

Morse Companion: Speak With Ease

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Abstract— This paper introduces an approach to enhance communication for individuals with Amyotrophic Lateral Sclerosis (ALS) by utilizing infrared (IR) sensors to detect eye blinks and converting them into Morse code. The proposed system aims to provide an alternative means of communication by capitalizing on the natural ability of ALS patients to control their eye movements. By using IR sensors, the system can differentiate between short blinks (dots) and long blinks (dashes) based on the duration of the blink. Morse code, a widely recognized communication method, is then used to encode these blinks into meaningful messages. Short blinks are interpreted as dots (·) while long blinks are interpreted as dashes (–). These dots and dashes are subsequently translated into text characters following Morse code conventions. By converting blinks into text characters, the system offers an intuitive way for ALS patients to communicate, thereby improving accessibility and quality of life. This system also allows patients to efficiently express their immediate needs or discomfort using simple eye movements by choosing frequently used phrases. Additionally, the system incorporates text-to-audio conversion to enhance simplicity and accessibility. Experimental validation confirms the feasibility and effectiveness of the system, underscoring its potential as an assistive technology for individuals with ALS.

Index Terms—Amyotrophic Lateral Sclerosis · Eye blink detection · Infrared (IR) sensors · Morse code

I. INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS), colloquially known as Lou Gehrig's disease, is a debilitating neurodegenerative disorder characterized by the gradual deterioration of motor neurons in the brain and spinal cord. This degeneration results in a progressive loss of voluntary muscle control, impacting essential functions such as movement, speech, swallowing, and eventually, breathing. ALS patients often face an arduous journey marked by a devastating decline in physical function, ultimately leading to paralysis and, tragically, death within a few years of diagnosis.

One of the most significant challenges faced by ALS patients is the deterioration of communication abilities, often leading to difficulties in speaking and writing due to muscle weakness. In advanced stages, patients may experience locked-in syndrome, retaining cognitive function while becoming immobile except for controlling eye movements.

Utilizing eye blink detection systems with infrared sensors offers hope for ALS patients to communicate. Morsecode, with its concise encoding system of dots and dashes, complements eye blink detection technology well, facilitating clear message transmission even in challenging conditions. Our project integrates Morse code with eye blink detection to create a comprehensive communication system tailored for ALS patients, translating blinks into English text for easy understanding.

To enhance accessibility and efficiency, our system includes text-to-audio conversion. Additionally, it enables patients to swiftly convey their urgent needs or discomfort through basic eye movements, selecting commonly used phrases.

This multi-faceted approach represents a significant advancement in assistive technologies for ALS patients, empowering them to communicate more effectively and fostering meaningful connections with the world around them.

II. BACKGROUND

Various studies have been conducted to address the challenge of communicating with patients afflicted by ALS, a condition that gradually restricts the movement of their muscles. Given that eye movements remain the sole viable means of movement for these individuals, efforts have been concentrated on exploring this avenue of communication[8].

Researches revolving around feature extraction to extract relevant information from facial landmarks detected by the dlib module have proved to be crucial for accurate eye tracking and blink detection. [13]. Various systems utilize advanced techniques in face/eye detection, eye blink conversion to Morse code, and text-to-speech synthesis to track eyelid movements and convert them into understandable text and speech for communication purposes. [16].

Previous researches have explored Morse Code translation from eye blinks using tree-based machine learning algorithms and Open CV[1]. Studies have also been conducted to implement deep learning algorithms for eye blink detection. [9]. By detecting and interpreting blink patterns, this system allows voluntary long blinks to trigger actions such as mouse clicks, while filtering out involuntary short blinks[1]. Techniques have been devised that combine facial landmarks detection, signal processing with Savitzky-Golay filtering, and false blink detection mechanisms to achieve robust and accurate eye blink detection, setting it apart from traditional methods in the field[3]. A more recent research proposed a system called iMouse that helps patients with neuro-locomotor disabilities, such as ALS, communicate by utilizing simplified Morse code and eyeblink detection technology. The iMouse system incorporates quadrant navigation on a virtual keyboard, where the user can select an area containing the desired alphabet through eye movements. By using only seven simplified eyeblink combinations representing the corresponding letters in the selected area, the system enables patients to input text with increased speed and accuracy[4].

Researches focusing on developing a system that allows paralyzed individuals to generate Morse code through their eye blinks, which is then converted into text using an Arduino microcontroller have been going on for some time now to enable users to communicate with caregivers, loved ones, and others, providing them with a means to express themselves and engage in conversations using innovative eye-tracking technology[6]. Researchers have developed a Wireless Home Assistive System (WHAS) for severely disabled individuals that includes various components such as assistive input accessories, a Morse code translator (MCT), and a human-machine interface to

facilitate communication and control of devices for individuals with severe disabilities. The WHAS utilizes different types of assistive input accessories, including mechanical switches, sensing switches, and bio-signal switches, to cater to the diverse physical needs of users[7]. Yet another unique system developed for communication with Motor Neuron Disease patients is WiMorse which leverages finger movement for text input using ambient WiFi signals. WiMorse achieves over 95 percentage recognition accuracy for finger-generated Morse code, ensuring reliable communication for MND patients despite their physical limitations. [14].

