Intelligent Glove For Group Conversation For Deaf-Blind Users

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***Abstract*—Deaf-blind people have different degree of combined visual and auditory impairment resulting in problems with communication, information access and mobility. This impairment requires the person to depend on a caretaker who also plays the role of an interpreter with the external world of hearing and sighted people. In this paper, we proposes an efficient way of bidirectional group communication for deaf-blind people, an assistive hardware/software system that supports users to interact with the environment, to establish social relationships and to gain access to information sources without an caregiver.**

***Index Terms*—Deaf-blindness, Deaf-blind English alphabet, Human centered design**

I. Introduction

The primary mode of communication for deaf-blind is touch. Touch cues can be utilized in basic communication .Advanced tactile signing techniques and tactile alphabets, such as, the deaf-blind manual, Lorm, or Malossi, are the preferred and popular communication system. In the last decade, many devices explored the possibility of incorporating touch-based languages into wearable technology in the form of gloves. However there are no current devices that facilitates bidirectional, one-to-many communication which supports both text and voice messages.

In this paper, we propose an intelligent Glove, a wearable interface designed for deaf-blind people with support for bidirectional, one-to-many communication aimed to make them completely independent in communicating with others, interacting with the world, working, and being fully included in the society. In Section 2, we provide a taxonomy of the related terms and keywords. In Section 3, we review the exiting technologies to support deaf-blind communication. In Section 4, we introduce the hardware design of the proposed prototype. In Section 5, we identify the evaluation procedure for the proposed design followed by possible future works in Section 6. We conclude in Section 7.

II. Background

A. Deaf-Blindness

Existing literature [1]–[3] defines deaf-blindness using different specific language but all seem to intersect on the idea that deaf-blindness is a condition where a person is considered both deaf, the impairment of hearing, and blind, impairment of sight. In addition to people with complete loss of hearing and sight, individuals who are partially impaired are also considered to be deaf-blind. A person can be deaf-blind at the time of birth or acquire it at any time throughout their life.

Understanding what deaf-blindness is can be challenging due to large number of subgroups that must be considered. Figure 1 visualizes these subgroups. The two main groups the deaf-blindness can be divided into is *congenital* and *acquired*. Congenital is when both hearing and vision impairment is found to be present at birth. In these cases it is important to realize that the child will be severely hindered when using traditional methods for early development and education [2]. The acquired subgroup can be further broken down into 3 subgroups: (1) congenital hearing impairment and acquired vision impairment; (2) congenital vision impairment and acquired hearing impairment; and (3) acquired vision impairment and hearing impairment.

B. Communicating as a Deaf-Blind Person

Humans are social in nature and require effective communication to function with society. Unfortunately, those with deaf-blindness are at a disadvantage with the methods in which they can communicate. For example, if a person is born deaf or blind, then they might use sign language, braille, white cane or the assistance of another person. Acquiring a second impairment resulting in a form of deaf-blindness (See Figure 1.) further reduces the options in which one can communicate. This is further complicated by the degree to which the individual is impaired. Possible forms of communication may be [4]:

- Spoken languages
- Sign languages
- Tactile languages[1]
- Deaf-blind manual alphabet[2]
- Spartan[3]
- Braille Keyboard typing

Each of these forms of communication has their own limitations that makes them less than ideal. For example, spoken language and sign language are very quick and similar in speed but also require a steep learning phase. In addition, sign language is only effective to other people who also know the language. Similarly, if spoken language is the communication option of choice, then it is easy for surrounding people to

[1]Tactile languages: feel signs being made on wrist
[2]Deaf-blind manual alphabet: manually sign each letter of the alphabet
[3]Spartan: draw capital letters onto the person's palm

