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Flex Sensor and Machine Learning-Based Mute Communication System

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Abstract

Individuals facing speech impairments encounter significant communication challenges. To address this, we have developed a groundbreaking system that seamlessly translates custom hand gestures into written text and spoken language. Our system combines flex sensors and state-of-the-art machine learning techniques, empowering individuals with speech impairments to express themselves effectively and improve their overall communication experience. By connecting flex sensors to an Arduino board and utilizing MATLAB for robust data collection, analysis, and processing, we achieve a highly accurate gesture recognition system. Through meticulous steps of data labeling, rigorous training of a machine learning model, and thorough accuracy evaluations, our system recognizes a wide range of gestures, including numbers 0-9, letters A-Z, and 10 Kannada language gestures conveying meaningful phrases. The hand gesture recognition system achieved notable performance with an accuracy of 83.5%, precision of 88.6%, recall of 95.1%, and F1 Score of 91.7%.

Key Words: speech impairments, hand gestures, gesture recognition, flex sensors, machine learning, communication accessibility

1.INTRODUCTION

Communication plays a vital role in human interaction, facilitating the expression of thoughts, emotions, and ideas. However, individuals with speech impairments or muteness encounter significant challenges in verbal communication. Therefore, there is a need for innovative approaches to address these limitations and enable effective communication for individuals with speech impairments.

The objective of this research is to develop a hand gesture recognition system that utilizes machine learning techniques to translate customized hand gestures into spoken language. By analyzing and interpreting the gestures and movements made by the user's hand, the system aims to provide real-time conversion into text or spoken letters/phrases, facilitating effective communication for individuals with speech impairments. This research addresses the problem of limited communication options faced by individuals with speech impairments, enabling them to express themselves more efficiently and fostering inclusivity.

A comprehensive literature survey has been conducted to understand the existing research and advancements in sign language recognition and gesture-based communication systems. Several papers have explored various approaches to sign language recognition. For instance, [1] proposed a machine learning-based system using a Leap Motion Device and Convolutional Neural Networks (CNNs) to detect hand gestures from multiple sign languages. Similarly, [2] focused on a real-time two-way sign language translator using OpenCV and CNNs. Other studies [3-4] investigated methods for training sign language models using One-Shot learning and computer vision techniques.

Moreover, research efforts [5-6] have explored real-time sign language recognition models using OpenCV, Keras, and deep neural networks. Several papers [7-10] have contributed to efficient gesture identification, transfer learning for Indian Sign Language (ISL) gestures, and Indo-Russian sign gesture recognition. Additionally, works [11-15] have proposed approaches using multiple feature extraction methods, desktop applications, flex sensors, and computer vision techniques for sign language recognition.

The proposed approach for this research involves a calibration process to establish a mapping between resistance values and bend angles of flex sensors. Sensor data is captured from flex sensors connected to an Arduino board, and feature extraction techniques are

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applied to extract meaningful information from the data. A hand gesture recognition model has been trained using the Ensemble Bagged Trees machine learning algorithm. The Ensemble Bagged Trees algorithm is well-suited for hand gesture recognition due to its ability to accurately capture the nuances and variations in gestures. By leveraging multiple decision tree models, it effectively models the intricate patterns present in the data. Additionally, the algorithm's implementation of Bagging mitigates overfitting, improving the model's generalization performance. This makes Ensemble Bagged Trees a robust choice for accurate gesture recognition, aligning with the calibration process employed in this research.

The innovative aspect lies in the integration of machine learning techniques, flex sensors, and real-time recognition to enable effective communication through customized hand gestures.

