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Electromyography based Gesture Recognition: An Implementation of Hand Gesture Analysis Using Sensors

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Abstract

Motion sign-based language has an important role in the mute community, that is for data transmission. Usually, silent and dumb people counter very difficult situations to convey information to normal people. This paper proposes research that can ease the life of the deaf community. The work presented in this paper is a communication bridge between normal-hearing persons and persons with less hearing ability or impaired persons. The proposed research 'Gesture–Talk' can be used as an interpreter between any normal person and deaf and mute persons. The Gesture–Talk is based on the language used in Pakistan which is Pakistan Sign Language (PSL), which is a standard language used by deaf persons in Pakistan. Using Gesture–Talk, PSL can be translated into voice. The idea is to develop a small portable application that can be used as a middle layer application between normal and deaf people. The authors have used an electrical sensor that will collect the data by detecting electrical pulses that will be sent to the microcomputer (raspberry pi 3) where the data will be processed and sent to the speaker from which voice will be generated. A cost-effective and novel approach has been proposed in this research paper compared to the other existing approaches. Moreover, Artificial Intelligence (AI) based predictive or classification algorithms may be applied for the best optimal results.

Index Terms: *Speech Translation, Raspberry Pi, Sign Language, Speech Translation, Myo Arm Band.*

I. INTRODUCTION

Language is used by everyone to communicate with others. Deaf communities developed sign language, which is primarily used by hearing-impaired people to communicate with one another. Sign language is a highly organized nonverbal language that uses both non-manual and manual correspondence. Outward appearance, head movement, stance, and body orientation are all examples of non-manual signals. While manual signals include hand movement and orientation, which have a typical meaning [1]. Communication with ordinary people is a major challenge for them because not everyone can understand their gesture-based communication. Many researchers have worked for decades to improve hand gesture recognition technology. Many applications, such as sign language recognition, augmented or virtual reality, sign language interpreters for the disabled, and robot control depend heavily on hand gesture recognition. Because of the new generation of gesture interface technology, the importance of gesture recognition has grown at a rapid rate. Sign language is primarily a language for the deaf-mute community who are unable to communicate with others using spoken languages. Even though they can see, using hand signs to communicate becomes inconvenient if a common hand sign language is not followed. A standard sign language has a well-defined set of signs and their meanings, which makes it simple to comprehend. Different gestures primarily hand movements are used in sign language for communication. Sign languages differ from speaking languages in several ways. Because hands send clearer signals and gestures can be made spontaneously, hand gestures are used more frequently for interaction with humans and machines compared to other body gestures such as head and eyes. The majority of research in this sector solely supports a learner's ability to recognize or translate sign language. A motion learning support system for sign language has been created. In 2004 researcher Kuribayashi and his associates used data gloves to create such a system. This system focused on Japanese finger-spelling. A student is trained to master the skill of producing the correct hand motion by the system. Using text and animation, the system demonstrates proper hand movements. The approach allows the learner to learn each character of Japanese finger spelling one at a time, but it does not permit a series of characters like words [1].

Another system based on Kinect and the bending sensor was developed in 2013 by Kitagawa and his associates. There are 182 sign language terms in Kitagawa's system. The system makes use of Kinect to figure out how their hands and bodies are connected. However, Kinect is unable to gather comprehensive motion data for their hands. As a result, their technology collects data about the form of trainees' hands using data gloves with bending sensors [2]. Besides many advantages, however, there are certain issues, such as the fact that they take a long time to wear and that the student feels burdened while using them therefore the main goal of this research is to design such glove that use data and are very simple to put on and take off and uses magnetic position sensors to replicate finger motion using 3D models. This approach also gives the learner error feedback, which is calculated using the data from their hand form.

II. RECOGNITION APPROACHES

The virtual button-based approach, data glove approach, and visual-based approach are the most popular methodologies used in automatic sign language translation systems today [3].

This section will go through some of the most common ways of recognizing gestures in-depth:

A. Virtual Button-Based Approach

A virtual button's function is to generate button events, such as a press and discharge, by detecting individual hand actions of holding and discharging. This virtual button may also recognize certain gestures and issue appropriate commands. Patterns of the wrist form are used in the virtual button approach. It is capable of detecting a squeezing movement. The patterns of finger flexor depend on the wrist can be identified by moving fingers using miniature Infrared-IR optic sensors. These patterns are used to detect movement in the fingers or hands [4]. Because the area contains finger flexor tendons that delicately respond to finger movements, the IR emitter, and IR optic sensor is mounted to the bottom of the wrist. These sensors generate voltage values based on the amount of Infrared-IR radiation received. This sensor was employed in the system to track distinct patterns of wrist shape caused by the movement of the finger flexor in the wrist when the fingers are moved [5].

