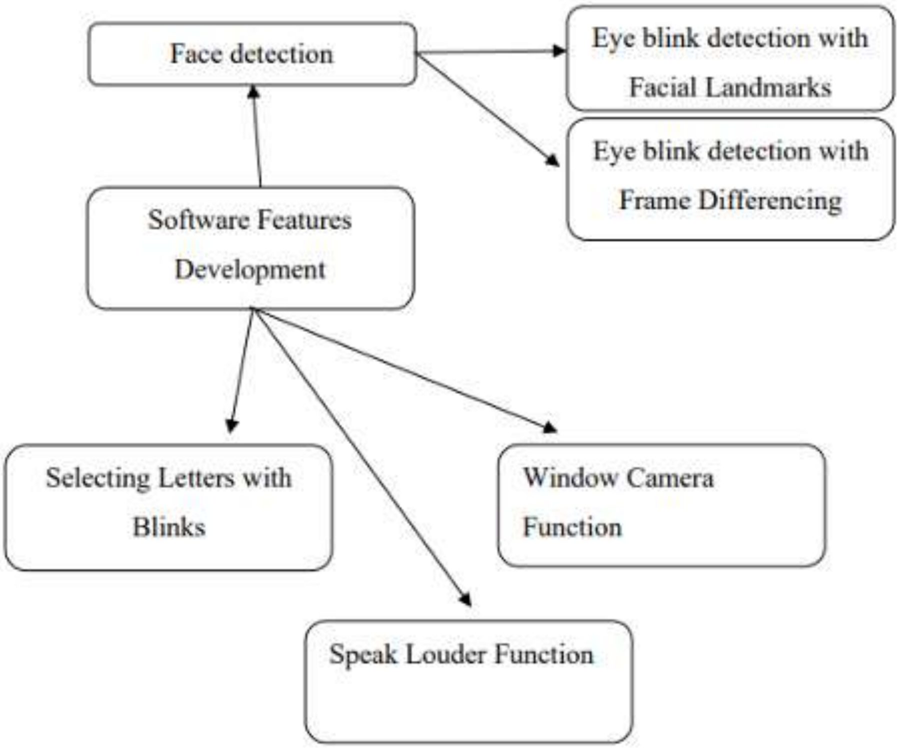
➢ Lightweight software that works on low-end computers.

➢ Uses computer vision (Haar cascades) for accurate blink detection.

➢ Integrates predictive text via language modelling to reduce blinking effort.

➢ Cost-effective and accessible to a larger number of patients.

VI. ARCHITECTURE DIAGRAM:



VII. TECHNIQUES:

The "Blink to Text" system utilizes several key techniques to enable communication for individuals with Locked-in Syndrome. At its core, the system employs computer vision using Haar Cascade Classifiers to detect facial features and accurately determine eye blinks in real time through a webcam feed. The blinking patterns are then analysed—distinguishing between short and long blinks—to encode signals that can be interpreted as letters, commands, or selections. This blink-based input is mapped to a predefined scheme, allowing users to form words and navigate the interface. To enhance usability and reduce the number of blinks required, the system incorporates language modelling techniques, such as n-gram or deep learning-based prediction models, to suggest the next word or autocomplete text. Additionally, the software features a blink-controlled user interface, where users can select actions like "space," "delete," or "send" using only eye movements. Visual or auditory feedback is provided for each interaction to confirm input. Designed to run efficiently on low-end computers, the software offers a lightweight and accessible solution, ensuring that individuals with severe paralysis can operate it independently. Overall, "Blink to Text" combines computer vision, signal decoding, predictive text, and user interface control to provide a powerful communication tool for the paralyzed.

VIII. PROJECT DESCRIPTION:

Face Detection:

The Face Detection module is a crucial component of the overall Eye Blink Detection system. It is responsible for identifying and locating faces within an input image or video stream. Face detection is a foundational step as it provides the necessary region of interest (ROI) containing the face, which is then used for subsequent eye blink detection.

Detecting Blink of The Eyes with Facial Landmarks:

The Detecting Blink of the Eyes with Facial Landmarks module is a critical component within the Eye Blink Detection Algorithms. This module focuses on analysing facial landmarks to identify and track the blinking of eyes. Facial landmarks are specific points on the face, such as the corners of the eyes, nose, and mouth, which can be used to understand facial expressions and movements.

Detecting Blink of the Eyes with Frame Differencing:

Detecting blink of the eyes with frame differencing is an approach that leverages the temporal changes in consecutive video frames to identify eye blinks. This method is based on the concept of frame differencing, where the differences between successive frames are analysed to detect significant changes, such as eye closure.

Using Blinks for Selection:

This module is designed to harness eye blinks as a means of user input or selection in human-computer interaction systems. This module takes advantage of the detected eye blink events to interpret intentional actions and trigger specific commands, making it a valuable component in applications such as hands-free control, accessibility interfaces.

User Interface Window for The Camera:

In the context of a software application or system that involves camera input, a "Window for the Camera" typically refers to the graphical user interface (GUI) element where the camera feed is displayed. This window acts as a viewport through which users can observe the real-time video stream from the camera.

Customizing The Software Features:

This module used to the capability of modifying or tailoring the functionalities and characteristics of a software application to meet specific user requirements such as pause the program, open the camera window button, dialogue box button, predicting next word box. This customization allows users to adapt the software to their unique workflows, making it more versatile and user-friendly.

lX. CONCLUSION AND FEATURES:

The implementation of an eye-tracking system for syndrome patients presents a significant step forward in assistive technology. By accurately detecting eye movements and translating them into written statements, the system enables improved communication for individuals with limited motor or verbal abilities. This technology not only enhances their independence but also contributes to their social and emotional well-being. Future enhancements, such as real-time responsiveness, multilingual support, and personalized calibration, can further optimize the system's usability and effectiveness across a broader spectrum of neurological and physical conditions.

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