Innovative Device for Enhancing Deaf-Mute Persons Communication Possibilities

Diana Cotoros, Anca Stanciu, and Alexandra Hutini

***Abstract*—The device presented in this paper was designed in order to give a hand to the deaf-mute community, by helping them to reintegrate in the society, using the modern technologies. We aim at manufacturing an intelligent glove based on the use of sensors in order to obtain a communication bridge with a decent speech level between the persons suffering hearing loss and the persons with normal hearing. The development and design of the glove represents an endeavor that aims at obtaining pertinent data from fingers' motion. The prototype functionality can be easily compared with gloves for virtual applications as they work on the same principle, namely sensory activity and test subjects will verify the concept objectives.**

***Index Terms*—Deaf-mute community, sensory glove, flex sensors, Arduino board.**

I. Introduction

Speech is the principal mean of communication between human beings. Unconsciously the hands, face or body movements always accompanied communication because during a conversation people feel the need of gesticulating in order to express their feelings and make themselves better understood. Deaf-mute persons transformed these involuntary gestures in a certain language, a mimic one, which may be slightly different according to the residence country.

It is well-known that auditory function facilitates communication. This aspect is critical in interaction with other individuals and helps maintaining organized cohabitation. The ability of speech is the result of emitting sounds that people are perceiving like words. Language, regardless of its nature is learning by imitation and if the ear is unable to perceive the pattern then it cannot reproduce it. This is the reason why deafness is mostly the cause of dumbness.

But the biggest problem for a deaf-mute person is the fact that most normal people do not understand the sign language leading thus to difficult situations for the hearing impaired and creating a gap between normal and disabled people, [1]. During the last years, many research and advanced technologies were involved in developing new possibilities for this disabled category, usually based on vibro-tactile or visual feedback, provided these senses are compensating at a certain extent the loss of hearing [2].

Some patents provided all kinds of devices usually comprising of a processor control, which includes a microphone and a speech recognizer to receive and process audio data in order to identify potentially dangerous situations [3].

Another approach focused upon detecting the hands gestures in the field of robotics by developing both artificial hands mimicking the natural behavior of the human hand and prosthetic hands helping to recover the lost functions. Gesture recognition is classified into two main categories: vision based and sensor based, but the problem resides in translating the sign language into a form of communication which is accessible to a normal person by help of any type of interpreter, usually a sensor glove of various conceptions and structures.[4]-[6].

Systems based on vision use cameras as main instruments to obtain input data required to recognize hand gestures. The main benefit of using a camera is the act that it eliminates the need of sensors, reducing the production costs of the system. Cameras are cheap enough and most laptops or smartphones are using a camera with high resolution. However, there are various issues like:

-limited visual field of the capture device

-high calculus costs

-recognizing the hand shape affected by the background status

-illumination sensitivity that may influence tracking the fingers' motion

But the main shortcomings of the systems based on vision are due to the need for complex processing by using a computer and the continuous use of a camera, which is kind of difficult in everyday life.

Systems equipped with sensors like: flex sensors (or bending), accelerometers (ACC), proximity sensors and abduction sensors, are used to measure the bending fingers angles, the abduction between them and the wrist orientation. The degrees of freedom which can be accomplished by using such a glove are ranging between 5 and 22, according to the number of included sensors. A major benefit of the sensors systems is the fact that they can directly report the relevant and necessary data as far as the voltage values in the calculus device, avoiding thus the need for data processing.

Communication resides from four fundamental elements: sender, receiver, information and channel. The sender represents the source of the communication process, by initiating the message transfer towards the receiver that will interpret the information according to their own perceptions. But the communication cannot take place if the auditory, visual or vocal channels are not activated. Hearing damage or its definitive loss due to an accident or a serious illness may lead to speech deficiencies, or even worse when the individual is born deaf because even if he is physically able to speak, the lack of hearing conditions or stops him to develop this skill. As a result we can say there are two types of

Manuscript received September 18, 2020; revised December 23, 2020.

D, Cotoros is with Transilvania University of Brasov, Department of Product Design, Mechatronics and Environment, Brasov, Romania (e-mail: dcotoros@unitbv.ro).