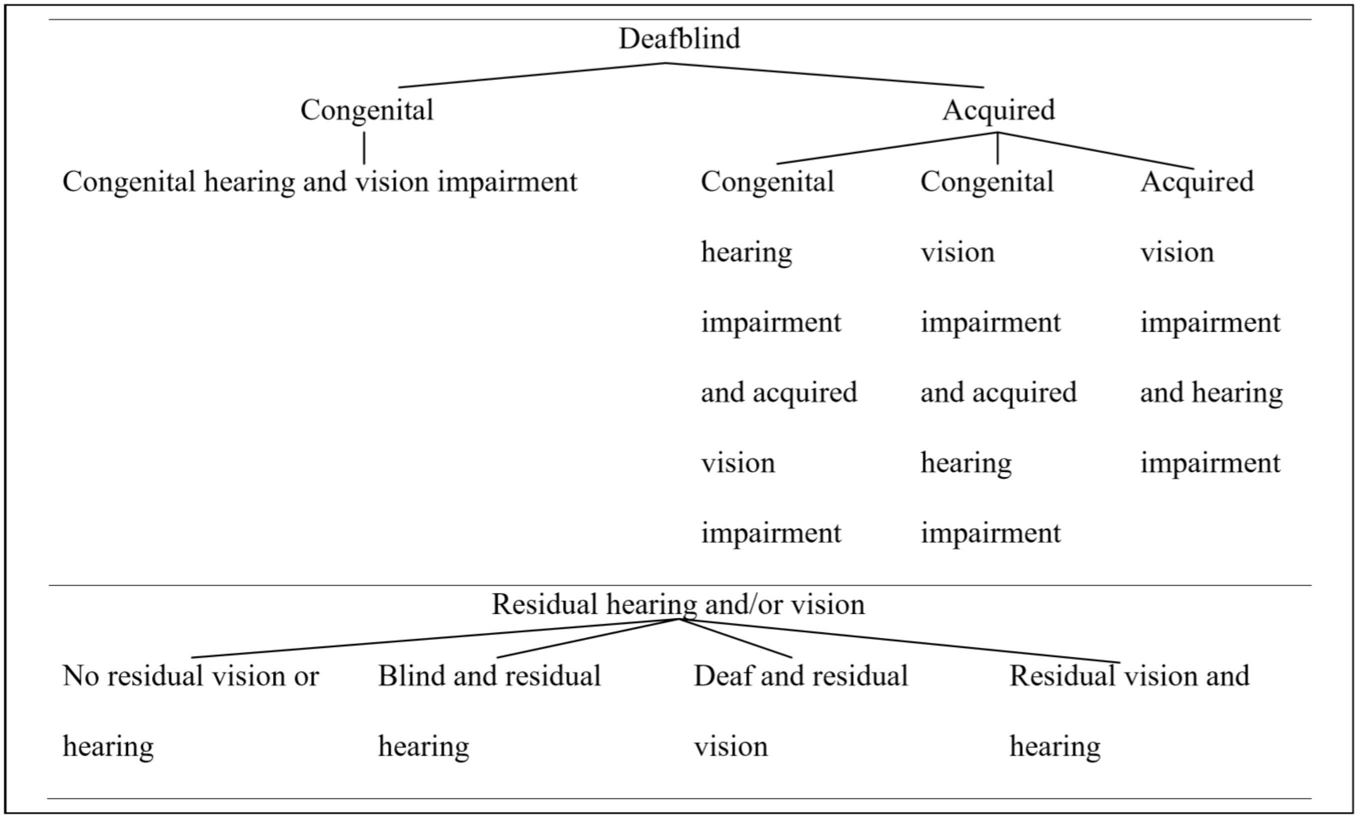

Fig. 1. J. Dammeyer's representation of subgroups for deaf-blindness [3]

understand but is difficult to understand the response [4]. This greatly reduces the number of people to communicate with, such as a random stranger in public. Manual alphabet and Spartan are much easier to learn but are slow and cannot be used in a community setting due to the nature of these forms of communication that require touching a single person. In most forms of communicate available to deaf-blind people, community communication is difficult.

C. Human Centered Design

Human centered design is the approach we have used for our design. Human centered design **(HCD)** is exactly what it sounds like, an approach to solving problems with a focus on people. There are three phases of HCD: (1) Inspiration; (2) Ideation; and (3) Implementation [5].

The inspiration phase is the time to study and understand what the client or people your design is intended for. This means doing the observation yourself and forming what the problem is based on those observation. While the client has prior knowledge and has a need, their recommendation for the solution must not be immediately taken on as the solution. This is because clients/users do not always know what they need. Ideation is the next phase where there is now an understanding of the problem and ideas can be generated. Prototyping of these ideas with user feedback should allow for a sense of if the idea is a move in the right direction to solving the problem. The implementation phase is where the focus will be making the product as close to a finished product and eventually moving into the hands of the target market.

