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# Construction of a robotic arm to improve the communication of people with auditive or non-verbal disabilities

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**Abstract**

This article presents a system that works as an alternative solution to help teaching sign language to most hearing people in a different way, by using a robotic hand that allows the rest of the population to learn this language in order to communicate and include the deaf community in society. Study experimental in nature, since a communication system was made through a robotic arm that is capable of simulating sign language in order to improve the quality of life of people with hearing difficulties. The methodology was analyzed in two phases: the first design and development and the second phase: Programming and integration of hardware and software. The change of materials in the unions allowed to obtain a flexible hand, which returned to its original position, this meant the improvement of the design, as for the development of the application for the control of the Arduino, a login interface was developed for the administration of the robotic hand. This ongoing investigation has been able to build an articulated robotic hand, with a high degree of flexibility.



*Keywords:* Peruvian Sign Language, robotic arm, articulated hand

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## 1. Introduction

Disability is the condition of life of a person, acquired during gestation, birth, or childhood or any other stage of life, that is manifested by significant limitations in the intellectual, motor, sensory (sight and hearing), and adaptive behavior, that according to [1], depends on the degree of hearing impairment, the sounds of oral language, and the barriers in the individual's environment. Likewise, people with hearing limitations face daily difficulties not only in communicating but also when entering the education system at any level. At present, they have different systems that allow the development of their cognitive process and the acquisition of life skills, such as the sign language system, dactylology, bimodal communication, and subtitles, among other [2] methods that somehow contribute to achieve a better standard of living and their inclusion in society. These losses have an impact on the development of thinking, speaking, and language skills; also, on behavioral, social, and emotional development, and school and work performance. Generally, these individuals have the ability to use sign language as a means of communicating with each other, yet they remain isolated from the community because of their hearing difficulty. Sign language is a linguistic system that has its own particularities and autonomy in relation to any language that is used by hearing people. It teaches manual and non-manual features with a linguistic function and a grammar of its own, manifesting itself in a visuospatial dimension [2] [3].

Sign language is by nature, a more detailed form of expressing emotions, allowing for it to be used by people with hearing impairment in a more practical way, and it is clearly designed for the manual representation of signs and letters of the alphabet. This combination of signing and reading is known as total communication. As stated by Cesar A. Hernandez [4], people with residual hearing capacity can make use of technological devices such as cochlear implants or hearing aids in order to enhance this residual capacity and allow access to spoken language; however, it is important to define the capacity and possibility of using technological tools that are appropriate for people with hearing impairment. Accordingly, it is important to note the studies and advances that have been developed with the technological advantages that are used in people with hearing disabilities, as it is allowing them to be included in society in various aspects such as work and community service what makes them feel useful to society and have more freedom as individuals. There are two types of joints that are most commonly used in robotics: the rotary joints that provide the robot with a level of rotational freedom around the joint axis, and the prismatic joints, which allow a movement along the joint axis [4] [5]. Likewise, robotics is defined as an activity that develops the construction of artifacts that try to simulate the human desire of creating beings in their own likeness and also, that unload people from hazardous or dangerous forms of work [6] [7]. On this grounds, technology in robotics has been taken into account as part of a service that is used in favor of people with disabilities, including hearing impairment, since it is an interdisciplinary area of many possibilities, as proposed by Ricillo [8], hence the need and the aim of this project: to develop a robotic arm, capable of simulating sign language, so that users have the ability to communicate more skillfully in their environment.

## 2. Methodology

Counting with the technological advancement and in the search of solutions and contributions with tools that generate possibilities and benefits for the hearing impaired community; we considered the development of this project, which consists of a communication system based on sign language by means of a robotic arm.

The methodology was developed as follows: Design and development, programming and integration of hardware and software.

### *2.1 Type of study*

This type of development or study generally presents difficulties due to human limitations in the capacity for numerical processing and precision and mostly, in the conditioning and coordination between man and robot [9]. Nevertheless, the practicality and instructions that are applied to the system allow the user to generate a fast and agile way of handling the device.

