



Hand Talk Assistive Technology For Deaf And Hard-Of-Hearing People: A Smart Communication Aid For The Hearing And Speech Impaired

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Abstract:

Communication barriers faced by the hearing and speech impaired can be reduced with assistive technologies. This project proposes a low-cost, real-time sign language recognition system using flex sensors and the K-Nearest Neighbors (KNN) algorithm. The system captures finger movements via flex sensors, converts the gestures into text, and uses a text-to-speech module to vocalize the interpreted word. The use of machine learning ensures improved accuracy and adaptability. This approach enables effective communication for those with speech or hearing difficulties and holds the potential for further enhancements in accessibility technology.

Index Terms — Sign Language, Flex Sensors, KNN Algorithm, Arduino Uno, Text-to-Speech, MIT App, Assistive Technology.

1. INTRODUCTION

Sign language is a vital mode of communication for individuals with hearing or speech impairments. However, many people outside the community are unfamiliar with it, creating a communication gap. This project addresses this issue by developing a smart wearable glove that can detect hand gestures and convert them into audio and text output. This system aims to eliminate the dependency on human interpreters and provide an automated, easy-to-use communication channel.

The glove is embedded with flex sensors that detect the bending of fingers, which are critical in identifying different sign gestures. An Arduino Uno microcontroller processes the sensor data and communicates via Bluetooth with a PC or smartphone. The gestures are recognized using a machine learning algorithm (KNN), and the recognized text is converted into voice output using text-to-speech technology. This project thus contributes toward accessible technology for inclusive communication.

2. BACKGROUND

Traditional assistive tools for the deaf and hard-of-hearing, such as sign language books or interpreters, are not always readily available. Existing electronic systems either require vision-based input (camera and image processing) or provide limited gesture recognition due to fixed threshold-based classification methods. Vision-based systems pose privacy concerns and require high processing power.

In contrast, sensor-based gloves using flex sensors offer a low-cost, non-intrusive, and accurate alternative for gesture detection. While prior research has used flex sensors for capturing hand motion, most systems lacked machine learning integration or real-time audio feedback. This project improves upon existing methods by applying KNN—a simple yet powerful classification algorithm—along with voice output via Bluetooth-connected mobile phones.

3. METHODOLOGY

The methodology of the proposed sign language recognition system is structured into three major stages: data collection, algorithm development, and system implementation. Each stage plays a vital role in building an accurate and real-time communication solution for the hearing and speech impaired.

5.1 Data Collection

Gesture data was collected using a smart glove embedded with three flex sensors, each placed on different fingers. These sensors detect finger bending by producing varying resistance values, which are converted to analog voltage signals. An Arduino Uno microcontroller reads these signals and transmits them to a PC or mobile device via the HC-05 Bluetooth module. For each gesture (e.g., “Hello”, “Yes”, “Stop”), multiple samples were recorded and labeled, forming a dataset in CSV format. This dataset forms the input for the machine learning model.

Flex 1	Flex 2	Flex 3	Gesture Label
430	650	390	Hello
500	670	420	Thank You
470	690	350	Yes
412	640	398	No
550	660	400	Stop
520	625	410	I Need Help
520	620	420	I Need Water

Table 1: Sample Flex Sensor Dataset for Gesture Recognition

5.2 K-Nearest Neighbors (KNN) Algorithm

The K-Nearest Neighbors (KNN) algorithm was used to classify gestures based on the collected sensor data. It is a supervised machine learning technique that assigns the class label of the majority among the k-nearest neighbors. In this system, k=3 was chosen to balance accuracy and noise tolerance. The Euclidean distance between the new gesture input and each data point in the training dataset was calculated using the formula:

$$ED = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2]}$$

After sorting all distances, the top three closest samples were selected, and the most frequent label among them was assigned as the prediction.

K-Nearest Neighbors (KNN) Algorithm for Sign Language Gesture Recognition

Step 1: Import gesture data recorded from flex sensors (e.g., Flex1, Flex2, Flex3) in CSV format.

Step 2: Predefine the number of neighbors k to be used for classification (e.g., k = 3).

Step 3: For each test gesture input, calculate the Euclidean Distance (ED) between the test sample and each sample in the training dataset using the relation:

$$ED = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2]}$$

Step 4: Sort all training samples based on their ED values in ascending order.

Step 5: Select the top k nearest neighbors (minimum distance samples) from the sorted list.

Step 6: Count the number of occurrences for each gesture label among the k neighbors.

Step 7: Assign the label with the highest frequency as the predicted gesture for the test input.

