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Wearable Translator of the Dactylogical Alphabet of the Honduran Sign Language

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Abstract Inequality of opportunity for the hearing impaired has been a problem for many years. Hearing impaired people find it difficult to communicate effectively with hearing people because most people do not know sign language. This research seeks to provide a tool that facilitates and helps people to learn sign language and achieve communication between the hearing impaired and hearing people. For the development of the prototype, it was necessary to approach the hearing-impaired people, an electrical analysis to know the variation of flexibility of people, the design of a PCB personality board and the design of a 3D glove. Then the assembly of the electrical components to the glove was done and a pilot test was conducted with students of the faculty of engineering, where positive results were obtained on the programming at the time of performing the desired letter. Finally, a prototype was created that allowed the translation of the Honduran sign language alphabet through the development of an application that included a voice command to reproduce the formed word.

Keywords — dactylological alphabet, education, hearing impaired, sign language, wearable

I. Introduction

Throughout time in Honduras as well as worldwide, the idea that people with disabilities were incapable of being able to stand up for themselves, so their opinion was not taken into account, was promoted. With the passage of time, they became more valued and included in society, avoiding exclusion and ensuring the rights that they should acquire as human beings.

Studies related to the topic of disability are reduced and insufficient in Honduras, however, the results obtained in 2002 by the Permanent Multipurpose Household Survey of the National Institute of Statistics (INE), it was found that the Honduran population had a 2.65% who suffered from disability. In 2013, according to INE Census data, the prevalence of people with disabilities increased to 4.6% [1].

Today, in the country many families do not have the economic resources to be able to afford public education for their children, creating a barrier for people in being able to learn about this language. Generally, people who have learned about sign language have received instruction through sign language courses or have learned in a self-taught manner, since in Honduras the necessary priority is not given to the inclusion of sign language. This makes it difficult for hearing and hearing impaired people to communicate [2].

Knowing the problems in communication between the hearing impaired and the hearing people in Honduras, the project focuses on the development of a technology for didactic purposes. The objective of this technology is to achieve a first step in Honduras to help hearing impaired and hearing people to have an effective communication without any barrier.

A. Disability

For several decades, the definition of disabled people has been implemented. Since 1970, new concepts have emerged based on a social model that was used to conceptualize disability. However, these terms focused on disability as an abstract concept. Disability was defined by comparing it to discrimination, poverty, diversity, denied access and human rights. The Convention on the Rights of Persons with Disabilities (CRPD) defines disability as those who are impaired by barriers in their environment, limiting their participation with society [3].

The World Health Assembly named the International Classification of Functioning Disability and Health (ICF) as the new classification model for defining disability. That definition reads as follows:

"Disability is understood as a multidimensional phenomenon, a continuum of human functioning that becomes noticeable with people's daily lives. Put another way, disability comprises the complex interaction between the subject and his or her environment."

According to Moreno [4] in his book categorizes disability into 5 types: physical and organic, visual, auditory, intellectual and psychic.

- Physical and organic disability: Related to the alterations that are related to the locomotor system, organs and systems that cause partial or total damage.
- Visual disability: Related to the alterations that people have with the organ of vision.
- Hearing disability: Related to alterations in the auditory system.
- Intellectual disability: Related to the complication of understanding and a limitation in the speed of mental functions.
- Psychic disability: Related to cognitive functioning.

B. Hearing Disability

As mentioned above, hearing impairment is defined as the loss of the anatomical function of the auditory system. Therefore, it is a limiting factor for people to hear, which generates complications to the oral language.

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In the research conducted by Rodriguez [5] classifies according to the educational environment hearing impairment as:

- Hearing impaired: related to people whose hearing is deficient, they have the availability that with prosthesis or without it, is still functional for their daily life. It allows the obtaining of oral language using the auditory pathway.

- Deaf: Related to people whose hearing is not functional in their daily life and does not allow them to acquire language through the auditory pathway. However, it may occur, to a greater or lesser extent, through the visual pathway.