This study is experimental in nature, since a communication system was made through a robotic arm that is capable of simulating sign language in order to improve the quality of life of people with hearing difficulties. People need to communicate, and this need is either not met by those who face this disability, or the communication process is very difficult for them to perform. This difficulty manifests not only in transmitting ideas, but also in receiving them; and this impossibility generates a series of limitations and do not allow people with hearing disability to have quality of life day after day [10]. One of the limitations that affect hearing impaired people not only physically but emotionally, is the integration with the community, since it is very complex to adapt to a society that in some cases rejects, thus generates a series of learning problems that affect disabled people throughout their lives.

### *2.2. Investigation objectives*

The different sign languages that are used by deaf people around the world have not been invented as artificial techniques. They do not imply a second-degree codification, but have been created naturally within the groups of deaf people and their use is preserved and developed creatively, even if they have not been taught [11]. This information was taken into account as the base for the development of a robotic arm, which would allow the use of this sign language, within an appropriate and practical framework for the user. It should also contain a dictionary of common terms that may facilitate the interaction between the software and the user or consultant [12].

The aim of this investigation is to develop a system for the communication with hearing impaired people by means of the construction of a robotic arm, able to simulate sign language. The model of the system that has been developed is presented in Figure 1. The communication is handled through an APP that was developed in Android Studio, which manages the robotic arm. When a person without a communication impairment wants to communicate with one whose communication takes place through sign language, she/he simply has to speak in the application and the robotic hand will recognize voice commands from the sign language alphabet and the message is received by the hearing impaired person.

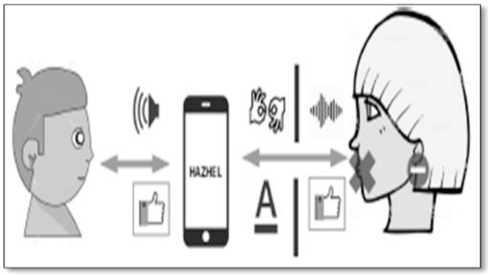



Figure 1. System operation diagram.

### *2.3. Participants*

This project is being developed in the city of Arequipa - Peru, at the Universidad Católica de Santa María, Faculty of Sciences and Engineering, Systems Engineering Program, within the framework of the degree that the members are developing. On the other hand, the population in Peru is approximately thirty-two million people (32,000,000), from which 73% are living in urban centers. There is a linguistic variation in the country, having Quechua and Spanish as official languages. On the other hand, there is 15% illiteracy and approximately 30% of the population lives in extreme poverty; all this leads us to analyze the panorama of deaf people. Likewise, the percentage of the population in 2014 with disabilities, in the case of disability, is as follows [13]: Move or use your arms or hands 14%, walk, raise or lower using your legs 28%, lister even if you wear a hearing aid 15%, learn, remember or concentrate 17%, see (even if you wear glasses) 26%. That is how in this section, we analyzed the problems that prevent hearing impaired people from developing normally and the problem of assuming that the right for education in Peru is only for children; reason why much people with this disability have never received education.

### *2.4. Materials and instruments*

The materials that were used for this project are detailed below: Arduino One, 5 Servomotors, Rubber bands, Bluetooth Module, Servo and Arduino extension cables.

### 2.5. Survey

At the present time, the Ministry of Education, together with other alliances, has taken responsibility for providing special education in Peru. Hitherto, only 26 special education centers have been registered and they are distributed as following: nine (9) in Lima, five (5) in Iquitos and Arequipa, and two (2) in Chiclayo, Cusco, and Trujillo.

With the enactment of the new law that consists in the integration of special people to different study centers, there was a result of integration but not of adaptation, since hearing impaired were placed in schools for listeners that did not have interpreters. Now, more than ever, the need to solve this problem is imminent.