The principles of HCD are simple to explain and understand. The four principles are: (1) Focus upon the people; (2) Find the right people; (3) Think of everything as a system; (4) Always test your design decisions [6]. Their simplicity is part of why it has become popular in addition to the ability to adapt HCD to most existing processes.

D. Minimal Viable Product

The term **Minimal Viable Product (MVP)** has become synonymous with the startup culture that has taken off in the last decade. MVP is similar to HCD in some ways but they differ in that MVP is meant to be a iterative process of making a product or service. HCD is more of an ideology that can be applied to almost any process including MVP. After each iteration, the goal is to have a product that is production ready. This product does not need to be a complete version that is ready to distribute to its user base. For the features that do make it into the iteration, they must be fully functioning and usable if it was sold.

V. Lenarduzzi and D. Taibi [7] have tracked how MVP has changed over time as more and more disciplines adopted the process. One of many signs that a minimal viable feature has been met is if the product can be deployed to the customer.

From a requirements perspective, they must meet the needs of early adopters who are the target market. The implementation should be as small as possible but still motivate its users/customers to provide feedback on how to improve in future iterations.

MVP is seen in software all the time. Many startups form off of a core idea and fully flesh it out as a product or service. Snapchat[4], a popular social media platform, started out allowing users to send a photo to a friend for a user defined number of seconds and then would disappear from the user's phone. While the app was very basic in its functionality it was still a viable product. Over the years Snapchat has added new features such as video messages, text messages, the ability to save images, etc. Each time ensuring that for every new iteration, their product was still viable and fully usable. It is very likely that most of these features were thought of and planned long before they made it into the release of the application. If they had waited to release their application after all features were completed, then it is possible the company may not have been as successful as they are today.

III. Literature Review

Caporusso et al. [8] describe DB-HAND, as an assistive hardware/software system that supports deaf-blind users. DB-HAND consists of an input/output wearable peripheral (a glove equipped with sensors and actuators) that acts as a interface to enable communication using Malossi language that is easily learned by a deafblind. Fig.2 shows the distribution of the symbols in Malossi alphabet. DB-HAND is a wearable-hardware/portable-software system that includes a glove equipped with transducers that convert signals from tactile impulses to text messages and vice-versa. Messages are sent and received by the user in Malossi alphabet exactly as it is taught to deafblind people, without any other variation. Once messages are sent by the user, tactile impulses are converted to digital format and they are then interpreted by DB-HAND software application, which distinguishes them as either commands or simple text, depending on the content of the message. In the first case, the user's input is recognized as a control signal for an application (e.g. "close the tab" or "open a new window"); otherwise, it is entered as text in the program having the focus. Feedback is provided by converting the response of an application in Malossi alphabet: messages are delivered to the user's hand as sequences of vibrations in the areas where the letters are located. This way deafblind people are enabled to autonomously operate a personal computer, read and write text documents, surf on Internet pages, chat, send e-mails, participate to forums and, extensively gain access to information and establish social relationships.

Gollner et al. [9] have designed an intelligent glove for those deaf-blind people who use Lorm language. The main motivation for the authors of this paper, was the hardness of dead-blind people in engaging in social activities since

[4]Snapchat Website: https://www.snapchat.com/

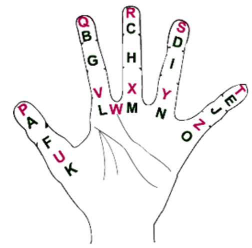

Fig. 2. Location of the characters in Malossi alphabet [8]

their languages are almost unknown for the rest of the people. Moreover, by rapid growth in using smartphones, and consequently textual communications, the traditional ways of communication do not provide this opportunity for deaf-blind people to have communication in the textual medium. The authors have followed the HCD procedure in their research. First of all, they have had multiple interviews to define their target clients, knowing better their problems, and also getting familiar with existing solutions for those problems. Moreover, they have designed multiple prototypes, each of which has tried to address issues found in the feedback sessions. The main glove consists of fabric sensors as input, the vibration motors as output and also an ATmega32, equipped with Bluetooth as the main processing unit. The design schema of this glove is shown in Fig.3

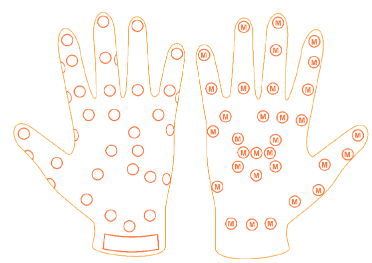

Fig. 3. Sensors and vibration modules in Mobile Lorm Glove [9]

Although this paper, is one of the most reputable design papers for the deaf-blind community, the main issue with this paper, is a high level of modification to the traditional Lorm language, which is not pleasant for many clients.