2. PROPOSED SOLUTION

To facilitate data collection and processing, the 5 Flex sensors are seamlessly connected to an Arduino board using wires and a breadboard, forming an essential component of the system setup. A code is developed in the Arduino IDE to collect data from the flex sensors and transmit it to the computer through USB serial communication. Subsequently, MATLAB code is written to collect data from the Arduino board. The collected data is then labeled according to the desired hand gestures. The labeled data is split into training and test sets, with the training set utilized to train a machine learning model, selected through the classification learner tool. The trained model is evaluated for accuracy using the test set. The key focus of this project is to enable the translation of customized sign language gestures into both English characters and Kannada phrases. By integrating this translation capability within the hand gesture recognition system, the aim is to enhance communication and accessibility for individuals using sign language, fostering inclusivity and bridging language barriers.

3. IMPLEMENTATION

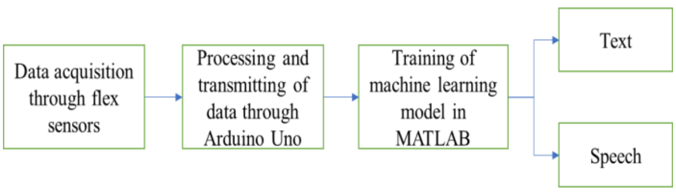


Fig. 3.1: Project flow

We present an experimental approach to develop a robust hand gesture recognition system using Arduino, Flex sensors, and Machine Learning. The research procedure involves calibrating the Flex sensors by collecting resistance values in both flat and fully bent positions, and creating calibration constants using code written in the Arduino IDE. Sensor data is then captured from participants performing hand gestures using the calibrated Flex sensors. Statistical features, such as mean, standard deviation, are extracted from the captured data to capture relevant finger movement information. A classification algorithm, Ensemble Bagged trees, which has achieved a training accuracy of 99.7%, is employed to train the recognition model using the extracted features, and the performance of the model is evaluated.

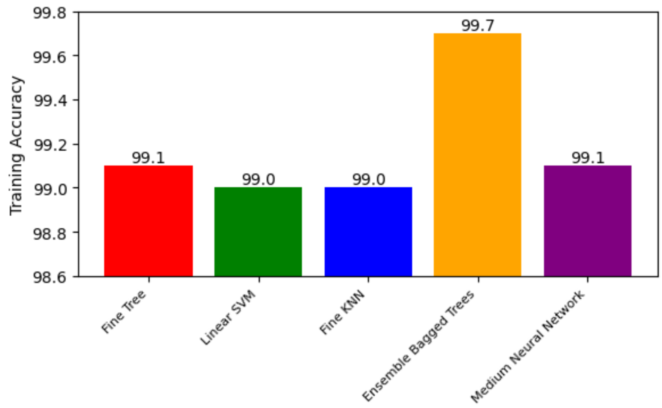


Fig. 3.2: Training accuracy of ML algorithms

To achieve real-time recognition, the system continuously reads sensor data from the Arduino and utilizes the pre-trained model to predict hand gestures. Validation of the system is conducted using real-time data, and the performance of the system is thoroughly assessed. The proposed methodology ensures accurate calibration of the Flex sensors, precise data capture from the Arduino, informative feature extraction, robust training of the machine learning model, and rigorous validation of the hand gesture recognition system.

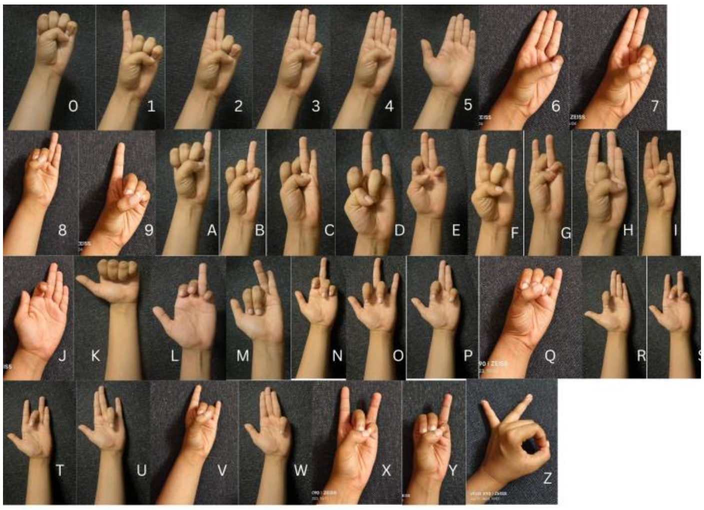


Fig. 3.3. Customized Sign Language (0-9, A-Z)