In 1960, linguist William Stokoe proposed that the signs used by the American Deaf to communicate were a natural language and not a language impoverished from English. By 1970, the first research on sign language began to appear in the world. This research had an impact on the way people thought about the deaf. The Deaf community was expanding among the American society and some others, becoming more and more known [6].

Sign languages is a means of communication used by hearing impaired people to be able to communicate. They use body movements of hand and arm movements, gestures of facial expressions. It can be employed in a basic way, by gestures or grimaces invented by people to facilitate communication, as well as it can also be used through the use of manuals that define the correct use of the language [7].

C. Dactylogoical Alphabet

The dactylological alphabet is a communication system developed by the deaf community, consisting of manual representation for each letter of the alphabet. It can be used in the air, which is generally used by the hearing impaired, but can be used in the tactile manner by the deaf-blind. The use of the typographical alphabet allows the hearing impaired person to represent any word he or she requires to facilitate communication, regardless of its complexity. Generally, it is used for nouns, proper nouns and words that do not have a representation in the language [8].

D. Importance of the Hand as a Means of Communication

Many people think that the voice is the only means of communication between people, but they do not take into account that for people with hearing impairment or any other disease that hinders their ability to speak, their means of communication is through the use of the hand. According to the World Health Organization, there are 360 million people around the world who are hearing impaired, where their mother language is sign language [9].

In Honduras, there is a shortage of studies that investigate the issue of people with disabilities due to the lack of reliable statistical information, the importance that has been visualized both at the family and social level, lack of interest by the government and the needs of people. Persons with disabilities in Honduras, as in many places that are still developing, are not provided with the necessary support for their participation, whether in health, education or work [10].

E. Related Works

Throughout the years, human beings have always made use of technology to develop and design electronic devices to replace an anatomical part of the body. Technological advances have been evolving with the same goal, to benefit mankind. Among them is the hearing-impaired community. These technologies have been created to facilitate their incorporation into society in an independent manner.

Different types of sign language translator gloves have been built, among them are the following:

1) Didactic kit for learning ecuadorian sign language

Navarrete and Rodriguez [11] made a design that consisted of an Arduino UNO, where the signal was sent by a Bluetooth module. For the prototype they used a fabric and rubber glove for the placement of the Flex sensors. Finally, for the translation of sign language, they created a mobile application for the Android operating system where it has the options to complement the operation of the glove.

2) Data glove japanese sign language training with gyroscopic sensor

Mori and Toyonaga [12] designed a prototype Japanese sign language translator glove that uses a video capture system and data glove to be able to identify words in representation of the shape of the hand, body, and bending performed with the fingers. However, he points out that some words cannot be captured by static flexion, as some words include hand and arm movement. So they decided to use a gyroscopic sensor to capture these signals .

3) Akel: design of a smart glove thath recognizes turkish sign language and a mobile application base on an operating system

Ozer [13] divided his research into two stages, in the first one he made a design of a smart glove containing flexibility sensors one for each finger. The data is processed with the help of an Arduino one microcontroller and transferred to the mobile application. Once the word has been processed, the mobile will allow to reproduce through audio the word generated by the user. In the second stage, I realize in the application that allows hearing people to translate the word into sign language, in order to obtain a fluid communication between hearing people and hearing impaired people.

4) Real time glove and android applicaction for visual and audibale arabic sign language translation

Salem [14] developed a prototype that was composed of flex sensors, an accelerometer to measure orientation and hand movements. It has a bluetooth module to connect to the Arduino Nano interface. Additionally it has an Android system application, where the translation of sign language is carried out.

Translation of american sign language through smart wearable glove technology

Rizwan [15] developed a glove that contains bending sensors made with a carbon surface on plastic strips. When the strip is bent, it changes the resistance of the flex sensor. It uses an

Arduino Leonardo to process the signal generated by the bending sensors and an accelerometer to record the hand movements in x,y,z coordinates. Additionally, an Android application was created to display the American Sign Language translation.

The objective of the research is to create a prototype translator of the Honduran sign language dactylological alphabet for didactic purposes.