In a similar work to the Mobile Lorm glove [10] proposes an intelligent glove for converting textual messages to Braille language and vice verse. The authors of this paper, have used many findings of the mobile Lorm glove, e.g., using each side of the hand for only one task, either sending or receiving the message.The general scheme of braille is shown in Fig. 4

As the deaf-blind manual, Lorm, and Malossi, are the preferred communication system in the communities of people who are deaf-blind Caporusso et al. [11] introduced db-GLOVE, a wearable interface for touch-and gesture-based interaction which is specifically designed for providing people suffering from multi-sensory conditions with support for bidi-

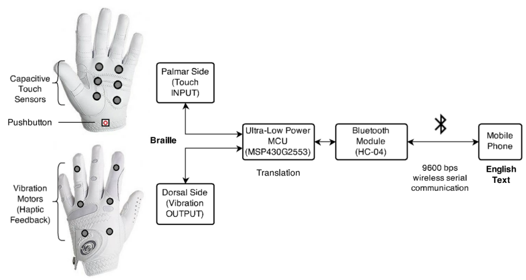

Fig. 4. A general schema of Braille Glove [10]

rectional communication. dbGLOVE is designed to refine the work discussed in [8] to incorporate several already existing touch-based languages, so that people who are deaf-blind are not required to learn a new communication system, which is among the most complicated tasks for them. The proposed device can be utilized by the people with multi-sensory impairments to input text and messages via touch. These, in turn, can be displayed on a screen so that the sighted can visualize them, they can be translated into speech with a Text-To-Speech (TTS) system, or they can be transmitted over the Internet to people who are co-located or remotely located. In addition to providing users with an input interface to PCs and smartphones, dbGLOVE incorporates actuators which enable simulating touch cues in the form of vibrations over the palm of the hand, so that the deaf-blind can use it as an output device, to receive feedback and to read messages. db-HAND architecture shown in Fig. 5 consists of a device structured in two components: the central unit and a replaceable pad. The former is responsible for acquiring input from the user (i.e., movement of the hand, touch cues over the surface of the pad, and the flexion/ extension of the fingers), processing signals, and communicating with an external device (e.g., PC or smartphone) equipped with drivers and applications.

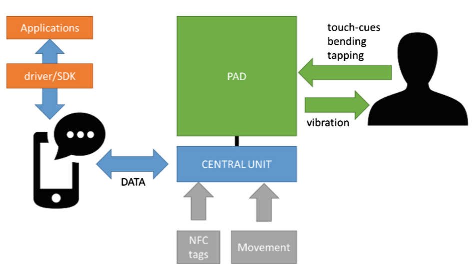

Fig. 5. Block-diagram of db-GLOVE architecture [11]

Multiple research designs are inspired by the way the deaf-blind people communicate. Using the palm as the medium for communication has inspired the designer of the PalmType [12]. PalmType, provides a virtual QWERTY keyboard on the palm, in a way that each alphabet touch would be detected via the wrist-worn sensors. These sensors will send the typed messages to other smart wearable devices, e.g, Google glasses. The main motivation for the authors of the PalmType has been providing a new way of communication through smart wearable devices, which are usually limited in the type of input messages to the ways such as voice commands. Although this project has not been designed for the deaf-blind community explicitly, it has addressed some of the issues in the previous design projects for the deaf-blind clients, for instance, in contrast with the Mobile Lorm glove, there is no need for the client to wear the gloves. Moreover, many deaf-blind people have partial impairment in their hearing and/or visual system. Therefore design projects which are compatible with other devices such as smart glasses would be useful.