Another innovative system that utilizes Morse code as an adapted access communication tool for physically disabled individuals is the use of Field Programmable Gate Array (FPGA) in conjunction with Morse code, GSM module (SIM900A), and LCD screen to create a wireless communication. [15]. We explored the background of using infrared sensor for detection eyeblink detection by referring a new design for an infrared (IR) eyeblink detector that is used to measure the eyeblink response in rabbits during classical conditioning experiments. [10]. There has been extensive research in conversion of eye-blink signals into speech. One such system uses Morse-coded signals generated by voluntary eye-blinks and a single-channel wireless NeuroSky MindWave Mobile device to convert eye-blink to speech conversion by using Dynamic Time Warping (DTW) algorithm[11].

III. PROPOSED SYSTEM

Individuals with motor neuron diseases, particularly ALS, face significant communication challenges that must be addressed urgently. The progressive loss of voluntary muscle control, including speech, highlights the need for advanced technologies to help these individuals communicate independently. Relying on external assistance for verbal expression hinders autonomy and self-expression. It is crucial to innovate solutions that allow effective communication without constant reliance on others, ultimately improving the quality of life for those dealing with motor neuron diseases. We focused on creating an assistive device that utilizes eye blink detection to enable communication through Morse code, offering a promising solution to enhance their ability to express

themselves.

Introducing the Morse Companion, a revolutionary IoT-based wearable device designed to empower individuals affected by motor neuron diseases like ALS. By harnessing the power of highly efficient IR sensors, the Morse Companion accurately detects and tracks eye blinks, translating them into Morse code—a timeless communication method. With an ESP32 microcontroller categorizing eye blinks and sending data to a Firebase database, the Morse Companion ensures seamless data management and accessibility. Leveraging this database, our companion application effortlessly retrieves the encoded messages, converting them into both text and audio outputs. This dual approach guarantees accessibility for users with varying needs and preferences, ensuring that communication remains efficient and inclusive. With its user-friendly design, affordability, and portability, this device proves to be incredibly valuable for individuals who are paralyzed and unable to communicate orally or through sign language. Furthermore, the system minimizes the need for external assistance.

A. Methodology

Efforts to aid communication for ALS patients often focus on eye movements due to their limited motor abilities. While camera-based letter selection methods seem feasible, they can be time-consuming and less accurate for longer sentences, especially in low-light conditions. To address these challenges, we propose an IoT-based approach that captures and computes eye blink duration, potentially offering a more efficient communication method.

B. System Architecture

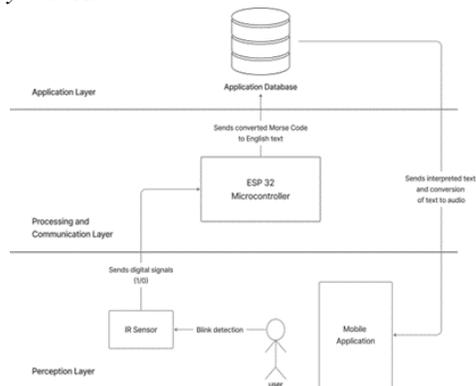


Fig. 1. System Architecture

C. Hardware Setup

The hardware was setup utilizing a commonplace spectacles and integrating it with a TCRT5000 IR sensor, connected to an ESP32 WROOM 32 microcontroller unit. The TCRT5000 IR sensor, securely affixed onto the spectacle frame, was positioned in close proximity to one of the lenses to effectively detect eye blinks. Utilizing female-to-female jumper wires, the TCRT5000 IR sensor was linked to the ESP32, with the VCC pin connected to a 3.3V pin, the GND pin to a ground pin, and the OUT pin to a GPIO pin, such as GPIO pin 2, for digital signal transmission. Powering the ESP32 was facilitated through a micro USB cable connection. This hardware configuration allowed for seamless integration with the ESP32’s processing capabilities, enabling efficient communication interpretation solely through eye blinks, thus offering a novel communication solution for ALS patients.

