Sensor Based Hand Gesture Recognition System for English Alphabets used in Sign Language of Deaf-Mute People

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***Abstract*—Hand gesture and sign language are significant ways of communication for deaf-mute people. It puts a barrier in comprehension of a conversation between a mute person and a normal person, because a normal person does not understand the sign language. In this paper we developed a sensor based device which deciphers this sign language of hand gesture for English alphabets. We propose that if this wearable device, which is a hand glove, is put on by a mute person, the device would recognize the 26 letters almost accurately. We discuss the challenges and future potential of this device so that it would completely be able to facilitate communication of such class of people. Hand gesture recognition is also a challenging problem of the human computer interface area.**

Keywords—Hand gesture recognition, Sign language recognition, Human computer interface, Accelerometer, Sensors, Sensing based device, Flex Sensor, Gyroscope.

I. Introduction

Communication is an essential and natural need of human beings. Verbal communication is the most versatile and commonly used of all ways of communication. But there are people who cannot speak. It becomes too difficult for such differently abled people to communicate with the rest of the world of people who could verbally converse. Mute people converse in sign language. This sign language has been developed perfectly over time in almost all languages. But the normal people are not trained in this sign language and that poses a serious communication barrier between a deaf-mute person and the rest. Wikipedia [1] estimates that, world has around 40 million deaf people who can't speak too.

Sign Language is used in various media such as in news channels for deaf-mute communities. Scuba divers also learn the sign language to communicate inside the water. Sign language is practiced by armed forces, too, for sharing encrypted messages. There are many different kind of sign languages, such as: American, British, Japanese, Indian Sign Languages etc. Interpretation of sign language through computer has been a challenging problem of human computer interface (HCI) and brain computing as well.

Many projects and solutions have been reported in the literature to decipher sign language in textual or verbal form. Among them, Cornell University's group's work on Sign Language Translation, called "The Sound of Signing", demonstrates it with an exhaustive electronic hand glove [2]. They explained their method through a video also [3]. Their developed system uses flex sensors, contact sensors, and accelerometers to recognize motion of the fingers and thereby identifies letters of American Sign Language (ASL). A survey paper of 3D hand gesture recognition methods [4] concludes that though image processing based methods are effective and precise, these are complex systems as these require lot of computational power. Another work on 3D hand gesture recognition [5] uses 2 cameras for hand motion sensing and recognizes the gestures made by thumb and index finger only. In a recent work on handwriting recognition [6] the authors have embedded sensors on a pen that read the motion of the pen and accordingly generates the raw data. The raw data then was smoothened using Kalman filter followed by recognition of English alphabets. Recently a mobile video camera based feature extraction is also reported [7] which uses artificial neural network.

Most of these systems are developed keeping HCI in mind or using algorithm of 3D motion sensing. We did not find any attempt be made keeping the problem faced by deaf-mute people so that they could communicate with normal persons. In this paper we propose a system in that direction.

II. Proposed System

Our proposed system implements ASL's standard hand gestures based sign language used by mute people. Another requirement we take particular care of is that the system should be in form of a wearable device which has its own data collection module, mapping that data with the corresponding sign and then converting that sign into the alphabet – all in one. We did not use any separate processing unit or bulky CPU which runs a Matlab programme to do the job. Our complete system is wrapped in one customized device that a mute person can put on his hand.

Basically it is a hand glove as shown in Fig. 1. We have attached accelerometer and gyroscope (MPU6050) on the center of Opisthenar that will monitor the orientation of the hand. The flex sensors cover each finger that give the analog data based on the fingers' bending moments to the Arduino

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Micro board kept on the wrist. The data from all sensors which are initially analog in nature are gathered at the Arduino board. It converts them into digital using ADC, performs some pre-processing and sends these data through UART to Raspberry Pi Zero W board that we have used for