Step 8: Display the predicted gesture on LCD or send it via Bluetooth to the MIT app for text-to-speech output.

5.3 System Implementation

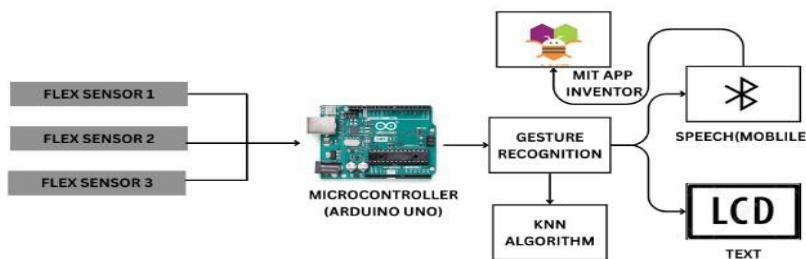


Figure 1: Block Diagram of Sign Language to Speech System

The Arduino Uno is programmed to continuously read the analog values from the three flex sensors and transmit them through Bluetooth. On the receiver side, a Python program receives the data, runs the KNN model, and outputs the predicted gesture label. This label is sent to:

A 16x2 LCD Display connected to the Arduino for real-time visual feedback.

An MIT App Inventor mobile application that receives the label via Bluetooth and uses the phone's built-in text-to-speech engine to provide audio feedback. This dual-output design ensures that the system is accessible in both quiet and noisy environments Implementation.

IV. RESULTS AND DISCUSSION

The system was tested with 3 flex sensors and trained on a dataset of static hand gestures. The KNN algorithm (with $k=3$) was trained and tested on manually collected samples in CSV format. After multiple runs, the classifier consistently achieved accuracy above 90%, indicating reliable gesture recognition.

Key Results:

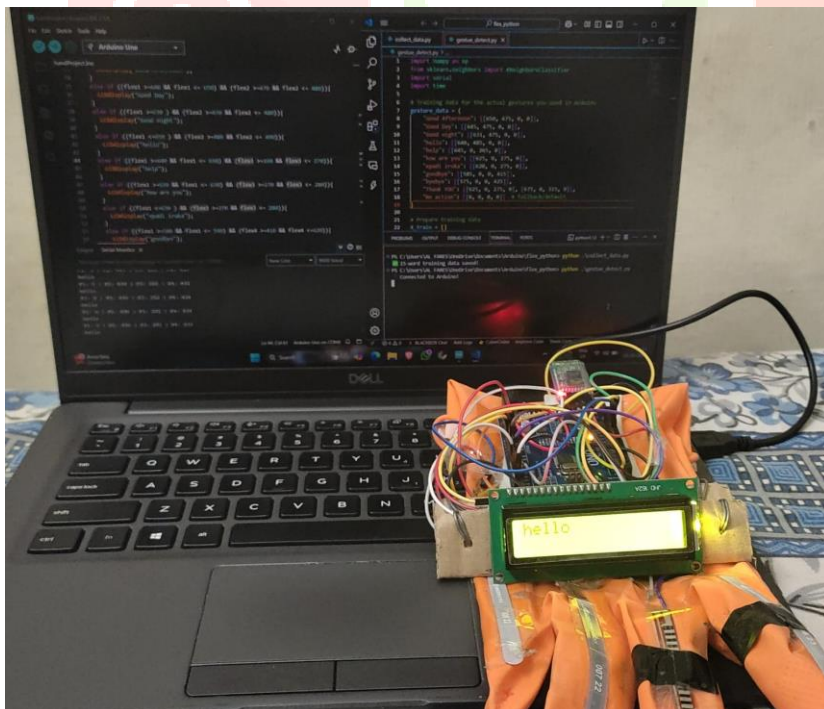
Average KNN accuracy: 93.2%

Bluetooth transmission latency: <1 second

MIT App speech delay: ~1.5 seconds

LCD updates in real time with negligible lag

This shows the system can be deployed for practical usage with minimal delay and sufficient accuracy for basic communication needs. Users reported that the audio output improved accessibility significantly, especially when communicating with people unfamiliar with sign language.



V. CONCLUSION

The proposed sign language recognition system effectively translates gestures into both text and speech using a simple sensor-based glove and a machine learning algorithm. The project enhances accessibility for the hearing and speech impaired, offering real-time translation and audio support. Future work can involve expanding the gesture dataset, improving accuracy with more advanced algorithms, and integrating Bluetooth or IoT features for mobile compatibility.

VI. REFERENCES

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