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Eye Blink-Based Morse Code Detection and Real-time Translation into Text

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Abstract— **Communication barriers faced by individuals with severe impairments necessitate innovative solutions. To address this, an advanced system for Morse code detection using eye blink recognition has been developed, utilizing OpenCV and dlib libraries. The system captures real-time video to track and identify eye movements, employing facial landmark detection to precisely determine eye states. By calculating the Eye Aspect Ratio (EAR), it effectively distinguishes between intentional blinks and natural eye closures, converting these into Morse code. The generated Morse code is then translated into text, providing a user-friendly communication tool. Designed for robustness, the system performs reliably under various lighting conditions and adapts to individual blinking behaviors, ensuring a seamless and accessible communication interface.**

Index Terms— Eye blink detection, Morse Code Communication, Eye Aspect Ratio (EAR), Computer Vision, Facial Landmark Detection, OpenCV, dlib.

I. INTRODUCTION

Communication is a fundamental aspect of human interaction, yet for individuals with severe physical disabilities, it often becomes a significant challenge. Conditions such as amyotrophic lateral sclerosis (ALS), spinal cord injuries, muscular dystrophy, or strokes can impair a person's ability to speak or use their hands, leaving them with limited or no means of verbal or written communication. In such cases, alternative communication methods become essential to help these individuals express their needs, thoughts, and emotions.

One of the most reliable methods for such communication is Morse code, a time-tested system of transmitting messages using sequences of short and long signals—referred to as dots and dashes. Morse code has been used for over a century due to its simplicity and effectiveness in encoding language into basic signals that can be easily transmitted and decoded. It is well-suited for scenarios where minimal physical input is available, making it an ideal medium for individuals who may only be able to control small movements, such as eye blinks.

The Eye Blink-Based Morse Code Detection system addresses the communication barriers faced by individuals with limited motor function by using their eye blinks to input Morse code. Eye movements, especially blinks, are often one of the few controllable actions for people with severe disabilities, making them a practical choice for input mechanisms. By detecting intentional blinks and translating them into Morse code, the system provides a non-intrusive and efficient communication tool that can be used without the need for complex or expensive hardware.

The system works by capturing live video input from a webcam, detecting the user's eyes in real-time, and monitoring their blink patterns. By calculating the Eye Aspect Ratio (EAR), the system distinguishes between short blinks (dots) and long blinks (dashes), which are then mapped to Morse code. The Morse code is subsequently converted into readable text and displayed on the screen, enabling users to communicate effectively. The use of Morse code in this system is particularly valuable because it allows communication using only a minimal physical effort, yet it is flexible enough to encode full sentences and complex ideas.

The Eye Blink-Based Morse Code Detection system offers an accessible, cost-effective, and user-friendly solution for people with severe disabilities. Unlike more complex or expensive communication aids that may require specialized hardware or extensive setup, this system operates using a standard consumer-grade webcam and a simple computer setup, making it available to a broader range of users. Moreover, the use of Morse code allows the system to be both robust and universally applicable, as Morse code can be easily adapted to any language and is already familiar in many assistive communication contexts.

II. LITERATURE REVIEW

Eye blink detection serves as the foundation for developing communication systems aimed at individuals with disabilities. Early studies focused on blink detection primarily relied on specialized equipment such as infrared cameras and electrooculography (EOG) sensors, as seen in Jumb et al. [1] and Renuka and Devaraju [4]. While effective, these systems are often costly and impractical for daily use due to specialized hardware requirements. As an alternative, researchers explored more accessible methods using machine learning and image processing algorithms to detect blinks via standard cameras. Kazemi and Sullivan [8] pioneered a facial alignment method that uses an ensemble of regression trees for precise landmark localization, allowing for faster, real-time blink detection. Their method has been foundational for later developments in blink detection systems using conventional webcams.