D. Eye Blink Classification Using ESP32

For categorizing the eye blinks, we developed a robust system within the ESP32 microcontroller aimed at accurately classifying detected eye blinks. Leveraging the real-time digital output from the TCRT5000 IR sensor, our firmware was engineered to implement sophisticated algorithms capable of distinguishing between normal blinks, categorized as those lasting less than 300 milliseconds and discarded, short blinks, ranging between 1000 milliseconds to 1500 milliseconds and interpreted as dots (.), and long blinks, which come within the range of 2000 of 2800 milliseconds and designated as dashes (-). This process involved the utilization of predefined duration thresholds to precisely differentiate each type of blink. By harnessing the computational capabilities of the ESP32, we ensured efficient processing of incoming sensor data, facilitating timely and accurate classification of blink types. Our meticulous approach to algorithm refinement aimed to minimize instances of false positives and negatives, thereby augmenting the reliability and practicality of the eye blink communication system.



Fig. 2. Eye blink classification algorithm

- 1) **Start Sequence:** Within the system, a predefined start sequence, denoted as "-.-.", serves as an initiation protocol. Upon successful recognition of this sequence, designated by the ESP32 microcontroller through analysis of user-inputted Morse code, the system prompts the display of the greeting "Hello." Subsequently, users are prompted to select their preferred mode of interaction with the device. This selection encompasses two distinct options: "phrases (.)" or "letters(-)." This pivotal decision determines the subsequent operation mode, shaping the functionality of the communication device to cater to the user's specific requirements.
- 2) **Phrase Mode:** After inputting the start sequence, we devised a selection mechanism where the input of a dot signifies the selection of the phrase mode. Within this mode, we curated a collection of frequently used phrases, each represented by a unique Morse code sequence (each of length 3) consisting of a combination of dots and dashes. This compilation totals eight distinct phrases, ensuring a comprehensive range of commonly required expressions. Upon inputting the Morse code corresponding to the desired phrase and awaiting the predefined timeout duration of 5000 milliseconds, a signal is triggered to initiate the translation process. Subsequently, the translated phrase is seamlessly displayed on the application screen, facilitating effective communication for ALS patients with ease and efficiency.

Phrases	Morse Code Sequence
I feel pain	••••
I need medicine	•••-
I am hungry	•-••
I am thirsty	-•••
I need help	•-•-
I need to use the washroom	-••-
I feel cold	-•-•
I feel hot	-•-•

Fig. 3. Phrases with its corresponding Morse Code Sequence

- 3) **Letter Mode:** Following the activation of the start sequence, if the user inputs a dash, the system transitions into letter mode, facilitating personalized communication through Morse code input. Within this mode, users have the freedom to input Morse code sequences corresponding to any letters as defined by the International Morse code System. Upon entering the desired Morse code sequence for a letter and waiting for the predefined timeout duration of 5000 milliseconds, a signal prompts the translation of the Morse code into its corresponding letter. The translated letter is then appended to a sentence string, allowing users to construct coherent messages sequentially. Users may input multiple letters, with each translation adding to the evolving sentence string displayed on the application screen. Additionally, the system recognizes the input of five consecutive dots (.....), signifying a space between words, with a corresponding space added to the sentence string. To indicate the completion of a sentence, users input five consecutive dashes (-----), prompting the system to return to the mode selection prompt. This intuitive design empowers users to express themselves freely catering to their unique needs and preferences.

A	•-•-
B	-•••
C	-•-•
D	-••-
E	••••
F	••-•
G	•••-
H	••-•
I	••••
J	•-••
K	-•••
L	•-•-
M	-•••
N	-••-
O	-••-
P	•-•-
Q	-•-•
R	•-•-
S	•••-
T	•••-
U	•••-
V	•••-
W	•-•-
X	•••-
Y	•••-
Z	•••-

Fig. 4. International Morse Code for English Alphabets

E. Text Display via Flutter Application

A Flutter application facilitates the seamless display of translated text received from the ESP32 microcontroller. Upon launching, the app and the ESP32 device establishes a connection with the Firebase realtime database. Following the translation of Morse code to English within the ESP32, the translated text is sent to the database where the application listens to it and whenever there is a change in the database, the application retrieves it and displays it on the screen. With a user-friendly interface, the app provides a straightforward and intuitive experience, ensuring effortless communication for users. In addition to displaying translated text, the Flutter application utilizes specific Flutter packages, such as the "flutter_tts" package, to enhance user experience further. Through the integration of these packages, the application seamlessly converts the displayed text into audio, providing an additional mode of communication for users. This feature significantly enhances ease of use, by offering an auditory representation of the communicated messages.

F. Phrase Prediction using Machine Learning

A feedforward neural network optimized for multi-class classification problems is the implemented model. TensorFlow's Keras API, a high-level neural network API that facilitates quick and simple prototyping, is used to implement it. Three dense layers, each with 64 units, plus ReLU activation functions for the hidden layers make up the neural network architecture. The output layer generates probabilities for each of the eight potential classes using a softmax activation function. The Adam optimizer and sparse categorical crossentropy loss function are used to train the model. Ten percent of the training data is put aside for testing and is divided into training and testing sets. In order to increase its accuracy on the training set of data, the model learns to minimize the loss function during training by modifying its parameters. The user enters three blinks to create a Morse code sequence that corresponds to a phrase when the phrase mode is selected. The database receives the blink durations. After the values are read by the application, the model analyzes them and forecasts the output class. Each of the eight output classes represents a different phrase. Metrics like the accuracy and confusion matrix are used to evaluate the

model's performance and determine how well it performs in identifying data that has not yet been seen.