By the high popularity of smart devices, such as smartphones, many assistive communication devices have been designed in a modular-based to benefit from the services offered by smart devices. [13] introduces an assistive glove called GlovePi, that uses android built-in text processing for conveying the typed messages via the glove. The client would be able to send the messages by touching the sensors in the Malossi language. these messages will be transferred to an android smartphone via a raspberry pie module. The android application would be able to send these messages in the textual format or read them via the speaker. This ability makes live conversation possible. However, some features in this design project make it a little challenging for daily usages, for instance, the listener should have installed this application on his/her device, and connect to the raspberry pie of the speaker before a conversation. This necessity to install an application for strange people would be a limiting factor for the popularity of this device. The general diagram of this design project has been mentioned in Fig. 6

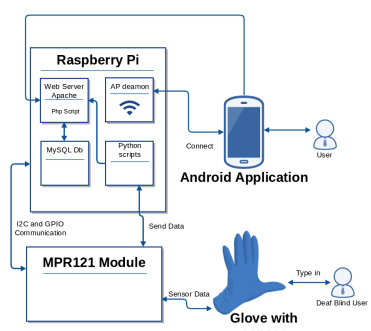

Fig. 6. The general scheme of the components in GlovePi [13]

GLOS [14], is a low-cost and non-invasive device that will allow the deafblind individuals to comprehend speeches in real-time. This wearable device uses components such as a Raspberry Pi 3 board, a simple microphone, and haptic feedback vibrating disks. The recorded speech from the microphone is processed by the board and encoded into 5 haptic vibrating modules attached to a glove. GLOS has the potential in helping deafblind individuals in order to increase their capability to communicate with non-impaired ones.

IV. Methodology & Design

First and foremost, to polish our main inspiration for this project, we have to ask a group of participants who are true members of deaf-blind community. Although during the last three months, we were trying to consider ourselves in the deaf-blind's shoes, we can not evaluate our initial idea without an active collaboration of deaf-blind people. We have selected Human Centered Design(HCD) instructions as our guideline in the design process.What distinguishes HCD from other problem solving approaches is its focus on understanding the perspective of the person who experiences a problem, their needs, and whether the solution that has been designed for them is truly meeting their needs effectively or not. After clarification of our initial idea, the main focus is on the hardware design of the project.

A. Formative Interviews

In order to identify usability issues with current available technologies for communication for deaf-blind users, we will conduct formative interviews with 12(6 male, 6 female) users. Participants will be recruited through CNIB Foundation and who are users of current communication devices and who also have the dexterity to use a mobile device. Our questions will focus on two primary topics: current use of communication devices, and breakdowns and workarounds related to these communication devices. Each interview will last about 20 minutes.

We will ask informants about the communication devices they used regularly. We will then identify the language used in these devices(deaf-blind manual, Lorm, Malossi, or Braille) and if the particular device converts text or voice to the corresponding haptic feedback. We will also ask about how they coped with these technologies and if they have any workarounds. Finally, we will ask about difficulties that they encountered using these technologies.

B. Hardware design

According to human-centered design principles, each successful design product, besides its functionality and applicability, should be viable and more importantly affordable to the clients. That is the main reason that almost all the related works that we reviewed in the literature review section, have used some common micro-controllers as their main controlling unit. Among these papers, Raspberry Pie micro-computer and also AtMega-32 microcontroller have been more interesting for designers. Both of these computation units are tiny medium-level devices that can be used for general-purpose functions. Due to the features of our design pattern, Raspberry pie would be more appropriate for us. We decided the former since it would lead to the cheaper prototype, since the Raspberry Pie is en assembled general-purpose computer that supports various mediums of connection, e.g., Bluetooth and wireless. Besides the final cost, the lightweight of this micro-computer will lead to a better user experience since it would be easy to carry by the client. Among the available models of Raspberry Pies, Raspberry Pie 3 B+ would be our ideal controlling unit. This microcomputer comes with 4 USB ports, and it has been equipped with 1GB RAM, and a powerful 1.4 GHz 64-bit ARM Cortex A53, that can run hard tasks, e.g., signal processing.
The tactile language that we have chosen for our product is the deaf-blind English alphabet. This tactile language has been popular in many English spoken countries since the 1970s. A general catalog of the way that each alphabet conveyed has been depicted in Fig. 7
The general scheme of this product has four main component:

1) **Sensors**: In contrast to the related design papers that have been reviewed for this project, e.g., the Lorm glove [9], to provide the ability to use all the English alphabets, we have to detect various events on the glove, e.g., the touches, different levels of pressure and also the motion of the fingers on the palm. Due to these requirements, we have considered 38 coin-shaped sensors on the palm and the fingers. These sensors could work independently as well as in a cohort to convey different alphabets according to the instructions of the deaf-blind alphabet. As it has been shown in the Fig 7, this language is used on the palm of either right or left hand.

