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Research Article

Empowering Communication: Artificial Intelligence-Driven Robotic Hands for Deaf and Deaf-Blind Individuals through Assistive Technology

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Abstract

For people who are mute or have trouble speaking, sign language, often known as hand speaking, has grown in popularity as a communication tool. Sign language conveys words and letters using hand gestures. Understanding other individuals and their surroundings is difficult for those who are deaf or deaf-blind. Deaf people communicate with others through sign language to get over their isolation. Deaf-blind individuals, on the other hand, are blind and utilize tactile sign language, which they interpret by moving and touching other people's hands. It is more difficult for deaf or deaf-blind people to interact with others in their community when they are unfamiliar with sign language or uncomfortable with its tactile form. Additionally, as it enables them to interact with their surroundings, learning sign language is essential for deaf individuals as well as those who live with them. This robotic hand is designed to help the deaf and deaf-blind communicate through the use of artificial intelligence (AI) assistive technologies. It can also help with sign language training and be a useful tool for anyone who want to learn sign language, even those who are deaf. For deaf students, artificial intelligence (AI) has a lot to offer, mostly in the form of improved accessibility and communication. Deaf students can follow lectures and debates thanks to real-time captioning and transcription provided by AI-powered speech recognition (ASR). Additionally, learning materials can be made more accessible by using AI to create sign language movies in response to text cues. Also covered are the challenges faced by deaf or deaf-blind individuals using assistive technology when using a robotic hand. Also covered are the difficulties with robotic hands for those who need assistive technology and are deaf or deaf-blind.

Keywords: *Artificial Intelligence (AI), Assistive Technology, Deaf, Hearing Loss, Robotic Arm, Sign Language.*

I. INTRODUCTION

Hearing loss is defined as the inability to hear as well as someone with normal hearing, defined as having hearing thresholds of 20 dB or better in both ears. One can experience mild, moderate, severe, or profound hearing loss. It can cause trouble hearing loud noises or conversational speaking in one or both ears. People with hearing loss ranging from mild to severe are referred to as “hard of hearing.” Individuals who are hard of hearing typically communicate verbally and can take advantage of captioning, cochlear implants, hearing aids, and other assistive technology [21-24]. People who identify as “deaf” typically have substantial hearing loss, which means they have little to no hearing. They communicate frequently by using sign language [1].

II. LITERATURE REVIEW

The deaf-blind employ a five-fingered mechanical finger spelling hand called Dexter. The hand functions as an output communication device, translating ASCII characters into one-hand sign language finger positions. Similar to how they would "read" a human interpreter's hand, the deaf-blind user "reads" the letters by putting their hand over Dexter's hand