DOI: 10.7763/IJMO.2021.V11.777

communication: verbal and non-verbal.

The device proposed by the paper was designed to significantly diminish the communication problems between the deaf-mute persons and the normal hearing persons and overcome the sign language barrier, by using a glove with flex sensors and translating messages into written words that can be understood by everyone.

II. Theoretical Aspects

It becomes obvious that the deaf community is practically stopped in its development and it is not due to their inability of evolving or performing professionally, but because of a damaged social system which is responsible for the fact that they cannot enjoy the facilities granted to a hearing person and also are unable to lead an independent life.

During the decades, a lot of methods were attempted, surgical as well as educational to remedy the hearing loss issue because it is usually impossible to treat or cure. Regaining hearing does not come together with speech, as a person who never heard must first understand the sounds and only then start learning something that a normal child learns in his early years of life, respectively word pronunciation and understanding their significance.

Sign language involves combining several forms of hands orientations and motions as well as arms. But in order to correctly transmit the words significance, facial expression is equally important. This is the main problem of the SLR systems developers, reason why most researches were based upon implementing portable devices as sensory gloves that concentrated on the hand activity. Thus, most of the developed gloves are able to recognize only the alphabet letters, but this is enough to allow the deaf persons to communicate because the can build words or sentences. There are mainly two categories of such devices: commercial systems and non-commercial systems.

The commercial system based on sensory gloves is a mean by which the deaf-mute persons are able to perform communication without meeting various obstacles or being dependent on an interpreter of sign language. This is using the technology based on bending sensitivity which captures the hands and fingers motions and transforms them into digital measurements in order to be read.

Commercial devices are usually using expensive components, as a consequence the price for the users is high. In academic research studies flex sensors are mostly used for measuring fingers’ bending because they present the benefit of a lower cost and a simple manner of operation, respectively when the finger is bent the flex sensor also bends, thus the output resistance of the sensor can be measured and calculated later in various applications.

By developing a non-commercial system we mean designing and manufacturing a device by own endeavor. The non-commercial sensory gloves have a main component consisting of the flex sensor, which plays the part of discerning the changes brought up by fingers bending and to transmit the data to other electronic devices, often to a computer processor.

The present paper aims at presenting a SLR type system (Sign Language Recognition) with minimal expenses and easy to use, based upon the use of a glove equipped with flex sensors. The concept of an intelligent glove is different of that of the systems based upon ASL (Alphabet signs language), because the development of a system able to identify the most frequent used expressions is required so that the communication process takes place as fast as possible.

In order to manufacture the intelligent glove it was necessary to place 5 flex sensors, one for each finger, an Arduino board Uno vR3 type, to collect the impulses received from sensors and convert them in digital values, and a LCD 1602 to display the data obtained following the conversion. In order to demonstrate the device functionality, four signs were chosen which in the mimickal gestural language are not translated as the messages assigned by the system programming because the glove can capture only the values resulted from fingers’ movements and not of the entire body as it is required in order to correctly transmit the information. The messages related to the four signs are the following: „I am thirsty”, „I am sick”, „Yes” and „Thank you”. In case the fingers are not in a suitable position for one of the four expressions, the display will mention the message “Nothing”. To be noted that the glove allows the change of the configuration settings without requiring the change of the entire source code, thus a high number of expressions can be accomplished.

III. Materials and Methods

The Arduino UNO vR3 board is very versatile, this being the reason why it is the most used board in the Arduino range. It is a development board based upon a microcontroller ATmega328p and is provided with 14 digital pins I / O, 6 analogic inputs, a quartz crystal of 16 MHz, a USB connection, a power plug, an ICSP set of pins and a reset button. It also contains everything necessary to support the microcontroller functionality because it can be connected to a computer by USB cable or can be powered by an Ac-DC adaptor or even a battery.

For the present device, it was required to use both the digital pins and the analogic pins on the Arduino board. The digital pins are used both for the digital input (reading the switch status), and for the digital output (controlling the LED). Analogic pins are used for reading the values of the analogic voltage received by the sensors and then converts them into digital values in order to allow reading.