IV. RESULTS AND OBSERVATIONS

Our paper introduces an innovative solution to facilitate communication for individuals with Amyotrophic Lateral Sclerosis (ALS) by leveraging infrared (IR) sensors to detect eye blinks and translating them into Morse code. With an overall test accuracy of 92.5%, our machine learning model demonstrates exceptional performance in accurately classifying phrases, promising enhanced accessibility and quality of life for ALS patients through intuitive eye-controlled communication.

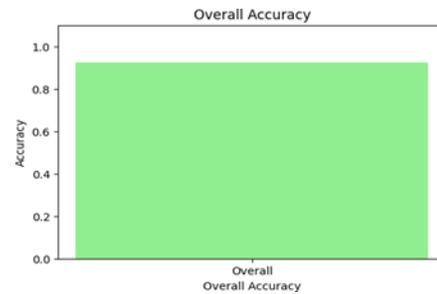


Fig. 5. Graph showing the overall accuracy of the model

The overall accuracy graph presents a concise summary of the model's performance across all classes. It showcases the percentage of correctly predicted instances across the entire dataset, offering a single measure of the model's effectiveness. In this case, with an overall accuracy of 92.5%, it indicates a strong performance in accurately classifying the input data into their respective classes.

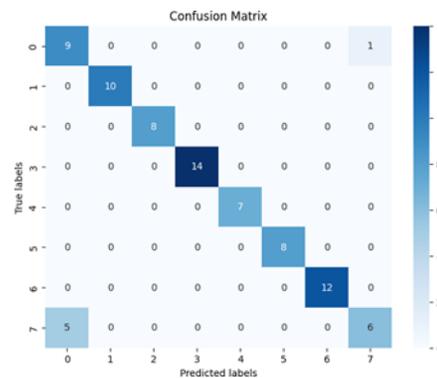


Fig. 6. Confusion Matrix

The model’s performance in classifying each class label is shown in the confusion matrix. The genuine class labels are represented by each row, and the predicted class labels are represented by each column. For instance, in the first row, the model misclassified one occurrence as class 8 while correctly classifying nine examples as class 1. In the same way, every instance in the second row that belonged to class 2 was appropriately classified. The number of successfully categorized examples for each class is represented by the diagonal elements, and misclassifications are represented by the off-diagonal elements. Three input features, one output variable, and eight different classes make up the dataset. The test accuracy of 92.5% that was provided shows that the model performs well across several classes and can correctly categorize data that has not yet been seen.

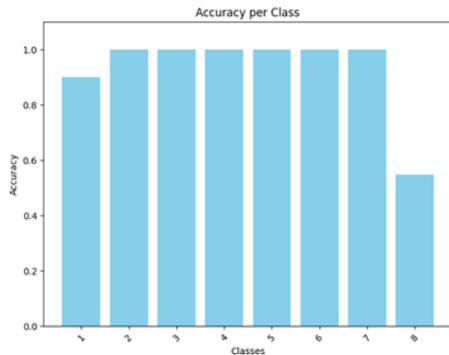


Fig. 7. Graph showing accuracy per class

The accuracy per class graph illustrates how well the model performs for each individual class. Each bar represents a class label, with its height indicating the accuracy of classifying instances belonging to that class. It provides a quick overview of the model’s performance across different classes, highlighting areas of strength and potential areas for improvement.

V. CONCLUSION AND FUTURE SCOPE

The Morse Companion, an innovative communication aid, is revolutionizing how individuals with conditions like ALS and speech impairments interact. Utilizing advanced eye-blink recognition technology, users can now communicate through intentional eye movements, facilitated by Morse code translation—a universally recognized method employing combinations of dots and dashes.

Looking ahead, the Morse Companion aims to enhance user experience and communication efficiency. It will introduce predictive text capabilities, anticipating phrases based on Morse code input, thus accelerating communication speed and enhancing user-friendliness. Furthermore, seamless integration with auditory assistive devices such as hearing aids or cochlear implants ensures accessibility for users already utilizing such technology.

Moreover, envisioning the future, the Morse Companion seeks to integrate with conventional spectacles, integrating the system discreetly into everyday eyewear. This portable IoT device not only addresses current communication challenges but also sets the stage for ongoing advancements, fostering inclusivity and accessibility. By empowering individuals with speech difficulties to communicate effortlessly and effectively, it aspires to create a more inclusive and accessible environment for all.

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