The rest of this work is organized as follows. At Section II describe stepts by steps the study methology to be usted in this investigation. Section III shows the results and discussion obtained in the development of the investigation, and finally Section lV offers the conlusions.

II. Method

The research was developed in a mixed approach. The analyzed flexural sensor signals include mathematical components which are processed by means of software tools to represent a quantitative approach. On the other hand, it has a qualitative approach since information was obtained on the current situation of hearing impaired people in Honduras and how the prototype can be applied for educational purposes.

A. Study Methology

The methodology used for the development of this research is the technological maturity scale. This method was developed by NASA with the objective of providing a material to measure the degree of maturity of a technology [16].

The research was developed based on the idea of an existing prototype. The author made an initial prototype sign language translator using a glove, flex sensors and an Arduino MEGA 2560 microprocessor. The system only allowed the translation of the vowels of the Honduran sign language alphabet, such translation was displayed through an Arduino LCD screen Communication was obtained with the Association of the Deaf of Honduras, which allowed a meeting to show them the base prototype and get feedback from them to improve the prototype.

An approach with the Honduran Association of the Deaf where a meeting was allowed to show them the base prototype and obtain feedback from them on improvements to the prototype. From this feedback, we brainstormed ideas for the development of improvements to the base prototype. The problems of the base prototype translator were identified and solutions were provided in order to provide a better product.

For the development of the prototype, research activities were included, such as: electrical analysis of the bending sensors. Also, the Arduino microprocessor was changed to the ESP32 microprocessor, and the operation was validated in conjunction with the bending sensors in order to obtain the potential for expansion and operational issues.

Subsequently, development of the PCB board design and development of the 3D glove was started. Once the printing of the designs was done, the electrical components were integrated into the 3D printed glove to obtain a system configuration that is similar to the final development in almost all its features. We started coding in the Arduino program the letters of the alphabet of the Honduran sign language. Likewise, the design and development of the application that will show the translation of the language was started.

Finally, pilot tests of the prototype were conducted with students from the engineering faculty under conditions similar to those expected to be used in real life situations. A questionnaire was applied to obtain feedback from the users on the operation and design of the prototype.

III. Results and Discussion

1) Applied research proof concept

As mentioned above, a validation of the prototype idea was carried out, which included the activity of performing an electrical analysis of the flexion sensors with the participation of 8 UNITEC students. The analysis consisted of asking the student to put on the glove and flex each finger separately in three different positions: finger extended, finger halfway and finger fully flexed. The values of the flexion sensors were measured through a multimeter that showed the variation of resistance measured in ohms (Ω) units according to the position the finger was placed. The results are shown in Table 1 to 3.

The results show no great variation in the sensor resistance values of each student in the finger flexions performed. A minimal difference was found between 5 digits or less to the range of values that oscillated between them. While it is true that each person has his or her degree of finger flexibility, the values were very similar.

TABLE I. Table of extended finger values

Electrical Analysis of Flex Sensors – Extended Fingers								
Student	***E1***	***E2***	***E3***	***E4***	***E5***	***E6***	***E7***	***E8***
Thumb Sensor	9.14 Ω	9.01 Ω	9.3 Ω	9.76 Ω	8.98 Ω	9.34 Ω	9.94 Ω	9.43 Ω
Index Sensor	20.15 Ω	16.02 Ω	16.63 Ω	17.12 Ω	17.24 Ω	15.51 Ω	18.65 Ω	17.09 Ω
Middle Sensor	20.6 Ω	20.82 Ω	18.80 Ω	20.11 Ω	20.47 Ω	20.09 Ω	19.43 Ω	19.92 Ω
Ring Sensor	10.54 Ω	9.75 Ω	9.88 Ω	10.15 Ω	10.22 Ω	9.91 Ω	9.76 Ω	10.16 Ω
Pinky Sensor	9.1 Ω	8.94 Ω	8.61 Ω	8.97 Ω	8.58 Ω	9.15 Ω	8.57 Ω	8.72 Ω