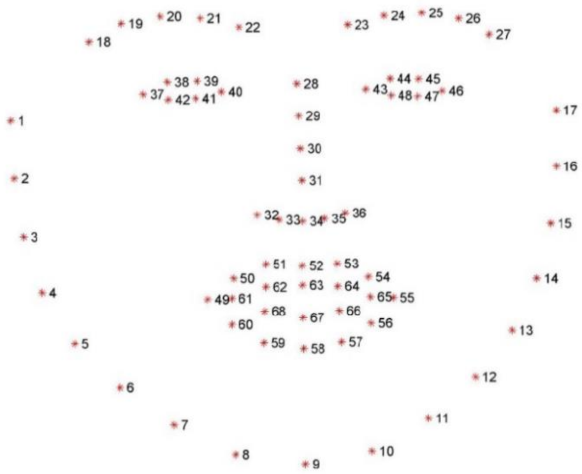


Fig. 1. Facial Landmark Detection

More recent work by Pauly and Sankar [10] introduced a novel blink detection method that combined Haar cascade classifiers and Histogram of Oriented Gradients (HOG) features, enhancing detection accuracy in varied lighting conditions. However, they noted limitations in robustness, as their system struggled with occlusions and variations in facial orientation. Furthermore, Kumar et al. [2] demonstrated that the Eye Aspect Ratio (EAR) calculation effectively distinguishes eye states without requiring specialized equipment, making it an affordable and accessible solution in assistive technology.

Morse code has been widely applied in assistive technologies for individuals with disabilities, as it only requires two types of input—dots and dashes—making it ideal for communication systems with minimal physical input. Kumar et al. [2] and Chen et al. [6] explored Morse code applications in assistive technologies, translating inputs from eye blinks or finger taps into Morse sequences that are subsequently decoded into text or speech. Chen et al. [6] designed an image-based Morse code text input system using finger gestures, demonstrating Morse code's versatility in adapting to various physical capabilities.

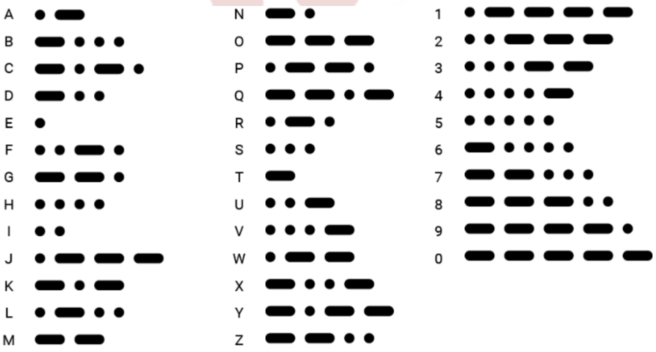


Fig. 2. Morse Code

Similarly, Srividhya et al. [9] implemented a Morse-based communication system for speech-impaired individuals, using eye blinks as input to generate synthetic speech. While effective, these systems are often hindered by limited customization and adaptability, making them unsuitable for users with unique blink patterns or specific environmental challenges.

In addition to communication, Morse code has been explored for secure authentication using eye blinks, particularly in settings that require non-invasive, contactless methods. Renuka and Devaraju [4] developed a secure Morse code authentication system using Haar cascade classifiers to detect eye blinks and translate them into coded input for authentication purposes. This system demonstrated Morse code's potential for secure, contactless entry methods, but it was also limited by its dependency on controlled lighting conditions and fixed camera angles, which affected accuracy. Ravi and Prashanth [5] extended this research by combining machine learning models with blink-based authentication, increasing reliability and security.

However, the reliance on fixed conditions limits the practical applicability of these systems. The Eye Blink-Based Morse Code Detection system in this project addresses these issues by adapting EAR thresholds based on user feedback and ambient conditions, enhancing both security and usability. By making blink detection more reliable across variable lighting and environments, this project aims to expand the usability of Morse code for both communication and secure entry purposes in diverse settings.

A. Limitation in Existing Systems

High Dependency on Expensive Hardware: Traditional blink detection systems often require specialized hardware such as infrared-based eye trackers or EOG sensors, which, while effective, can be prohibitively expensive. Jumb et al. [1] and Renuka and Devaraju [4] utilized such equipment in their studies, limiting their systems' accessibility for the general population. Many individuals with disabilities cannot afford these high-cost systems, highlighting the need for affordable alternatives. This project addresses this gap by employing readily available webcams and open-source software, making the system more accessible to a wider audience.

Insufficient Real-Time Feedback and Customization: A significant drawback in existing blink detection systems is the lack of real-time feedback, which is essential for ensuring that users can monitor and adjust their input accurately. Kumar et al. [2] and Chen et al. [6] found that systems without real-time feedback often left users unable to verify whether their blinks were accurately registered, resulting in communication errors. Additionally, many systems lack customizable options for blink sensitivity and interface settings, which reduces usability, especially for individuals with unique blink rates or specific comfort needs. This project integrates real-time feedback and customizable settings, addressing these limitations to ensure accurate and personalized communication.