### 2.6. Natural observation

The state has officially recognized Peruvian sign language and has established that all entities that provide public services must have a free of charge interpretation service. It should be noted that there are 532,000 inhabitants in Peru who suffer from hearing disability, that is 1.8% of the population; in addition, 32.1% of the disabled (1,575,402 people) have difficulty hearing even when using hearing aids. There are only 23 sign language interpreters recognized by the Association of Interpreters and Guides in Peru (Asisep). [14] [13]. Given that technology continues to advance, day by day more and better resources and procedures can be found to enable the improvement of tools and new devices. There are only two special schools in Peru, one for primary students and the other one for secondary students, both providing care for people with disabilities. These numbers are concerning as this population has many limitations in obtaining adequate public services, and the worst, these figures increase year after year [10]; notwithstanding, despite the efforts that have been made, Peru is lagging in establishing tools that generate inclusion, given that they are seen as individuals who are at the edge of the society.

### 2.7. Procedure

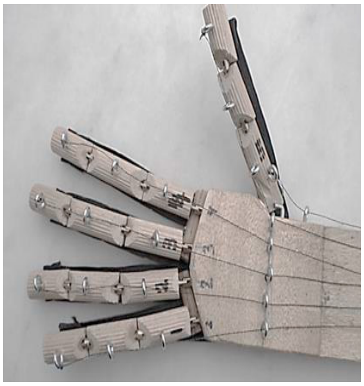
The development of the project was divided into two parts: design and development of the robotic hand, and software programming.

### 2.8. Design and development of the robotic hand

The design of a robotic hand consists of a mechanical structure, transmissions, actuators, sensors, end elements, and a controller. Its physical constitution is similar to the anatomy of the human being arms, and usually the components of the robot are referred to by the names of their corresponding part in the limb of a person [15]. For the aesthetic analysis, one must take into account the lengths of the phalanges, the weight, the gravity, the point of insertion of the muscle, the center of the joint, and the points of contact between the phalanges. In the kinematics of the hand, it is necessary to handle 30 mechanical variables: six for each finger, three force components, and three moment components. It is possible to measure the strength that one can apply in each of the fingers, as well as to change the grip kinematics, by using different finger phalange positions. This type of grip requires more power. The flexor and extensor muscles are there to secure the wrist and to grasp the object [16]. In the same way, taking into account that in its natural design, a hand is made of 27 bones, distributed as follows: eight in the metacarpus, five metacarpals, and a total of fourteen phalanges or also called digital; and that the hand itself is divided into three main parts: the phalanges or fingers, the metacarpal bones or palm, and the carpal bones or wrist, it is a must to develop a robotic system that is capable of simulating such operation [17].

Looking at the previous table, it is possible to understand that the mobility of the hand depends on the phalanges and the wrist or carpal bones, however, it is the first metacarpal in the thumb, which only has two phalanges, the one that gives mobility to the rest of the finger, allowing it to come into contact with the other fingers. In short, it allows the thumb to be opposite to the rest of the fingers allowing it to grasp or hold different elements and tools [17] [18], a key part in the development of the design of the robotic hand.

There is a variety of designs of robotic hands depending on the mechanism that is required for its operation. The mechanical systems are inserted in order to transmit the movement, increase the strength, and reduce the speed of rotation of the engines. Among the most commonly used mechanism systems in anthropomorphic robotics, we highlight the following: **Belts or chains**: Systems that are used to transmit strength movements between gearwheel. These systems are fast, and they respect the direction of rotation. The problem they may have is elasticity, possible displacements in the case of belts, and they have a lower torque compared to other systems. This option is discarded because we are talking about a small model, and the market does not offer belts or chains for reduced models (Fig. 2). **Gears**: Mechanical systems that are used to transmit mechanical power from one component to another. They consist of two gears called pinion (the smaller one) and crown (the larger one). The movement is transmitted in a circular fashion by contact with the gearwheel. The direction of movement is reversed. This system makes it possible to reduce speed while increasing strength and vice versa. These are not very elastic systems with a high torque [19], (Fig. 3).