TABLE II. Table of finger values in half

Electrical Analysis of Flex Sensors – Fingers in Half								
Student	***E1***	***E2***	***E3***	***E4***	***E5***	***E6***	***E7***	***E8***
Thumb Sensor	10.41 Ω	10.95 Ω	12.11 Ω	11.20 Ω	10.60 Ω	11.64 Ω	11.48 Ω	10.96 Ω
Index Sensor	29.35 Ω	23.11 Ω	24.40 Ω	26.40 Ω	25.40 Ω	26.80 Ω	26.65 Ω	23.50 Ω
Middle Sensor	33.50 Ω	32.91 Ω	31.40 Ω	33.40 Ω	33.44 Ω	36.06 Ω	34.72 Ω	29.57 Ω
Ring Sensor	13.30 Ω	13.53 Ω	13.42 Ω	12.58 Ω	13.94 Ω	13.59 Ω	14.22 Ω	13.5 Ω
Pinky Sensor	11.70 Ω	11.90 Ω	12.78 Ω	11.70 Ω	12.04 Ω	13.6 Ω	13.05 Ω	12.2 Ω

TABLE III. TABLE OF VALUES FOR FULLY FLEXED FINGERS

Electrical Analysis of Flex Sensors – Fingers Fully Flexed								
Student	***E1***	***E2***	***E3***	***E4***	***E5***	***E6***	***E7***	***E8***
Thumb Sensor	11.8 Ω	14.02 Ω	12.79 Ω	12.5 Ω	12.81 Ω	14.31 Ω	13.5 Ω	12.15 Ω
Index Sensor	39.8 Ω	39.23 Ω	35.4 Ω	34.4 Ω	36.5 Ω	38.4 Ω	36.5 Ω	38 Ω
Middle Sensor	40.35 Ω	37.4 Ω	37.2 Ω	39.67 Ω	40.19 Ω	38.15 Ω	40.2 Ω	40.15 Ω
Ring Sensor	18.42 Ω	17.53 Ω	17.5 Ω	16.91 Ω	17.24 Ω	18.03 Ω	18.93 Ω	17.56 Ω
Pinky Sensor	15.3 Ω	16.7 Ω	12.62 Ω	14.19 Ω	15.13 Ω	17.6 Ω	17.99 Ω	17.03 Ω

2) Design

Fig. 1 shows the prototype control system block diagram. The prototype is developed with electronic components whose function is to perform the spelling of a word made by signs using a glove. The interpretation is performed according to the analog signals coming from five flexion sensors, one for each finger of the user's hand, as shown in Fig. 2. These signals are converted into digital signals with an ESP32 microcontroller through a programming code. Subsequently, the spelling is displayed via Bluetooth by a mobile application that maintains the connection with the microcontroller playing the generated word.

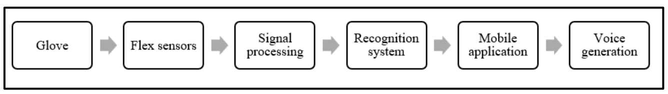

Fig. 1. Prototype control sustem block diagram

3) Prototype operation

Fig. 3 shows the design used for the PCB. The design was made in two layers, since, in only one layer, there were intertwined connections, and this would generate a short circuit in the board. Figure 32 shows a representation of the PCB board design, where the yellow color represented the traces taken by the first layer and the orange path represents the traces taken by the second layer. The PCB board was 85.2 mm wide and 51.2 mm high.

When the final printing of the PCB board was obtained, the continuity of the board was tested in each of the connections. This procedure was performed to verify that there were no short circuits generated by the printing on the CNC machine and thus avoid future damage to any electrical component.

Fig. 4 shows the assembled circuit of the glove. The sensors are located on each finger of the user. The sensors are connected to the pins of the ESP32 microcontroller through a custom PCB board.

The sensor signals are obtained by means of an electrical resistance during finger flexion, depending on the degree of flexion of the finger, they give different values. These values are recorded and then assigned to the letters of the alphabet.