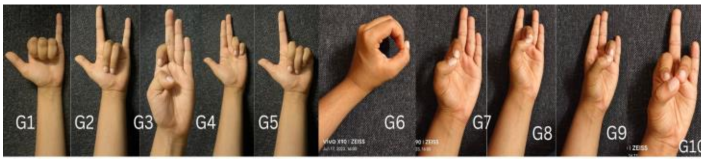


Fig. 3.4: Customized Sign Language for Kannada phrases

G1: nimma vayasu yestu	G6 : samaya estu agide
G2: heg iddira	G7: punaha helthira
G3: nimma hesaru enu	G8: kannada gottha nimmage
G4: sahaya bekagide	G9: elli irthira
G5: shouchalaya ellide	G10: dhanyavadagalu

Fig. 3.5: G1-G10 Kannada gestures

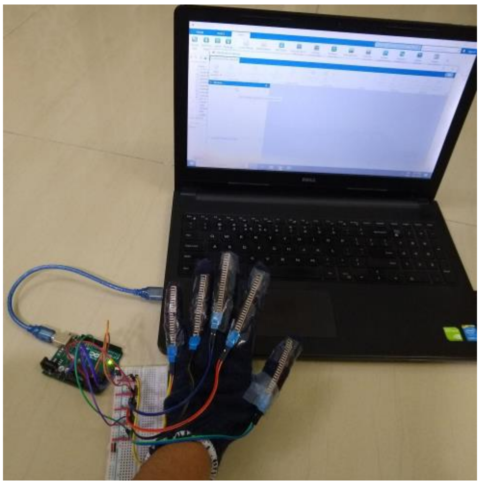


Fig. 3.6: Project Setup

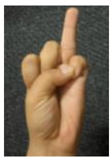
4. RESULTS

The Ensemble Bagged Trees algorithm was employed to train a machine learning model for the recognition of numbers (0-9), alphabets (A-Z), and 10 Kannada phrases. The model's performance on unseen data was assessed, and the obtained results are presented in a tabular format as shown in Table 4.1.

Accuracy	Precision	Recall	F1 Score
83.5%	88.6%	95.1%	91.7%

Table 4.1: Results

Table 4.2 presents an inclusive depiction of gesture information for a subset of gestures. The table includes their labels, corresponding images, flex sensor bend angles, and a qualitative assessment of the prediction accuracy for each gesture.

Label of gesture	Gesture	Bend angles as obtained by bending the flex sensors attached to the glove (Starting from Little,Ring,Middle,Index,Thumb)	Correct Prediction
0		154 82 75 93 92	Yes
1		127 68 71 2 70	Yes
2		100 64 9 2 55	Yes
A		0 85 148 126 75	No
B		247 5 111 106 53	Yes
G1(nimma vayasu yestu)		1 57 64 59 0	Yes
G2(heg iddira)		3 52 69 3 2	Yes

G3(nimma hesaru enu)		4 3 0 88 63	No

Table 4.2: Gesture Information

5. CONCLUSION

In conclusion, our innovative system utilizing machine learning to translate custom hand gestures into spoken language offers a powerful solution for individuals with speech impairments. By connecting flex sensors to an Arduino board and using MATLAB for data analysis, we have developed a robust gesture recognition system.This system allows individuals with speech impairments to express themselves effectively and communicate more easily by translating gestures into letters and phrases. It opens up new possibilities for improved social interactions, participation, and integration in various settings.Our solution fosters inclusivity, empowering individuals to overcome communication barriers and engage more actively in personal and professional environments.

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