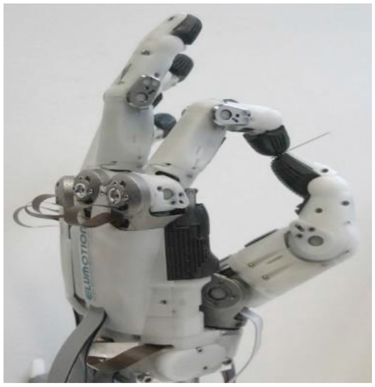


Figure 2. Prosthetic hand. Source: prometec. Jaume Nin [20] Figure 3. Geared hand. Types of robotic joint Source: [22]

In order to develop these perception methods, different criteria must be taken into account, some of which are conflicting with each other. Thus, it is necessary to consider the speed of the robot, its accuracy, its transcendence, and the possibility of inaccurate interpretation of the data, and the structure of the representation of the environment [9].

During the first phase, we took into consideration the design of the arm, the materials making it up, and how it works. Based on these premises, the use of wood was proposed, so as not to intervene with the use of the five servomotors, whose servo system communicates by means of electric pulses through a control circuit, in order to determine the angle of position of the motor [20], which were chosen because of their low cost, modularity, and the simplicity of programming.

### *2.9. Software programming*

In the development of software programming, the simple fact of getting a sequence of words into a computer is not enough, nor is just analyzing sentences; the computer must be programmed with full understanding of the domain text, and this actually possible for very limited domains. The efficiency of this type of system can be evaluated in the success rate of word or sentence recognition according to the type of recognizer that has been implemented, but this index or criterion depends essentially on one phonetics dictionary and on two models: on the one hand, the acoustic model, representing the probability distribution of phonemes in the audio signal, and on the other hand, the language model, representing the probability distribution of a sequence of words [21]. When the user makes a movement, applies pressure or makes a flexing motion, an analog signal is generated from the myoelectric sensor. This signal passes to the controller and by means of a pulse of a modulated signal; it generates the control action for the servomotors to tighten the tendons, allowing in this way the fingers to perform a rotational movement with which the fingers are curved [22]. Currently, there are several technologies to achieve gesture detection, but we will specifically address those involving hand gesture recognition. Technologies have been divided into two groups: local and portable. The best-known local technology is that of the Kinect sensor, which allows the physical recognition of people, movement, postures, and hand gestures. The other method is an automatic processing algorithm that learns the movements and gestures that are going to be detected and then compared [23].

There are several alternatives for robot programming, different to the box diagram or decision tree programming that is provided with the robot, which has rather limited functionality. The following languages are mainly used for programming using high-level programming languages: [24]. **RobotC**: Integrated development environment that aims at programming the NXT or RCX under the C programming language. One of its advantages is that it does not need to replace the original firmware of the robot; it works under the original one. Among its main features one can find an interface that is similar to VisualBasic, tools to perform the debugging of our applications, and tutorials to learn the language syntax; and it also allows the execution of different tasks in a concurrent way. **LejOS**: For programming in this language, it is necessary to replace the original firmware of the brick with this one. Currently, it can be installed on both the RCX and the NXT brick. It includes a JAVA virtual machine, which allows the Lego Mindstorms to run applications that have been implemented under this language. It includes functions for the control of virtually all the sensors and actuators, even those that have been developed by third parties, such as the compass, the accelerometer, and the camera. This firmware is the one chosen for the development of our project. **BricxCC**: Bricx Command Center is a well-known IDE that supports RCX programming with NQC, C, C++, Pascal, Forth, and Java using brickOS, pbForth, and LeJOS. With BricxCC you can develop programs in NBC and NXC. Both NBC and NXC use the standard NXT firmware. This software is available in open source. **NXC**: NXC is a high-level language like C. It uses the original LEGO firmware and is available for Windows, Mac OSX, and Linux (ia32). Developed by John Hansen. There is a programmer's guide and a tutorial available in English (http://bricxcc.sourceforge.net/nbc) and can be used as a BricxCC.