B. Visual-Based Approach

There has been a rise in the usage of visual-based methods as computer technology and software have advanced. A camera captures the image of the signer, and video processing was used to detect the sign language. The key advantage of the visual-based technique, as opposed to the data glove approach, is the adaptability of the framework [4-6]. The identification of facial expressions and head movements can also be added to the framework, as well as lip-reading. This approach can be divided into two strategies: the use of handcrafted shading gloves and the recognition of skin color. Color-coded gloves are provided to the signer for the specially made glove. Through color segmentation, the color will provide information from the signer's photographs. These gloves are essentially regular gloves with unique shading on each finger and palm. When compared to electronic data gloves, these gloves are less expensive in several ways. This system makes use of low-cost components like a webcam and a basic (color-shaded) glove. The webcam is utilized to capture still photos and video streams in Red-Green-Blue (RGB) shading from the signer. The framework just requires a camera to record the signer's moving photographs for skin-color detection, and no further devices are required. It turns out to be more usual and useful for frequent uses. This technology relies on the user directly communicating with the system by using an uncovered hand to focus necessary information for recognition [7]. The skin color region will be split using a color threshold technique in order to follow the position of the hand, and then the region of interest will be selected. Until the signer makes a stop sign, the image acquisition continues indefinitely [8]. Following the threshold, the segmented images are evaluated to determine the distinct characteristics of each sign. These visual-based approaches reduce the amount of equipment required and the expense. These methods, on the other hand, are only suitable and viable for interpreting alphabets and numbers, not for recognizing sign movements. Signs that have a similar attitude to another sign can be confused, lowering the system's precision. Furthermore, the picture acquisition process is sensitive to a number of environmental problems such as the camera's position, the background, and lighting impacts. The signer's varying height must also be taken into account. A sufficient amount of lighting is also required in order to be seen and assessed.

C. Data Glove Technology

The data-glove technology makes use of a specially designed electronic glove with built-in sensors that detect hand attitude [9]. The data-glove method is used by the majority of commercial sign language translation systems because it is simple to obtain data on finger bending and 3D orientation of the hand using gloves. The framework demands less computational effort, and continuous interpretation is far more straightforward. There are ten flex sensors on the data glove, two on each finger. The resistance varies in flex sensors. These sensors can detect the bending point of each finger joint and transmit the data to the microcontroller. It is attached to the data glove's outer layer, from the finger and palm association joints to the fingertips. A 3-axis accelerometer is also used to identify the change in acceleration of the hand's movement in different bearings to improve the precision in recognizing the hand pose. The accelerometer is affixed to the data glove's back. The data glove excels in detecting both finger-spelling and sign gestures, including both static and moving signs.