Limited Adaptability to Environmental Changes: Many existing systems perform well in controlled environments but struggle in real-world conditions with fluctuating lighting, facial orientation, or partial occlusions. Pauly and Sankar [10] and Kazemi and Sullivan [8] both highlighted the impact of environmental factors on the reliability of blink detection. Systems reliant on static lighting or consistent head positioning are less practical for users in dynamic environments. By adapting EAR-based blink detection and offering adjustable sensitivity settings, this project aims to ensure stable performance across a range of conditions, making the system more resilient and versatile in real-world use.

III. METHODOLOGY

The Morse code detection system utilizing eye blinks employs a structured methodology divided into distinct phases: eye detection, Eye Aspect Ratio (EAR) calculation, blink detection, and Morse code translation.

A. Detecting Eyes

A critical component of this project is detecting the user's eyes accurately in real-time. To achieve high precision, a custom eye detection model is trained using dlib's shape predictor. This model is trained specifically on eye regions to ensure the accuracy of eye landmark detection. The model is trained on iBUG 300-W dataset, focusing on landmarks around the eyes. The training process involves creating an XML file of eye landmark annotations and training it with dlib's shape predictor tool. This custom shape predictor is designed to handle diverse eye shapes, orientations, and lighting conditions, making it adaptable for real-world use.

After training, the model is integrated into the system using dlib's "shape_predictor" function. This function locates specific landmarks around the eyes, generating an accurate contour of the eye region for each video frame captured by the webcam. These landmarks are then converted into numpy arrays used to pass the coordinates of the eye (0-5 for the right eye and 6-12 for the left eye). This eye detection phase is essential for the subsequent calculation of the Eye Aspect Ratio (EAR).

B. Calculating the Eye-Aspect-Ratio (EAR)

The Eye Aspect Ratio (EAR) is a key metric for detecting blinks by measuring the vertical and horizontal distances between eye landmarks. EAR is calculated based on six specific eye landmarks identified by the custom shape predictor model, with three points on the upper and lower eyelids and two on the eye corners.

The EAR formula is as follows:

$$\mathrm{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

Fig. 3. Eye Aspect Ratio Formula

where:

- P1 and P4 are the horizontal eye corner points,
- P2, P3, P5, and P6 are the points on the upper and lower eyelids.

This formula calculates the EAR as the average vertical distance between eyelid points divided by the horizontal distance between the eye corners. A lower EAR indicates the eye is closed, while a higher EAR suggests the eye is open. The EAR threshold is determined based on user-specific testing, distinguishing between short and long blinks needed for Morse code input.

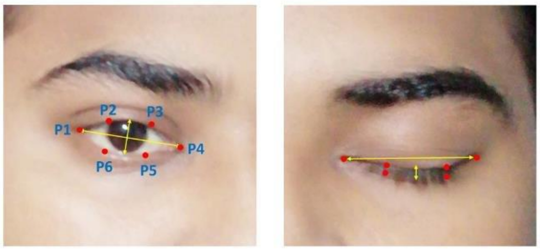


Fig. 4. EAR landmarks for open and closed eyes

C. Blink Detection and Morse Code Interpretation

Once EAR is calculated, the system monitors changes in EAR values across video frames to detect blinks.

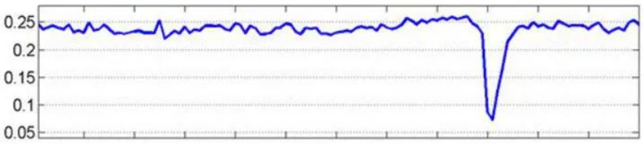


Fig. 5. EAR Threshold Graph

The EAR threshold graph is used to visualize how the Eye Aspect Ratio (EAR) changes over time, distinguishing between open and closed eye states. Typically, when the eye is open, the EAR remains above a certain threshold. As the eye begins to close, the EAR value decreases sharply, dropping below the threshold set for blink detection. By monitoring this threshold crossing, the system can accurately identify blink events. Short-duration drops below the threshold represent "dots," while longer durations indicate "dashes" for Morse code input. Adjusting this threshold based on individual variability enhances blink recognition accuracy across different users.