At the time of developing the software programming, it is important for the data that has been obtained in the simulation of the fingers of the robotic hand to allow to establish that none of the structure exceeds the point of breaking; that is to say, the strength that is produced by the servomotor should not reach as to break the structure of the fingers. However, the material may display deformation or stretching if the strengths or temperatures used are higher than those applied in the simulations. The programming and calibration at this stage are an important point for the proper functioning of the device, since the servomotors must be brought to specific angular positions. When sending a coded signal, the angular position of the servomotors changes and will remain steady as long as there is an input line [20]. On the other hand, there should be a part within the main program where the letter that corresponds to the sign is written in a text box so that the person knows, when the box appears, that the letter was recognized. After the sign, the robotic hand should be placed in a resting position, while the program asks the person to emulate the same sign as the hand did and checks with the patterns to see if the sign is correct. [25][23], and the five servos (for each point of tension), while the articulated hand is attached to a forearm at the base. We used wires for the flexible joints and for generating tension according to the signal that is sent from the mobile device, as shown in figure 2. This makes for the sensory perception system of the robot to be able to adapt automatically according to the variations that take place in its environment [9]. The model that was built is shown in figure 4.

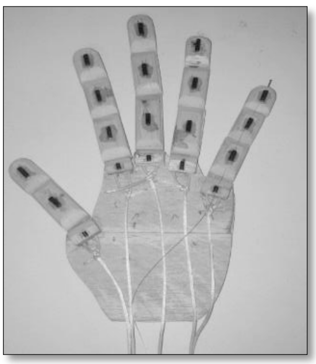


Figure 4. Articulated hand design.

## 3. Results

During the first part of the development of the project, there were some limitations, specifically in the assembly of the robotic arm

Initially, the joints of each phalanx of the finger were modeled with a material that stressed each finger when it was moved, even though this material fulfilled its function, the same pieces had enough resistance to be bent.

As per the development of the application for the control of the Arduino, figure 5. Shows the logue interface of the application, and figure 6 shows how the robotic hand is managed from the application.

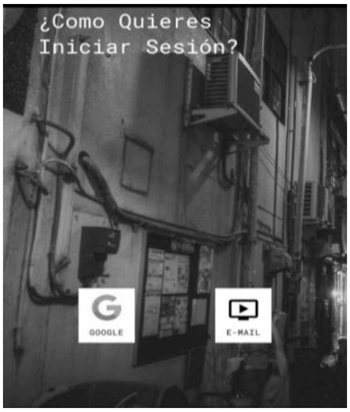



Figure 5. Login interface of the mobile application.

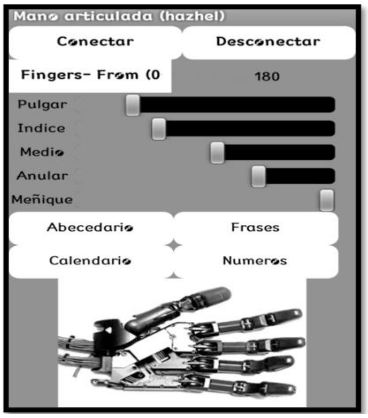



Figure 6. Mobile application administration interface.

## 4. Conclusions

This research, still in progress, has made possible to assemble an articulated robotic hand with a high degree of flexibility. It is important to mention that it is a low-cost device. There is no doubt that the development and implementation of this system can generate positive results in the population. This is because the autonomy of a mobile robot is based on the automatic navigation system, whose systems include planning, perception, and control tasks [9].

In order to advance in the process of improving the proposed model in the future, emission and reception updates will be carried out both to the user and to the target public, that is to say, tests that allow the recognition of signs.

Throughout the world, technological progress is being used to help people with disabilities, in order to make them part of a more inclusive society [10]. As time goes by and the technological era advances, it is encouraging to obtain information about new developments in robotics in the world, [26] as these new advances that are being generated can help the community as they contribute to make the receiver or individual move the substitute member, perform maneuvers, and even experiment with the purpose of building technological prostheses that allow "feeling”. A few decades ago, these advances were only a utopia, but nowadays, they are real and increasingly effective [5] [27]. Also, it seeks the advancement of voice synthesizers, no longer controlled with the fingers but directly with the brain.

## Acknowledgements

We appreciate the intention and good will of the government and state of Peru, for conducting studies with the purpose of reaching this population with disabilities, who are still at a disadvantage despite the technological advances of the current era, as according to the figures that are mentioned above, the situation of care and linkage of this population to access public services is quite limited.

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