III. LITERATURE SURVEY

A variety of ways were employed for the same system mentioned in this study, which can be used in a variety of applications. Vision-based, glove-based methods, Artificial Neural Networks (ANNs), Canonical Analysis, and so on are some of them. Hand segmentation approaches, feature extraction approaches, and gesture recognition approaches are the three broad categories into which all approaches are divided. A model was successfully developed that performs improved sign identification utilizing several machine learning algorithms. Better sensors and an efficient algorithm for the given task were used to improve response time and accuracy [10]. By incorporating a sensor network for recognition reasons, the traditional approach to sign language was modified. In sign language recognition, a proposed model was constructed using a mix of Artificial Neural Network (ANN) and Support Vector Machine (SVM). The findings of this combination algorithm were superior to those of the Hidden Markova Model (HMM) [11]. A solution was developed that combined three different types of sensors. To assess the impact of SVM on sign language recognition, these sensors comprise a flux sensor, a motion sensor, and a pressure sensor [12]. American Sign Language (ASL) movements are translated into text using an ‘Intel Real’ sense camera. A novel system was suggested that used an Intel Real camera with Support Vector Machine or SVM and Neural Network (NN) algorithms to recognize sign language [13]. A smart data glove was used to detect daily activity. For gesture interpretation, two primary techniques were used: computer vision and data glove interaction [14]. To conduct real-time sign detection, Convolution Neural Network (CNN) was used to understand real-time sign language. There are no obsolete datasets or pre-defined image datasets in this method. The researcher Cayamcela Manuel with associate designed a real-time data analysis method instead of the standard approach of employing prepared datasets [15]. The machine learning approach was used to analyze sensor data based on reflected impulses. The CNN algorithm was used to recognize sign language using reflected impulses [16]. A previously published developed a converter that identifies the disabled person's signed images and translates them into text and speech without the use of additional methods such as data gloves or other equipment [17]. Videos of hand gestures are taken and detected using the same technique for this system implementation. Scientists created and developed a voice recognition system that is both dependable and accurate [18]. This system used the speaker's speech to verify his or her identity and give controlled access to services such as voice-based biometrics, database access services, voice-based dialing, voice mail, and remote computer access. In comparison to other sign languages such as Asian Sign Language (ASL/), and Pakistani Sign Language (PSL) the other researchers used Indian Sign Language (ISL) in their research work [19]. The understanding of ISL remains unfocused according to this poll. This paper discusses the historical context, as well as the need for and scope of Indian Sign Language or ISL. Traditional hardware-based techniques face a number of issues when it comes to vision-based systems. Working on a system that is natural and accepted is feasible thanks to the effective use of computer vision and pattern recognition. The author's motive was to make communication between deaf and dumb people easier [20]. To that end, a computer is inserted into their communication line, allowing sign language to be automatically collected, recognized, converted to text, and presented on an LCD monitor. There are various disadvantages mentioned here, such as the cost of electronic gloves. Another disadvantage of the glove-based technique is that; no one can use the other's glove. Simple, efficient, and durable algorithms are used to convert RGB images to binary and match them with databases using a comparison algorithm. The author of a paper used Artificial Neural Network (ANN), to create an isolated word recognition system in this thesis. The ability of computers to recognize speech is comparable to that of the human brain. The author of this paper provides a detailed analysis of the ANN. The recognition system could be designed using this network technology [21]. With ‘Haar features’, an SVM classifier, and 95 percent accuracy, researchers created a real-time hand gesture detection system with a complex background [22]. Gradient histograms were compared to descriptors for sign identification [23]. For static and dynamic range images, the researcher of another paper used a depth camera that was implemented [24]. An ‘adaptive square technique’ was used to extract features, which were then classified using SVM with an accuracy of 87.6% for dynamic. Authors of a paper elaborated a model of a sign language interpreter that can articulate American Sign Language (ASL) [25]. This functional paradigm was built on generating an HCI solely from the user's hand movement. The researcher presented the visual recognition of static gestures or dynamic gestures in his paper, in which recognized hand gestures were obtained from the visual images on a 2D image plane, without any external devices. Gestures were spotted by a task-specific state transition based on natural human articulation [26].

IV. PROBLEM STATEMENT

Proposed research that is being used for converting the gestures into speech is that everyone is using image processing which limits the device to convert every sign language. Another thing is that all the previous work that has been done is on gloves. Gloves with wirings cannot be used everywhere and have limited usage because gloves cannot be worn especially when dealing with something wet. Previous work has been restricted to some gestures that cannot cover all.

V. METHODOLOGY

A. Hardware Detail

The overall hardware necessary for sign recognition is shown in Figure 1 below. The ‘Myo Armband’ is a gesture recognition armband an electronic device that could be worn on the arm and is manufactured by Thalamic Labs. The Myo (Electromyography) gesture recognition armband shown in Figure 2, has the capability to control the different technologies wirelessly using various hand motions. It has different sensors including Electromyography sensors that sense electrical activity in the forearm muscles, an accelerometer, gyroscope, and magnetometer which recognizes hand gestures. The main purpose of designing a glove is to recognize gestures and this is done using a Myo Armband, Raspberry Pi 3 microprocessor, speakers, and power bank. The sensors are selected based on a study of sign language signals, which helps to reduce the sensor needed. The glove is created manually after evaluating the hardware necessary for sign recognition and this is overall illustrated in Figure 1.