The system translates the sequence of dots and dashes into Morse code in real-time. Each letter or word pause is managed by specific timing rules, differentiating between individual letters and word separations, making it possible to construct complete sentences through simple blink patterns.

D. Converting Morse Code to Text

Detected blink sequences (dots and dashes) are converted into Morse code. This Morse code is then mapped to corresponding text characters using standard translation rules, ensuring accurate text output based on blink patterns. The translated text is displayed on a user interface, providing immediate feedback.

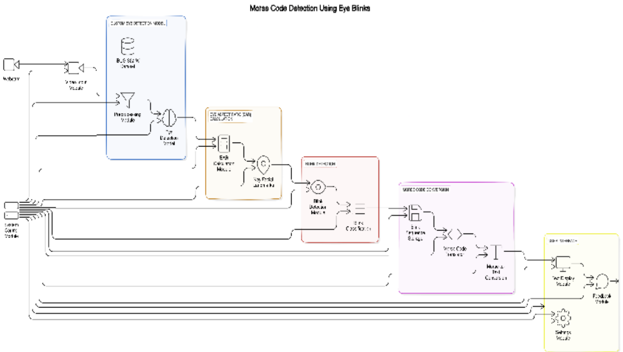


Fig. 6. Architecture Diagram

By using a customized eye detection model and EAR-based blink recognition, this system provides a robust and adaptable Morse code input method. The combination of real-time detection, adjustable thresholds, and immediate feedback makes the system effective for individuals with severe physical limitations, providing them a means of independent communication.

IV. RESULTS

The system's performance was evaluated based on key metrics including blink detection accuracy, Morse code translation accuracy, adaptability across different lighting conditions, and user satisfaction with customization options. These tests were conducted to ensure that the Eye Blink-Based Morse Code Detection system met the objectives of accessibility, reliability, and ease of use.

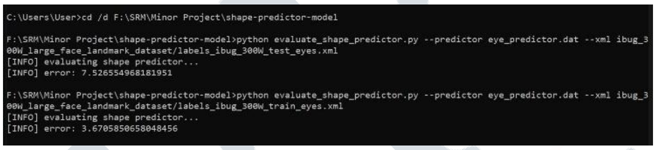
For accurate eye landmark detection, the system used a custom-trained dlib shape predictor model following the Rosebrock's method. The model was evaluated using Mean Absolute Error (MAE), which calculates the average pixel deviation between the predicted and actual landmark positions. MAE is given by the formula:

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^{n} | y_i - \hat{y}_i |$$

Fig. 7. Mean Absolute Error Formula

where 'n' is the total number of predictions, yi is the actual landmark position, and y^i is the predicted position. The MAE measures how close the predicted eye landmarks are to the actual landmarks, providing insight into model accuracy.

The custom model achieved an average training error of 3.67 pixels and a test error of 7.52 pixels. These low error values indicate that the model generalizes well and maintains high accuracy across different facial orientations and user conditions, as even small deviations can affect Eye Aspect Ratio (EAR) calculation and blink detection. The model's low MAE ensures precise eye landmark identification, which is essential for reliable blink detection and Morse code interpretation in real-time applications. This precision allows the system to accurately calculate EAR values, effectively distinguishing between blinks of varying durations necessary for Morse code input.



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C:\Users\User>cd /d F:\SRM\Minor Project\shape-predictor-model

F:\SRM\Minor Project\shape-predictor-model>python evaluate_shape_predictor.py --predictor eye_predictor.dat --xml ibug_3
00W_large_face_landmark_dataset/labels_ibug_300W_test_eyes.xml
[INFO] evaluating shape predictor...
[INFO] error: 7.526554968181951

F:\SRM\Minor Project\shape-predictor-model>python evaluate_shape_predictor.py --predictor eye_predictor.dat --xml ibug_3
00W_large_face_landmark_dataset/labels_ibug_300W_train_eyes.xml
[INFO] evaluating shape predictor...
[INFO] error: 3.6705850658048456
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Fig. 8. Train and Test Error of the model