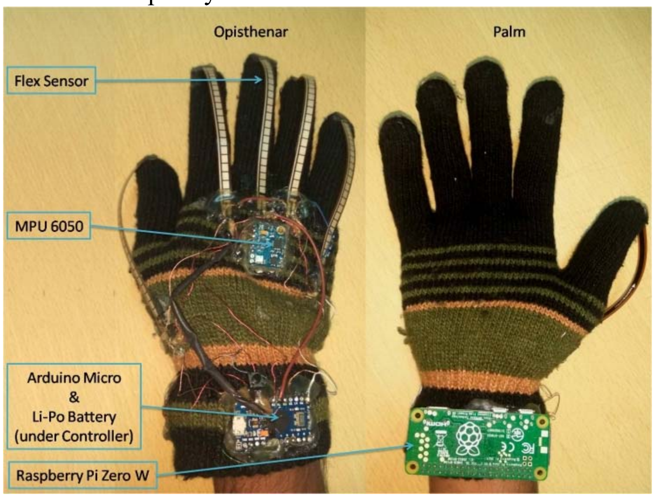

Figure 1: Design of Smart Glove

inbuilt computation task. In Raspberry Pi Zero W using a script written in Python Programming language we implement Dynamic Time Warping (DTW) and Nearest Mapping Algorithm. It converts the data into English Alphabet as per the training database. This is the algorithm.

III. EXPERIMENT AND RESULTS

The ASL has 24 steady gestures, e.g., A, B, C, etc. and 2 dynamic gestures, i.e., J and Z, as shown in Fig. 2.

Figure 2: Hand gestures of ASL, steady and dynamic (J & Z letters, shown with VLC symbol)

First of all we trained the data using the designed system. For this we first took data from all the sensors including 5 flex, accelerometer and gyroscope of all fingers in rest position (kept on the horizontal surface for 10 sec to get the calibration factor for all 5 flex sensors). Then we normalized these data to set a reference value from which any other position of the fingers would be marked as shown in Fig. 3 (for each finger at rest Arduino gave the zero value from its ADC, but when fingers were bent it gave the data from 0 to 170 from its ADC). This step was important in the sense to take care of the device may be used by any type of mute person, such as person suffering from Parkinson's disease or any other motor disability.

To train the system we have stored the data from all the sensors including 5 flex sensors, accelerometer and gyroscope with the help of 8 different users for at least 10 inputs for each alphabet.

Now we took up the recognition part. The test person put on the glove and made a gesture. The programme read it in real time by receiving 8 data for each gesture (5 from flex sensors and 3 from accelerometer, gyroscope combined). The system detected which finger was bent or opened along with the orientation of the hand. We stored data for all 26 alphabets including the dynamic gestures. Figs. 4 & 5 show the multiple digital data sent to the Raspberry Pi for the alphabet

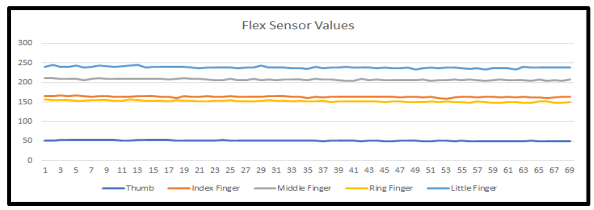

Figure 4: Waveforms for motion of various fingers for the alphabet A

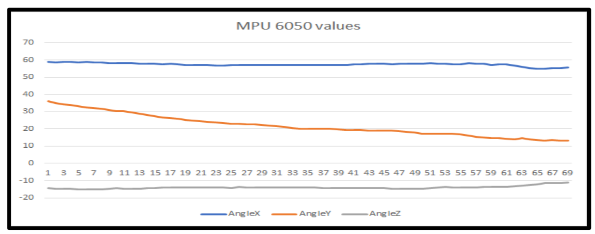

Figure 5: MPU6050 waveforms for the alphabet A

'A' in waveforms. The peak amplitude was obtained corresponding to the motion of the respective fingers. Whenever the remaining fingers were in steady position, the change in the amplitude was almost zero, i.e., the fingers maintained their steady value whenever in rest position. In Fig. 6 we present the data for the alphabet J (dynamic gesture) from the flex sensors which shows the change in data from the little finger when it dynamically goes from open to close and back to open position.