This figure explained that in the first part, the Myo Armband sensor is placed which takes the input from our hand gestures, and in the second one it contains the microprocessor, battery, and speaker. When Myo Armband gives the input to Raspberry Pi, it comprises the 'Pyo Connect' application which contains the Python language scripts. This application recognizes the hand gestures on certain sensor values and after processing it is converted to the output as speech. The Myo Armband sensor was connected to Raspberry Pi through Bluetooth dongle USB and a mini speaker is connected to the microprocessor which generates voice.

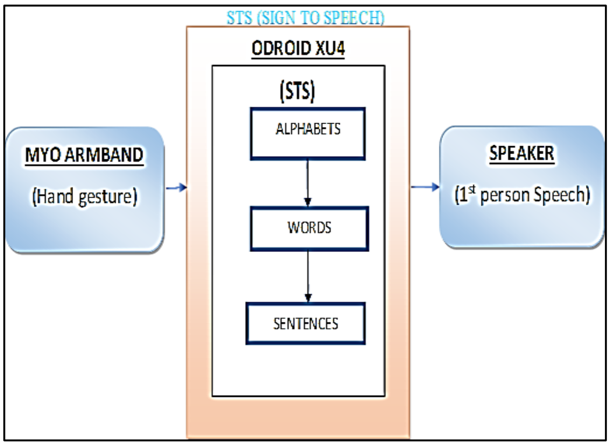

Figure 1: System Design Overview

Figure 2: MYO (Electromyography) Armband

B. Software Detail

i. Pyo-Connect:

Pyo-Connect was entirely coded in Python. The code will appear on your screen, after that code the libraries must be unzipped so coding on scripting can be completed using Pyo-Connect. There are two versions of Pyo-Connect i.e., version 1 and version 2. Scripts will be in another folder named scripts that can run with the '.py' extension. For example, Pyomanager.py, after this your menu and manager will be displayed on the screen. The 'Connect' and 'Disconnect' buttons allow a user to connect the armband which establishes a connection between Raspberry Pi 3 to Myo Armband, unlike the previous version Pyo-Connect version 2.0, shown in Figure 3, needs to be connected once and it holds the connection while your scripts will have the code.

Figure 3 shows that one or more scripts can be active at the same time. The live values could also be obtained in the Windows computer wirelessly through a Bluetooth dongle. Myo gesture recognition armband would be sending the real-time data all the time when it will be tied or worn on arm. These values are being obtained like this on which you have to work on it.

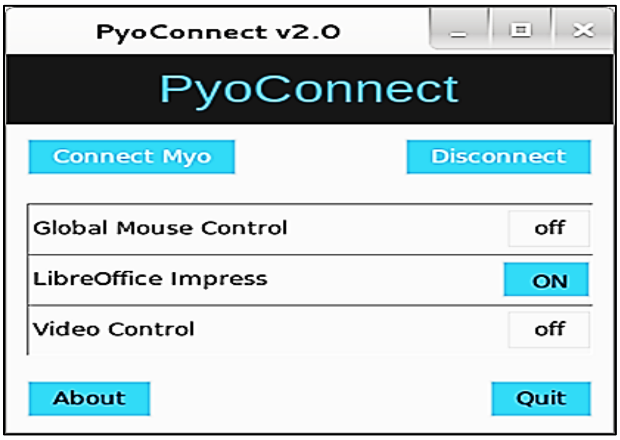

Figure 3: Pyo-Connect

ii. The Scripts:

The documentation of libraries will be the same for both, i.e., version 1.0 and version 2.0, the scripts help to use the Myo Armband with the Windows and Mac and other Operating System (OS) environments. It helps to work on Myo Armband's features and explore the other contents of the armband as illustrated in Figure 3.

iii. New Out of Box Software (NOOBS):

The New Out of Box Software or NOOBS is an operating system for the Raspberry Pi which also contains Raspbian and Libre Office. It provides the choice to the users of the alternative Operating System. The NOOBS (illustrated in Figure 4) and Raspbian both contain the Java SE platform NOOBS will repartition your card and ask for which operating system you want to get from the list shown.