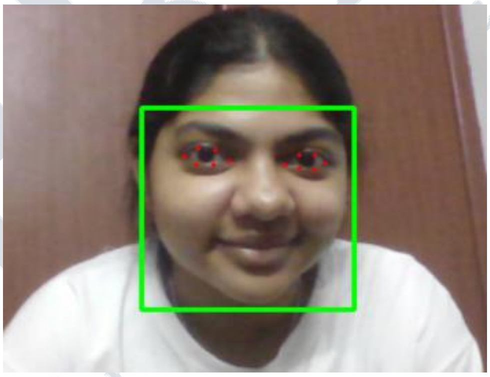


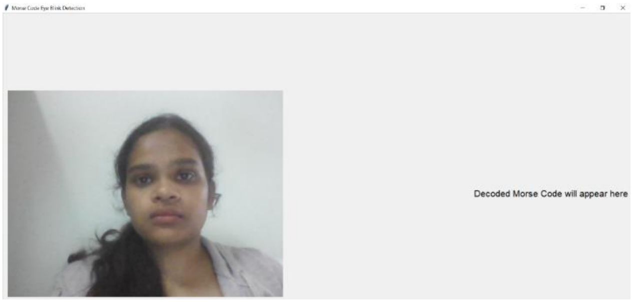
Fig. 9. Eye Detection

At each frame, the system effectively calculates eye-aspect ratio and successfully classifies deliberate blinks from unintentional blinks, and classifies the blinks into dot(.) or dash (-).

Fig. 10. EAR Calculation

The system's adaptability to various lighting conditions was critical to ensuring robust functionality in real-world settings. Tests conducted under bright, moderate, and low lighting demonstrated that the EAR threshold remained effective in distinguishing blinks with minimal impact on accuracy.

The user interface of the Eye Blink-Based Morse Code Detection system is designed to be intuitive and user-friendly, allowing individuals with minimal technical knowledge to easily navigate and use the system. It provides real-time feedback on detected blinks, displaying each Morse code symbol (dot or dash) as it is detected and showing the translated text in a clear, readable format. The interface layout is simple, with key features—such as Morse code display, text translation, and feedback—arranged for easy access and visibility.



Decoded Morse Code will appear here

Fig. 11. User Interface

V. DISCUSSION

The evaluation of the Eye Blink-Based Morse Code Detection system highlights its robust performance across several essential metrics. With high accuracy in blink detection and Morse code translation, the system meets its objectives of accessibility, reliability, and user-friendliness. The custom-trained dlib shape predictor model, built following Rosebrock's method, achieved a low Mean Absolute Error (MAE) of 3.67 pixels for training and 7.52 pixels for testing, ensuring precise eye landmark detection crucial for accurate Eye Aspect Ratio (EAR) calculations and reliable blink classification. This precision allows the system to effectively distinguish between intentional and unintentional blinks, translating them into Morse code dots and dashes. Adaptability tests show that the EAR threshold remains stable across different lighting conditions, enabling consistent performance. The user-friendly interface further enhances usability, providing real-time feedback that displays Morse code symbols and translated text in an organized, accessible format. Overall, the system demonstrates strong generalization and functionality, offering a practical communication tool for users with minimal technical knowledge and requiring minimal hardware.

VI. CONCLUSION

The Eye Blink-Based Morse Code Detection system provides a highly accessible and effective communication solution for individuals with severe physical impairments, enabling independent expression through simple eye blinks. Leveraging a custom-trained dlib shape predictor model and precise Eye Aspect Ratio (EAR) calculations, the system achieves reliable blink detection and Morse code translation. The low Mean Absolute Error (MAE) of the model underscores its accuracy in eye landmark detection, essential for distinguishing intentional blinks and maintaining consistent performance. Additionally, the system demonstrates robust adaptability across different lighting conditions, ensuring reliability in real-world environments. The user-friendly interface, with organized real-time feedback on Morse code symbols and text translation, enhances ease of use and promotes intuitive communication. Altogether, the system embodies a practical and efficient assistive tool, meeting the needs of diverse users and advancing inclusivity in assistive communication technology.

VII. FUTURE WORK

Future work on the Eye Blink-Based Morse Code Detection system could focus on enhancing customization and expanding compatibility to increase usability across diverse settings. Integrating advanced machine learning techniques, such as adaptive thresholding and personalized blink pattern recognition, could improve accuracy by tailoring the system to individual user needs and further minimizing detection errors. Additionally, optimizing the system for mobile devices and wearable platforms would make it more accessible and portable, allowing users to communicate on the go. Incorporating text-to-speech functionality could expand its versatility, providing audible feedback for real-time conversations. Finally, further testing with diverse user groups in varied environments would ensure robust performance, paving the way for a comprehensive and flexible communication tool that meets the needs of a broader population.

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