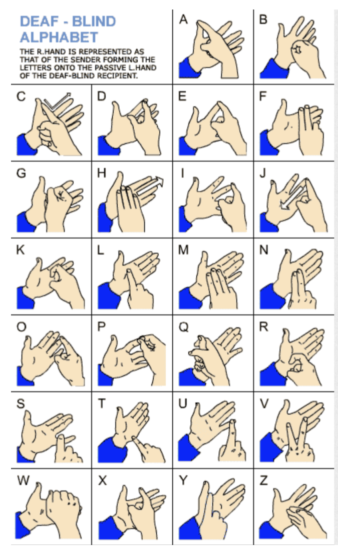

Fig. 7. A general catalouge of deaf-blind English alphabets source

Since all the design products related to these tactile languages remove the physical contacts, several new issues appear. For instance, in the original version of tactile languages, the listener knows when the message of the speaker is going to be finished when the physical connection between the hands of the speaker and the listener pauses. But in our design product, there is no physical contact that addresses this issue. To come up with this challenge, we have considered an automatically adjustable time-slot, that will be set by the processing unit. This time slot will be modified based on the pace of communication of each side of the conversation. When each side of the conversation starts to represent them self, all the alphabets that have been soken or pressed on the glove will be considered as a single word, i.e., this time slot would clarify the boundaries of the phrases. Fig. 8 shows the initial design of our intelligent glove. In this figure, the red dots depict the sensors.

2) **Vibration Modules**: We have considered multiple vibration modules in the same locations as the sensors. The reason that we have not considered the backside of the hand, similar to the Lorm glove [9], or using two gloves, one for sending and the other for receiving, is that in our opinion, both of these modifications would lead to lower user satisfaction. We know that a fraction of our target audience, are senior citizens who are not interested in dramatic modifications in the existing language. Besides the high degree of modification, using a pair of the glove would cause other challenges such as the connectivity, the power constraints, and communication latency. Besides the vibration modules on the palm, there are four rectangular wrist vibrators, that guide the client to recognize the direction that the speaker has stood during the conversation. These vibrators would lead to a more natural live conversation for both sides in the communication. We have considered four wrist modules to handle conversations up to four attendees. It has to be noted that this is the initial design idea, and we have to analyze the trade-off between the number of attendees and also the user experience for the client by observing the feedbacks of the clients after using the initial prototypes. Fig. 8 illustrates the general design of the glove. the blue dots represent the vibrators.

   In the absence of physical contact between the attendees, as well as the sending procedure, recognizing the end-point for each word and phrase would be problematic. For this component, we will benefit from a phenomenon called **funneling illusion** [15].

   This phenomenon creates a flow of vibration during transferring each word. For instance, consider that the user has received the word ”hello”. The processing unit after analyzing the whole word, issues a command to turn on the cohort of vibrators that are assigned to alphabet ”h”. After an appropriate period, the cohort that is representative of the alphabet ”e” should vibrate. However, by using funneling illusion, the decrement in the vibration of the ”h” related vibrators happens gradually and simultaneously with the gradual increment in the vibration of the responsible vibrators for the alphabet ”e”. This procedure will continue until the last alphabet of the word.

3) **Controlling unit**: Raspberry Pi 3 B+ would be our ideal controlling unit. This micro computer supports wireless connections as well as Bluetooth. This micro-computer comes with 4 USB ports, and it has been equipped with 1GB RAM , and a powerful 1.4 GHz 64-bit ARM Cortex A53, which can run hard tasks, e.g., signal processing. The main task of this component, is handling the input messages both in the accepted format through the glove and also the voice of the speaker and convert them to each other. This micro computer could work with raspian OS or Windows 10 IoT Core. Based on its hardware feature, it would be able to process the incoming voices. We found multiple libraries and frameworks for speech processing in python. Python speech recognition library offers both offline and online speech recognition via well-known APIs ,e.g., google assistant, IBM Watson and Alexa.