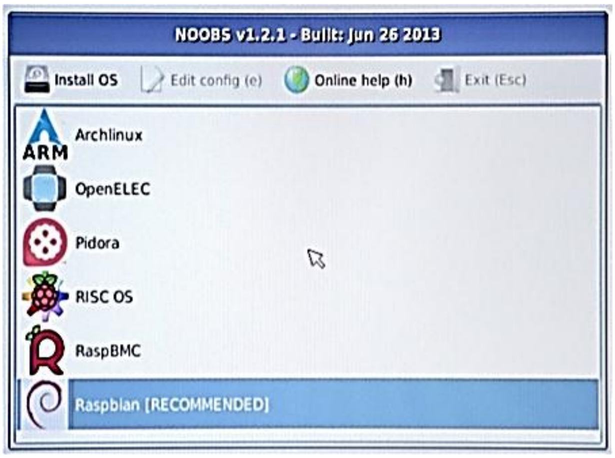

Figure 4: NOOBS (New Out of Box Software) GUI

iv. Details of Software Implementation:

Pyo-Connect software comprised of the script files which were coded in Python scripting language. The script-coded files contain the basic programming of this proposed research which takes input from the sensor and processes it then recognizes the gestures and converts them into certain words. The sensor provides a continuous form of data and the Pyo-Connect application will be converting it continuously thus forming the speech for hearing impaired persons. The user does not have to learn anything additional to use this software-based proposed research.

Figure 5: Software Implementation

Figure 5 shows the graphical illustration of the received data. If someone wants to have information on every sensor in a graphical manner it can be observed and recorded at a live location hosted by the manufacturers themselves. It gives you the independence to set its origin values to see the strength of every gesture and other necessary background information. This live location is useful in many ways like if a person is outside or at a neighbor's place, he/she will also be able to keep a check on the device's performance anywhere anytime. It will also show us if the device is perfectly worn by the user or not. If the user has not worn it correctly, then he/she will adjust it so the system could work perfectly.

VI. RESULTS

The outcome of the research will be the speech that is generated by the system by receiving the performance of any hand gestures by the user. The speech will be delivered to the required person using the speaker connected to the system by Bluetooth. This device will get used to by the user for example if there's a 'Person A' using the device, so with the passage of time and/or with the person's more frequent usage, the device's working efficiency will drastically increase. This will improve the quality of the proposed research as the main objective is to make a device that's simple to use. In other words, we know that hand gestures vary from person to person, i.e., every deaf/mute person using the device has his own way of saying things, therefore the devices work as a learning tool here, that is with the increase in usage of the device it's learning capability increases proportionally. Time will make the system functionally smart, efficient, and reliable. The user will get more comfortable using the Gesture-Talk with the passage of time. The proposed methodology which has been mentioned in this research paper has only elaborated on the basic fundamental functioning of the proposed approach. The mechanism would surely be enhanced and modified as it would be integrated with Artificial Intelligence and Machine Learning based algorithms in the future.

VII. ANALYSIS

This research has the potential to grow even further beyond expectations because this proposed research uses the most advanced sensor known as the 'MYO Gesture Recognition Armband' which takes in thousands of samples in just a few seconds. The proposed research, accurate and fast like this, has the ability to capture and react to 'motional changes', learning and adapting efficiently. This technology has vast applications for deaf and mute people in the future. Uncountable gestures can be made using appropriate methods and techniques. Resulting in giving a voice to the people and along with that its fast speed of catching the gesture will make it more efficient than others as illustrated in Figure 6.