4) Programming code

It is necessary to make a code that allows considering different ranges of resistance since people have different finger flexibility and different hand sizes, so a range of values was defined to know their intervals and thus, to be able to make the corresponding coding. The results obtained are shown in Table 4. The signal was generated, and the user waited 10 seconds with the signal until an established value range was obtained.

It is important to mention that, for pilot test purposes, only the letters a, o, l, h and delete text were recorded to create a blank space and redo the letter in the application.

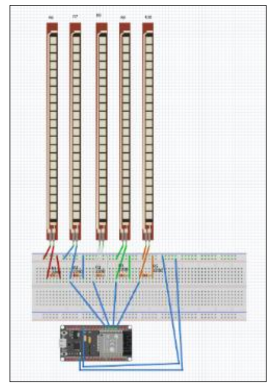

Fig. 2. Electrical System Design

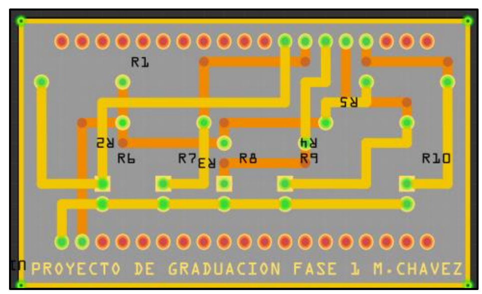

Fig. 3. PCB Design

Fig. 4. Final prototype

TABLE IV. TABLE OF RANGE VALUE

Range Value					
Letter	***Thumb***	***Index***	***Middle***	***Ring***	***Pinky***
Delete text	920	910	1725	1810	800
Letter A	830	555	1180	1160	565
Letter O	945	615	1290	1400	710
Letter L	955	820	1085	1190	580
Lettet H	800	755	1515	1155	580

Once the ranges of values were defined, we proceeded to create the programming that would be used to perform the sign language translation. The code considered the flexion of each person, so a deviation was defined so that the translation could be performed without any problem. The mathematical model to be used was (1). This model was applied for each of the letter representations mentioned above.

$$((\textit{finger reading} >= \textit{range} - \textit{deviation} \;\&\&\; \textit{finger reading} <= \textit{range} + \textit{deviation}) \quad (1)$$

5) Mobile application

An application was developed as shown in Fig. 5, to show the translation of the sign language and at the same time, it included a voice command to reproduce the word that was formed. Likewise, an interface was created that included information on deaf culture, use of correct terms, sign language and the dactylological alphabet.

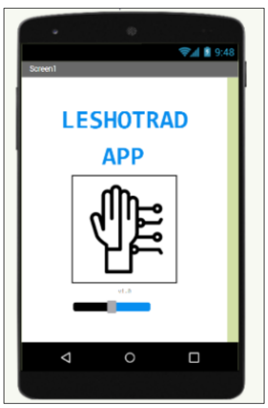

Fig. 5. Moblie application interface

B. *Prototype Evaluation Methodology*

1) Participants

The scope of the project was to test in a controlled environment due to time constraints. In the future we intend to test in a real environment with hearing impaired people

Seven students participated in the evaluation, 5 males and 2 females between 18 and 25 years of age.
age. It is important to mention that the people evaluated are not hearing impaired, but some of them have dealt with hearing impaired people.

2) Place of evaluation

The evaluation was carried out in the Biomedical Engineering laboratory in UNITEC, Tegucigalpa.

3) Procedure

A short presentation was given about Honduran sign language, correct use of sign language and the alphabet, and then each person was asked to manually make the word HOLA (hello in Spanish), as shown in Fig. 6.

4) Data collection

The results on word formation per student were as follows as shown in Table 2.

Finally, when the student finished performing the requested word, they were asked to fill out a survey to obtain feedback on the functioning of the prototype.

The survey applied was as follows:

1. Do you find the prototype comfortable when making the gestures?
2. What did you feel when using the prototype?
3. What difficulties did you have at the moment of making the requested word?
4. What did you think of the application?
5. Would you recommend the prototype?
6. What changes would you make to this prototype

Fig. 7, shows the result of the first question, considering three possible answers. 71.4% of the students found the prototype comfortable when they were asked to say the word HELLO, 14.3% did not find the prototype comfortable, and 14.3% responded that perhaps they found it comfortable.