Powering the flex sensors and the LCD 1602 display was performed by using VCC (5v) and GND pins available on the board. In order to control the LCD, the digital pins were used, while for the flex sensors the analogic outputs were involved but also the internal ADC (Analog Digital Converter) of the microcontroller to read the data.

The fingers’ bending motion is taken over by the flex sensors on the glove in the form of electric impulses and sent towards the microcontroller Atmel ATmega328p inserted in the Arduino board in order to be processed and the data are shown on the display.

This display is ideal for projects requiring simple and fast information. LCD 1602 is illuminated so that it allows reading in dark rooms or during night time. In order to design the backlight a 10k potentiometer is necessary. There is a possibility to reduce the number of pins used for connecting the LCD to only two, in case of using an I2C module.

The diagram of the LCD module is presented in Fig. 1.

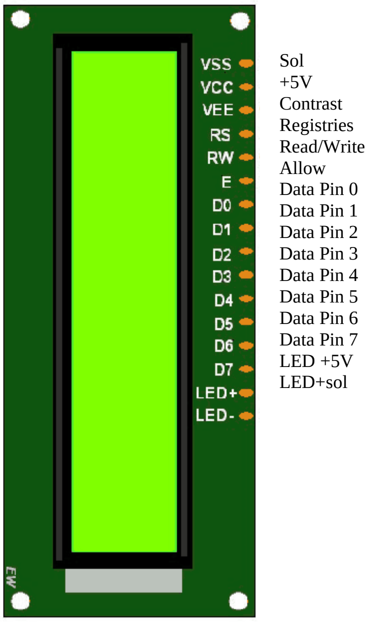


Fig. 1. LCD diagram.

The electronic assembly connecting the LCD and the development Arduino board is shown in Fig. 2.

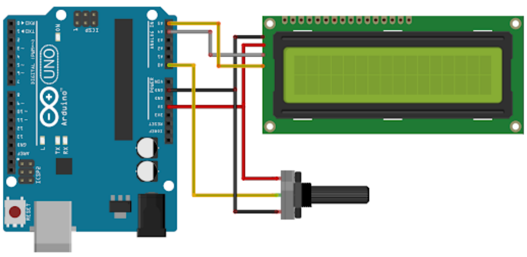


Fig. 2. Electronic assembly diagram of LCD and the Arduino board.

Flex sensors are used in various fields due to their interesting properties to change their bending resistance especially for the human segment in biomedical devices in order to record static and dynamic postures. The flex sensor detects the degree of bending thus when the sensor is bent it creates a resistance output correlated with the bending radius and its resistance increases with its bending.

In spite of the robustness characteristics, low cost and long service life, they often demonstrate a nonlinear response and sensitivity for small bending angles.

In order to use the flex sensor with an Arduino development board also a static resistor should be used to create a voltage divisor. Thus, a variable voltage is created and can be measured by the ADC converter.

The glove sends permanently data to the sensors and in order to process them an electronic board was required. This means that the functionality of the entire system is based upon the Arduino board which controls both the flex sensors and the messages display on LCD. The LCD control was accomplished by help of the library defined in Arduino.

The glove is designed to be a wearable device but at the present stage its supply is done by computer connection through an USB cable, which transfers the data in the server part, but it is possible to get power from a battery if necessary.

In order to manufacture the system, first the electronic diagram was designed using Proteus 8.4. After the functionality simulation both from electronic and programming point of view the physical implementation of the electronic module was performed. (Fig.3 and Fig.4)

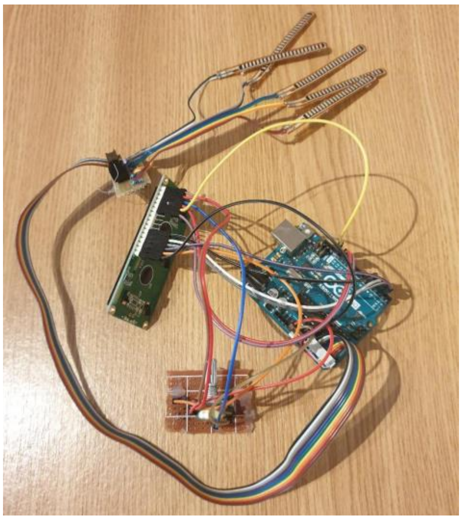


Fig. 3. The final assembly.