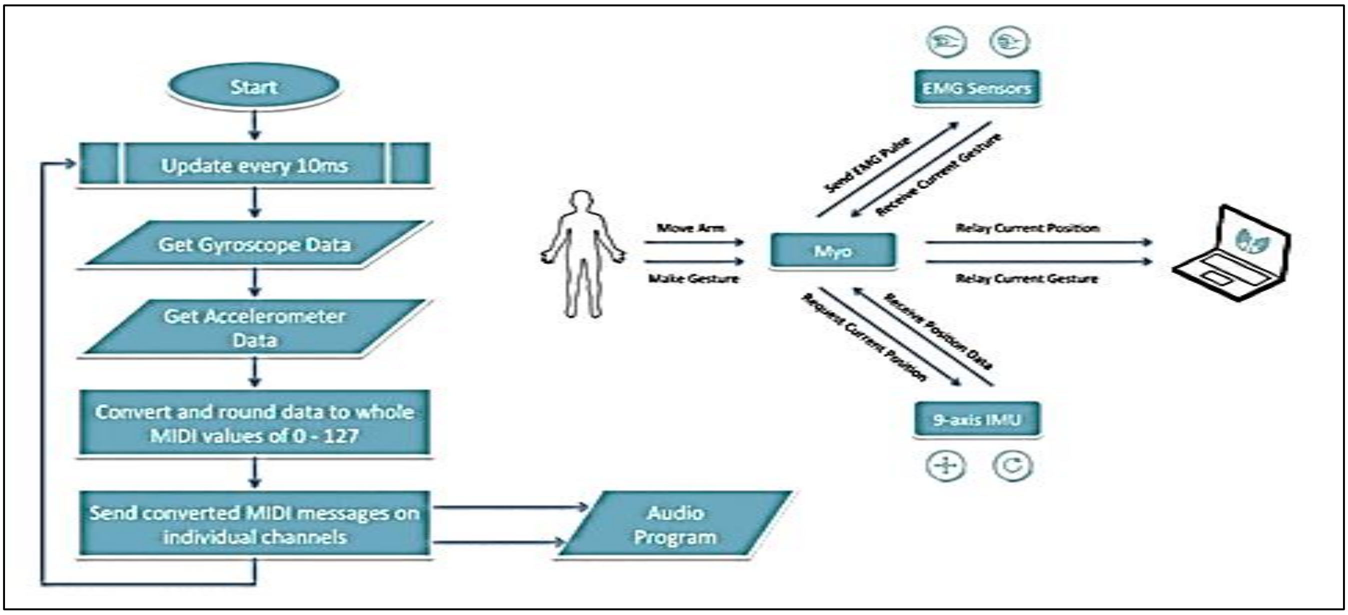

Figure 6: Fundamental Block Diagram

VIII. SIGN LANGUAGE

The authors are using PSL (Pakistan Sign Language) in this proposed research so that Pakistanis can use it easily because the deaf and mute people are already using this language in their daily lives. Researchers have converted the selected most used Pakistan sign language words that were identified by the sign language community and added them to their system so that users can speak through it word by word forming a sentence as they usually do.

IX. DATA ACQUISITION

Figure 7 portrayed the collected data set from electromyography. The data set was obtained with a timestamp as can be seen in the given table.

B	C	D	E	F	G	H	I	J
0	-1	2	-2	-2	-1	-19	-11,551,467,578.46	
1	-6	-1	1	1	1	0	11,551,467,578.46	
0	1	-3	-2	-2	1	-6	-61,551,467,578.46	
-2	7	0	-1	0	-2	4	-21,551,467,578.46	
-1	0	-4	-3	-4	1	30	21,551,467,578.46	
-1	-9	2	7	3	-2	-40	21,551,467,578.46	
-5	3	-10	-2	8	3	48	-21,551,467,578.47	
0	-2	3	2	-12	-6	-55	-41,551,467,578.47	
3	2	0	0	9	1	2	1551467579	
10	6	1	2	-5	-3	20	61,551,467,578.58	
-9	5	-2	5	-1	0	-5	-11,551,467,578.61	
-3	0	-4	-6	0	0	25	-31,551,467,578.61	
-2	-1	-1	-1	-2	-3	-6	-21,551,467,578.61	
5	-3	3	-4	-5	1	18	31,551,467,578.61	
1	-6	4	0	7	-2	-26	-31,551,467,578.61	
-6	19	-6	1	-2	-2	20	-21,551,467,578.61	
-1	-11	-2	-2	-3	0	-9	1551467579	
-1	1	-1	-9	-1	2	28	-41,551,467,578.61	
-2	-7	-1	1	-11	-6	-34	31,551,467,578.61	
-5	0	-3	-4	9	5	8	-11,551,467,578.62	
1	-3	-1	1	-2	0	2	-61,551,467,578.62	
-8	-4	-3	0	-4	-3	1	-31,551,467,578.62	
11	1	1	-10	-3	-1	0	61,551,467,578.62	

Figure 7: Electromyography Data (with Timestamp)