   This dual support of offline and online speech processing frameworks, will act as a strength for the glove. In the situations where the internet connection is not available, the offline version will help the client to engage in conversations with an appropriate level of accuracy. But the best accuracy and also some other features such as multi-lingual conversations will be possible in the presence of Internet connection. Some of the mentioned online API-based speech processing services offer speech processing in various languages, e.g., Japanese or Spanish. Therefore by using these online services, the client can not only attend live conversations, but also can communicate with non-English speakers as well.

4) **A set of Microphone/Speaker**: A microphone will be used to transfer the messages from others (mainly a person out of the deaf-blind community) to the client. Reversely, the speaker will be used to transfer the message through the sensors, to the audience. This component would make the true live conversations for the deaf-blind client. We have considered our product as a modular design to make it compatible with all the devices, e.g., the third-party smart-phones.

The general scheme of our design has been shown in Fig. 8

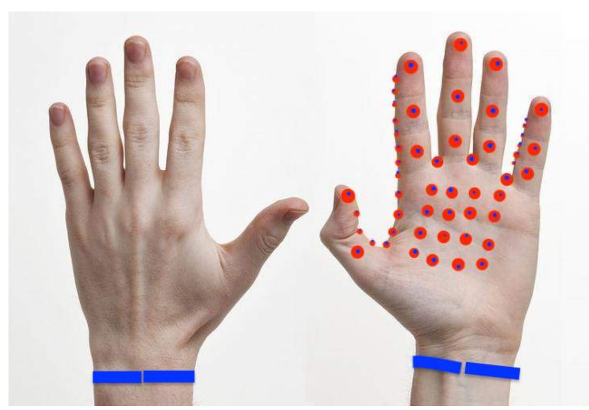

Fig. 8. A general scheme of intelligent glove

V. Evaluation

As a fundamental part of the Human-centered design, we will do our best to find some volunteers from the deaf-blind community for feedback observation, both before starting the design procedure and also after each initial prototype. So we will do a surveys before doing research by questionnaire. Moreover, our initial prototypes will be a mock of the glove without the functionality. We continue this feedback observation step by step as much as we go further in the technical details.

Thirty users will be selected to participate in our study to evaluate the performance of our prototype. Participants with normal vision and hearing, and no prior knowledge of any tactile languages will be selected. Also, they must have normal sense of touch, which will be evaluated with a simple assessment based on sensitivity to pressure. We did not recruit any people with multisensory impairments because our objective is to preliminarily evaluate the effectiveness of the device, before involving individuals who are more delicate and prone to frustration.

After the introduction, participants will be given our device and guided through its operation by the experimenter. The experimenter demonstrate each application, describing the operations needed to perform each of the three tasks. After being walked through each task, the participant will be prompted to verbally describe how to complete the task and then to perform three practice tasks. Once the participant successfully demonstrated the practice task three times, the experimenter moves to the next task. At the end of the practice session, the participant will be given an opportunity to perform any additional practice tasks that he or she wished. The practice period can last about 20 minutes. Once the practice session are completed for the device, the experimenter begins the experiment.

In the experimental study we will evaluate the efficacy of our prototype as a bi-directional communication tool and also as a one-to-many communication tool. We will also evaluate the performance of our prototype as a real-time speech recognition system that encodes live spoken words into haptic vibrations for the user to comprehend. To this end, we divide the study in three experimental tasks focusing on the output features of the device and on the input features of the device. We will utilize two different groups of users for task 1 and 2, because our objective is to evaluate the input and output features separately.The experiment is realized in a noisy environments to reproduce the condition of real-life scenarios, though all participants will be allowed to comfortably sit in front of a desk with the equipment.