Fig. 4. Location of sensors on the glove.

Flex sensors which were located on the glove play the part of transmitting a voltage signal towards the development board Arduino UNO vR3. The conversion between analog and digital is done by help of the microcontroller ATmega328p, which manages the program used for detecting the captured analogic voltage by the flex sensors and converts them in digital signal using the microcontroller ADC. Then the data obtained following the conversion are sent to the LCD 1602, which is going to display the message corresponding to the bent finger according to the developed software. The recognition program is written in C++ programming language using the IDE Arduino software.

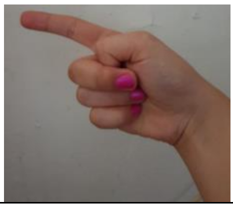
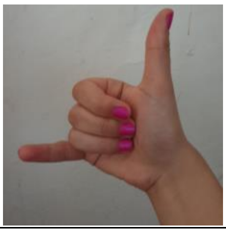
In order to accomplish the LCD programming, the LiquidCrystal.h library was used as it is predefined in this programming environment. This library was used for controlling the LCD of the device.

IV. Testing the Device

This stage is very important because there is necessary to prove that the device does not require calibration before use in order to recognize sign language and translating it into text.

The test subjects were asked to wear the glove and reproduce the four signs presented in table I.

TABLE I: EXPLANATIONS OF SIGNS

No. sign	Sign	Message
1.		Yes
2.		I am thirsty
3.		I am sick
4.		Thank you

According to the results obtained following the functionality testing, the proposed signs for demonstrating the system efficacy were recognized and translated into text for all subjects. This proves the fact that the users are not going to be confronted with issues due to the lack of sign knowledge because of avoiding calibration. When the system does not get any action it will display "NIMIC" which is the Romanian word for nothing (Fig. 5).

After analyzing the test results and interviews with the test subjects, the following conclusions were found:

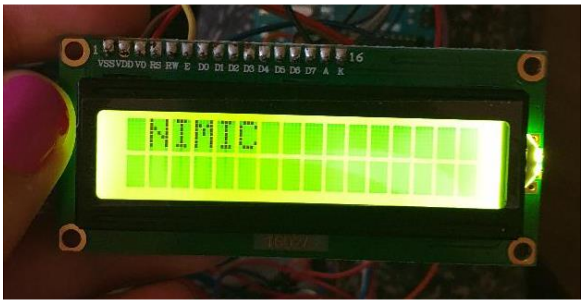


Fig. 5. Display of word "nothing" in Romanian.

The sensory glove does not present wearing difficulties from dimensional point of view, but the size of the glove effectively used to place the flex sensors is sometimes of essence. This must be chosen according to the hand size, so that the user does not feel any discomfort when using the device. There are also some difficulties due to the cabling system of the flex sensors. But considering the fact that the glove is to be used for a long period for communication, this aspect can be neglected.

1) The device is easy to use and this is confirmed by all subjects. The only action is to reproduce the sign corresponding to the required expression, and it will be displayed by the sensory glove LCD.
2) The proposed signs were easily reproduced but the subjects stated that it might be difficult to learn many other signs.
3) The subjects agreed that the system is suitable to translate sign language.

V. CONCLUSIONS

The hardware components that make up the device are small, allowing the system to be transported easily and safely. Also the reduced size of the components of the glove create a high mobility degree so that the device does not present difficulties in wearing. The sensory glove can be worn permanently by the user and used every time it is necessary. The software allows the system to be wearable because if the device is powered by a battery the connection to the computer is no longer necessary and the data resulted after the conversion performed by the Arduino board are not simulated in a program but directly displayed on the LCD. The device requires no calibration before use.