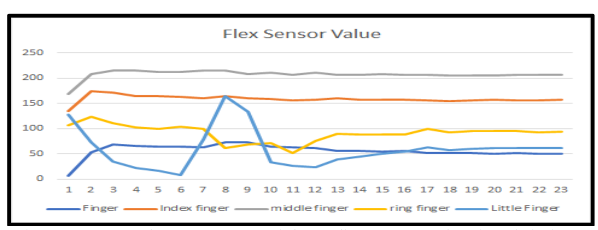

Figure 6: Waveforms generated from flex sensors for the alphabet J

The raw data that were obtained from the sensors needed certain processing to be carried out for their interpretation as these had inbuilt errors like offset value, high sensitivity of

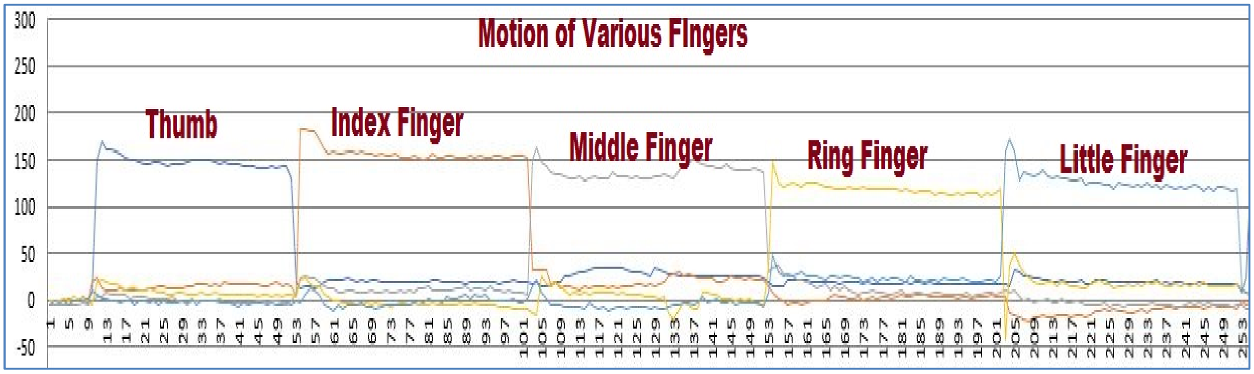

Figure 3 Waveforms for Motion of Various Fingers

the sensors, and cross axis-misalignment which made the data significantly unstable. For this we used the Kalman filter. The Kalman filter is an iterative mathematical process that uses a set of data inputs to quickly estimate the true value or entity, although the obtained values may contain the unpredictable or random values. It sets itself accordingly. We now processed the data collected from all sensors using Kalman filter for smoothening and noise removal.

This set of test data was then passed through the normal filtering followed by been sent to Raspberry Pi. Here the data were applied with DTW and nearest mapping algorithms. This algorithm compared the received data with the stored trained data to identify the closest sign accordingly.

The confusion matrix table for the letter recognition using the DTW and nearest mapping algorithm is as shown below. Its average accuracy is over 96.5%. For this we had randomly collected 50 sets of data of each alphabet by different persons taken at different time.

IV. Conclusion

We showed that our device is wearable, mobile and user-friendly. It uses simple algorithm to recognize the English alphabets of ASL in real time. The accuracy of the system is very encouraging and it is convenient to implement. The Arduino and Raspberry Pi boards are currently used for proof of concept. However, these may be replaced by a customized ASIC which may take care of all required functionalities including computation.

In future we are looking for providing it with a Bluetooth module so that this wearable device would become a product. Once we successfully make it compatible with a smartphone, we may even do away with the Raspberry Pi and do the computation of DTW and nearest mapping algorithms in the smartphone itself.

MATRIX	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
A	**47**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
B	0	**50**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	**49**	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	**47**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E	0	0	0	0	**48**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
F	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	**49**	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
I	0	0	0	0	0	0	0	0	**48**	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	1	**49**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	**47**	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M	0	0	0	0	0	0	0	0	0	0	0	0	**46**	4	0	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	3	**47**	0	0	0	0	0	0	0	0	0	0	0	0
O	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**49**	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0	0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**	0	0	0	0	0	0	0	0	0
R	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	**48**	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**48**	2	0	0	0	0	0	0
T	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**47**	0	0	0	0	0	0
U	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**49**	0	0	0	0	0
V	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**48**	0	0	0	0
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**	0	0	0
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**	0	0
Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**	0
Z	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**48**

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