In task 1, participants will be delivered tactile stimulations at various intensities over the palm of the hand, and they will be asked to identify the area in which the stimulation occurred. Specifically, trials involve 3 sets of stimulations each consisting of 5 pressure cues at different intensities, and on different sensitive areas. Both intensity and location will be chosen randomly, ensuring that each trial included different intensities and areas, in order to deliver at least one stimulus for each sensitive area . In each trial, motors will be activated according to a specific pattern. In the first task, we focus on evaluating the effectiveness of the device in representing output. Specifically our objective will be three-fold: (1) obtaining the range (minimum and maximum) in terms of intensity for vibration to be recognized correctly; (2) studying the efficacy of our prototype as an output device; and (3) identifying critical areas of the hand in terms of recognition of the stimulation.

In task 2, participants will be provided with an deaf-blind alphabet manual for 15 min before the beginning of the task. Then, they will be presented with random letters , and they have to touch the area of the device representing that letter. The objective of the test is to evaluate the effectiveness of the device in recognizing input from the user, in terms of sensitivity of the actuators, and thresholds for avoiding spurious signals. In regard to task 2, the focus is on the input features of the device. Specifically, the objective of the study will be two-fold, (1) to evaluate the accuracy in detecting input, and (2) the time spent by users to understand our communication system.

Next we will study the performance of our real-time speech recognition . The objective of the study will be two-fold, that is, (1) Accuracy of Conversion of Speech to Code, and (2) Operation Time. For this phase of real-time speech recognition thirty English sentences with various levels of difficulty will be tested. Three examples of sentences with increasing level of difficulty are: ”Hello”;”What is your name”;”How long have you had been in that address”. After the processing using our prototype the percentage of characters and words recognized correctly by each user will be measured. The operation time is broken down to two sections: (1) Speech Recognition and Conversion Time: This time is measured from the start of the audible speech to the start of the haptic vibrations. (2) Haptic Vibration Time: It is measured from the start of the haptic vibration to the end of it. (3) Total Communication Time: It is the sum of the speech recognition and conversion time and the haptic vibration time, from the start of the audible speech until the end of the haptic vibration.

VI. Future Works

We have considered multiple future works. Since this design project is the initial version, we have followed principles of HCD guidelines and also the minimum-valued-product guidelines. Concerning these guidelines, we have focused on releasing the experimental prototypes as soon as possible by focusing on general aspects of the design.

One important future work is reducing the final cost of the project. In the time of writing this project, the final cost of each raspberry pie is almost 73 USD. We can reduce this amount by designing our hardware specifically

Since the deaf-blind people experience different levels of impairment both in the visual and hearing perception, an intelligent glove which is compatible with other smart agents , e.g., smart glasses could be an extension to this work. Also, the glove could offer more features than the traditional deaf-blind alphabet by defining the other areas, e.g., the back of the hand, as a specified keyboard for the client-defined phrases. So by this shortcuts, the general pace of the conversation could be increased.

Battery life is a challenging issue that should be studied. In almost all the portable electronic devices, there is a trade-off between the duration of service persistancy and the capacity of the battery. Similar design products use an external lithium battery. This type of batteries have some drawbacks too, e.g., short service-time, heavy weight, and spoilability. Some new types of chargeable batteries have been produced, that could convert the moves to the electricity. By using this natural source of energy, we could at least reduce the size of the required external battery which leads to a lighter battery and consequently more user satisfaction.

Besides all the mentioned future works, one of the necessary issues that has to be studied carefully, is reducing the latency in the real-time conversations. Some approximate time-boundaries should be considered to make the live conversations realistic. In the absence of physical contact between the sides of a conversation, the processing and converting the messages to the acceptable format for both sides of the talk is time-consuming and could lead to long unpleasant time-delays. One of the possible extensions to this work is using machine learning to predict the next alphabet based on the applied gesture of the client. However, For this purpose, a curated labeled dataset would be needed.

VII. Conclusion

In this paper, we presented our design product which is an intelligent glove for deaf-blind clients, that helps them to engage in live conversations with the rest of the society. As a result, it empowers deaf-blind people to engage with a broader spectrum of people, thus enhancing their independence. Low rate of literacy in almost all deaf-blind languages has limited them to have communications with only some of their significant ones. By this glove, the deaf-blind client can use one of the most common tactile languages in the deaf-blind community, i.e., deaf-blind alphabet with the audience who are not familiar with this language. Moreover, this glove provides various opportunities, e.g., information gathering through the internet, and also interpretation between the client and smart-devices, such as smartphones.

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