The general aspects that need to be taken into account by the future researches concern the following:

-The material used for manufacturing the glove itself, for the SL recognizing system should not be randomly chosen because the sensors inside the systems are directly placed on the glove material surface. Thus, the material used for the glove should be elastic and comfortable in order to not restrain the user's freedom.

-In order to protect the electronic circuits housings are to be designed so that they provide the required cover. Besides the size of the board used to collect the impulses generated by sensors, as well as the other parts placed on the glove should be small enough to improve the glove aspect, so that it is suitable for everyday wear.

The development of the translation system based on using gloves aims at assisting persons with hearing disabilities in everyday life. As a follow, the device should not be permanently connected to a computer in order to ensure its portability.

Also in order to overcome the limitation brought by the reduced number of expressions and sentences that can be translated by the sensory glove, an accelerometer can be added, so that data can be recorded also from the hand motion, not only from the fingers as in the present system. The number of expression and/or sentences can be easily doubled by including two sensory gloves in the system.

ACKNOWLEDGMENT

The authors wish to address thanks to Alexandra Hutini, the student from Transilvania University, Medical Engineering, who helped developing the tests.

REFERENCES

[1] N. Advani, S. Bora, A. Bhat, and S. Yerolkar, "A survey on communication gap between Hearing and speech impaired speech persons and normal persons," *IJCSN International Journal of Computer Science and Network*, vol. 2, no. 6, Dec. 2013.

[2] M. Sobhan, M. Z. Chowdhury, I. Ahsan, H. Mahmud, and M. K. Hasan, "A communication aid system for deaf and mute using vibrotactile and visual feedback," *International Seminar on Application for Technology of Information and Communication (iSemantic)*, 2019.

[3] H. Butnaru and W. O. Krueger, "Communication device and method for deaf and mute persons," U.S. Patent 6,240,392 B1, May 29, 2001.

[4] R. Anbarasi, R. Hemavathy, and M. A. Dhanalakshmi, "Deaf-mute communication interpreter," *International Journal of Scientific Engineering and Technology*, vol. 2, no. 5, 2013, pp. 336-341.

[5] P. Mátételki and L. Kovács, "Interpreter glove - An assistive tool that can speak for the deaf and deaf-mute," *Software Quality*, 2014

[6] A. Raut, V. Singh, V. Rajput, and R. Mahale, "Hand sign interpreter," *The International Journal of Engineering and Science (IJES)*, vol. 1, no. 2, 2012, pp. 19-25.

Diana Cotoros was born in Brasov, Romania on November 1st 1962. She studied mechanical engineering at Transilvania University of Brasov and graduated in 1986, then got her Ph.D, in the field of mechanical engineering in 1998 by the same university.

She worked as an engineer until 1991 when she started working as an assistant professor for Transilvania University of Brasov. Since 2016 she has been PROFESSOR at the same university, published 9 books, around 120 papers and was involved in over 10 research projects. During the last years, her research interests shifted from mechanical engineering to medical engineering and biomaterials.

Prof. Cotoros is member of sromeca (Romanian Mecathronics Society) and received in 2010 the award of Transilvania University for ISI published papers.

Anca Stanciu was born in Calarasi, Romania on February 1th 1977. She studied technological engineering at Transilvania University of Brasov and graduated in 2005, then master in computational mechanics, Mechanical Engineering Faculty, continued her Ph.D., in the field of mechanical engineering in 2011, Faculty Mechanical Engineering, by the same university, got postdoctoral scholarship (18 months), the products and processes, "Transilvania" University of Brasov, Faculty Product Design and Environment.

She started working as an assistant professor for Transilvania University of Brasov in 2005. Since 2014 she has been LECTURER at the same university, published 3 books, around 50 papers and was involved in over 14 research projects. During the last years, her research interests shifted from mechanical engineering to medical engineering and biomaterials.

Lecturer Stanciu is member of SROMECA (Romanian Mecathronics Society) and received in 2013 Certificate of the postgraduate program for professional skills, "Quality, innovation, communication training system of higher education for teaching staff", science of education, patent received in 2020 for laminated composite materials.