For question two, the students expressed that they were afraid of damaging the glove when bending it to be able to perform the requested letter. Other students expressed that their hand felt very tense, due to the type of material used. Finally, another student expressed that it was complicated to put on the glove.

For question three, the students mentioned that the glove was only for right-handed people, that the material was very rigid, which made it difficult for them to sign. Another student mentioned that it was difficult for him to position his elbow correctly to be able to sign. Another student expressed the difficulty of positioning the thumb, due to the design of the glove. Finally, another student had no problem making the sign.

Fig. 6. Letter to spell

TABLE V. TABLE OF FORMED WORD PER STUDENT

Formed word	
Student	***Hola***
Student 1	HHoollaaa
Student 2	HHllooollllllaaaaaa
Student 3	HHHoollaa
Student 4	Hoollooaa
Student 5	Haollaa
Student 6	HHoolla
Student 7	HHoolla

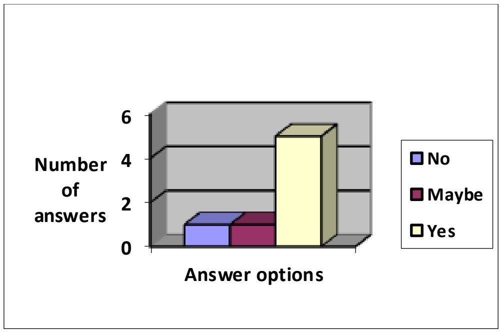

Fig. 7. Answers to question 1

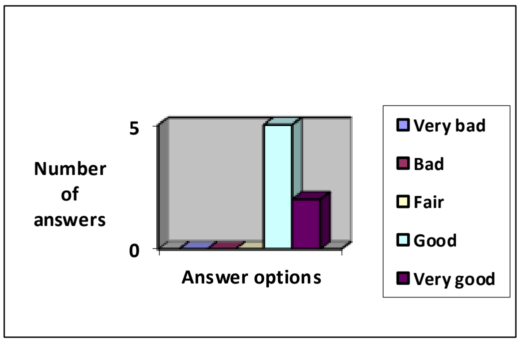

Fig. 8. Answers to question 4

Fig 8, shows the results obtained in question four, considering five possible answers. 71.4% of the students liked the interface of the application, however, 28.6% found the application good. During the pilot test, the students stated that it looked loaded with information.

The results obtained for question five were that 100% of the students would recommend the prototype to people close to them, institutions, universities, foundations or associations that are interested in learning about sign language.

Finally, in the last question, the students recommended to make a prototype for left-handed people, to change the material for one that allows more elasticity of the finger movements, to measure the glove to the size of the hand and to make an adjustment at the time of waiting for the change of letter in the code.

IV. Conclusions

A prototype translator of the typographical alphabet was created, which involved the testing of various materials and devices that allowed efficiency at the time of obtaining results, considering the precision involved in each movement during the initial tests throughout its development. That said, data were obtained with greater precision when choosing different types of materials from a common thermal insulation glove to the creation by software and hardware of a prototype with specific measures.

The failures of the base prototype made by the author were identified and solutions were provided for the solutions for these improvements. Among the best that were made was the creation of a customized PCB board that allowed to reduce the number of wires used, the size and the replacement of the protoboard. Similarly, a 3D-printed glove was created to provided greater comfort to the user when putting it on and handling it. These improvements helped to reduce the variation of the values coming from the flex sensors.

An electrical analysis of bending sensors was performed on UNITEC students. The results showed that even though the students had different hand sizes and finger flexibility, the values obtained in the multimers were very similar with a little difference between students. These results set the tone for defining the ranges of values in the programming code.

An application was developed to perform and display the translation of sign language made by the user. This application was designed with a user-friendly interface and with information about deaf culture and general information about sign language.

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