Figure 8 elaborated that the data has been collected from the accelerometer sensors. The sensors produced the following data with the time stampings.

```
 0.6875,  -0.3750,   0.3125,1551810975.297
-2.1250,   0.0000,   0.0000,1551810975.312
-0.3750,   0.0000,  -0.7500,1551810975.333
 2.0625,  -0.5625,   0.0625,1551810975.357
-1.6875,  -0.8750,   1.0000,1551810975.372
 0.0625,  -0.8750,   0.8750,1551810975.394
 2.0625,  -1.1875,   1.1875,1551810975.452
 0.2500,  -1.1875,   1.3750,1551810975.452
-0.6250,  -0.4375,   0.9375,1551810975.458
 1.1875,  -0.0625,   0.4375,1551810975.493
 0.1250,  -0.1875,   0.3750,1551810975.502
 0.6250,   0.1875,   0.3125,1551810975.532
 0.3750,   0.7500,   0.1250,1551810975.551
 1.2500,   1.0625,  -0.5000,1551810975.576
-0.6875,   0.6250,  -0.1250,1551810975.576
 0.4375,   0.8750,  -0.5625,1551810975.597
-0.8125,   0.6875,  -0.8750,1551810975.629
 0.5625,   0.1250,  -0.4375,1551810975.636
-0.8750,  -1.0000,  -0.1875,1551810975.673
-0.7500,  -0.7500,   0.2500,1551810975.680
-0.8125,  -0.6875,   0.2500,1551810975.695
-0.1875,  -0.7500,   0.9375,1551810975.716
 0.9375,  -0.5000,   1.2500,1551810975.735
-0.0625,  -0.1875,   0.9375,1551810975.772
-0.0625,  -0.1875,   0.1875,1551810975.777
```

Figure 8: Accelerometer Data (with Timestamp)

X. DISCUSSION

Disabled people's equipment and tools have been a source of innovation. In terms of investigation and product system development in assistive technologies that enable various disabled individuals to carry out their everyday activities; many innovations in the technology world today have aided diverse groups of persons with impairments [27]. Wireless devices, low-power electronics, and the capacity to design both the analog front-end and the digital processing back-end are all examples of such capabilities. Integrated circuits have also sparked the development of a new generation of miniature wearable devices [28-29]. In fact, instead of buttons, most contemporary wireless gadgets have touch screens [30]. With the addition of a system that is continually aware of hand movements in space, this revolutionary interface can become even more sophisticated [31]. The user interfaces of wireless gadgets are more user-friendly. This is also true in the world of electronics, where various sensors can address bending measurement and identify the human hand's many Degrees-Of-Freedom (DOF) and a vast range of motion. Similar novel technology can be applied to a variety of applications, including 'SL' translation [32-36]. Appropriate technology can be used to provide deaf and dumb people a huge boost in their daily lives and improve their quality of life.

XI. CONCLUSION

The basic idea was to help deaf and dumb people with the use of technology. Actually, the authors have used an electrical sensor that will collect the data by detecting electrical pulses that will be sent to the microcomputer (Raspberry Pi 3) where the data will be processed and sent to the speaker from which the voice will be generated. This proposed research will detect the electric pulses in the forearm and convert the data into a voice through a speaker. This proposed research is the next-generation device in the Gesture recognition history. It will help a lot of people in matching the normal world environment. The main challenge authors faced during the process was converting data into voice. Other difficulties they had, were studying and understanding the armband because it is a newly proposed research. It includes a lot of learning about how it works and how exactly can authors implement it, i.e., within the limited time frame the authors had to do this research. Another thing that was an issue that occurred, was taking more time for a new user which the authors try to eliminate as much as possible.

XII. FUTURE RECOMMENDATIONS

Authors would recommend working on more performing hand gestures in other sign languages by advanced programming. There can be many other advanced options that will make this proposed research more reliable by improving its performance. Authors would also recommend that in the future, with the help of new technology it can become cheaper. Hopefully, this will be a great contribution to our society. The specialty of this proposed research is that it can become even smaller, and more efficient, and it also has the adaptability to switch from one language to another so that one proposed research could be used for many different types of people who use different languages. The obtained sensors data can also be optimized by using AI optimization algorithms for the best optimal results.

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Authors Contributions

The contribution of the authors was as follows: Talha Ahmed Khan's contribution to this study was the concept, technical implementation, and correspondence. The methodology to conduct this research work was proposed by Shaheer Ahmed. Data collection and supervision were performed by Sadique Ahmad. Syed Safdar Ali Rizvi facilitated the data compilation and validation. Nitasha Khan's contribution was project administration, and paper writing.

Conflict of Interest

There is no conflict of interest between all the authors.

Data Availability Statement

No testing data is available in this paper.

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