and sensing the finger gestures. Early trials show that the deafblind can effectively use Dexter. The background, design, building, and testing of Dexter are reviewed in this work [7]. Deaf blindness is a unique disability characterized by a dual sensory reduction of both hearing and vision. For some deafblind individuals, communication via touch may be their most accessible sensory channel. Multiple techniques that rely purely on touch exist within the deafblind community. One method of interest, referred to as "Deafblind Tactile Fingerspelling Alphabet" in Australia or "Deafblind Manual Alphabet" in the U.K., comprises twenty-six tactile symbols representing the letters of the Latin alphabet. This letter describes HaptiComm, a device designed to reproduce the sensations generated during finger-spelling communication The HaptiComm comprises an array of twenty-four strategically placed electrodynamic actuators [25] specifically designed to produce distinct tactile sensations upon which the fingerspelling alphabet is constructed. The first experimental evaluation showed promising results, suggesting further investigations related to the timing and pace at which the stimuli are produced [4]. People who are deaf or deaf-blind find it more difficult to interact with others in their community when they are unfamiliar with sign language or uncomfortable using the tactile form of it. Furthermore, as sign language is a form of communication with their surroundings, studying it is essential for deaf individuals as well as others who coexist with deaf individuals. Teaching sign language with 2D resources—pictures and videos—is less successful than teaching it with 3D resources, which provide a comprehensive illustration of the gestures used in sign language. The concept and development of a robotic hand that converts written Arabic texts into the Arabic sign language alphabet is presented in this work. The purpose of this robotic hand [26] is to function as a communication tool for the deaf or deaf-blind individual using assistive technology. Furthermore, it can be a useful tool for deaf persons and those who wish to learn sign language to help with sign language instruction. Three experimental trials involving three distinct volunteer types—deaf, deaf-blind, and non-deaf/non-deaf-blind—were conducted to evaluate the robotic hand. The results were very promising; the success ratios for gestures recognition were 86%, 81%, and 67%, respectively [2]. In Arab countries, the number of hearing-impaired people exceeds 10 million. In Egypt, the number of hearing-impaired people is around 4 million. So, sign language is important for facilitating communication between the hearing impaired and the rest of society, but not all the rest of society knows this language, so a new approach is suggested for designing a smart glove that can be used as a part of an electronic system to translate the sign language into a spoken or written language. This design covers all Arabic sign language signs (word level) by using as few sensors as possible. The design is based on statistical analysis of all Arabic sign language words concerning finger angle, orientation, single-hand, double-hand, and single-stage movement gestures. This work uses a simulation model to explain the proposed design and discusses the findings of the statistical analysis [3]. One crucial step in gathering information about congenital deaf blindness (CDB) and deaf blindness (DB) is comparing the findings of various research investigations. The variability in the definitions and inclusion criteria employed in the publications made it difficult to determine the eligibility of the studies when attempting to conduct a systematic review of the literature on cognitive evaluation and CDB. The current systematic study seeks to offer recommendations for improved future research procedures as well as an overview of this methodological and terminological variation. A sample of the scientific literature on DB and CDB was provided by a systematic examination of definitions used in (N = 30) research using psychological assessment of individuals with CDB. Absent or heterogeneous definitions and inclusion criteria regarding both DB and CDB are evident in the sample. Fifty percent of the studies reported no definition of DB, and 76.7% reported no definition of CDB. The main discrepancies are: (1) medical/functional versus ability/functioning definitions regarding DB; and (2) different criteria for onset of DB in the case of defining CDB (e.g., age versus developmental level). The results of this study call attention to a scientifically inadequate approach to the study of DB and CDB. The results show that precise guidelines are required for sample descriptions of the CDB and/or DB populations. It is recommended that research involving individuals from CDB and DB supply the following data: definitions of DB and CDB that are employed; the degree of sensory impairments; the age at which DB manifests; the degree of sensory ability in connection to mobility, information access, and communication; and the communication and linguistic abilities at the outset of DB [5]. The creation of a wearable tactile communication device with vibrotactile feedback for assistive communication is presented in this work. The interface is based on finger Braille, a straightforward and effective tactile communication technique used by those who are deafblind. To depict the six dots of Braille, it is made up of a vibrotactile actuator and a flexible piezoresistive sensor that are integrated and placed at the index, middle, and ring fingers of both hands. While the actuator makes use of the electromagnetic principle through the use of a small NdFeB permanent magnet and a flexible coil, the sensors were constructed utilizing flexible piezoresistive material. Both were combined to create a tactile communication glove with Bluetooth that lets deafblind persons use Braille codes for communication. Twenty end-users (10 deafblind and 10 sighted and hearing) were used to evaluate the tactile interface under controlled conditions. The results showed that users can detect and distinguish vibration at frequencies between 10 and 200 Hz, which is within the FA-II receptors' perceivable frequency range. According to the findings, non-experts in Braille could send and receive words like "BEST" and "JOURNAL" with an accuracy of about 75% and 68%, respectively, in 25 and 55 seconds, respectively [6]. We address the planning and creation of a communication system in this effort to improve assistance for the deafblind. The foundation of the system is an advanced motion tracking glove that enables high-fidelity finger position detection and, as a result, identification of the fundamental signs of the Malossi alphabet. Various use cases are explored for a natural, simple-to-learn alphabet extension that facilitates single-hand signing without the need for touch surface sensors. The main goal is to communicate via an extended Malossi alphabet in a Data Glove-based interface for interactive control of mobile robots and remote messaging. The deafblind population, where remote communications and automated support and services are becoming more common, could find this very interesting. After a brief training period, the intended Data Glove-based communication interface can be mastered with little modification to the Malossi alphabet. The Data Glove's natural interaction style and the deafblind community's affinity for the Malossi alphabet should significantly aid in the broader acceptance of the created interface [8]. The development of a new bi-directional communication tool will enable spoken interaction amongst deaf, deaf-blind, and nonvocal people. When a nonverbal person uses their fingers to spell words, the technology analyzes their hand shapes and outputs the spelled words as synthetic speech. This part of the communication aid functions as a "talking glove" in actuality. Furthermore, through the application of cutting-edge voice recognition technology, a deaf user can read spoken messages on the small LCD screen of a customized digital wristwatch. In the same way, a portable braille display module can be used by a deaf-blind person to read spoken messages [9]. When interacting with others, those who are deaf or silent often struggle with communication. These people find it difficult to communicate their thoughts because not everyone can understand sign language. The goal of this study is to create a Data Acquisition and Control (DAC) system that converts sign language into universally readable text. Gesture Recognition and Sign Language Translator is the name of this system. We created a smart glove that recognizes hand motions and translates them into legible text. This text can appear on an integrated LCD display or be wirelessly delivered to a smartphone. The experimental results clearly show that a set of low-cost sensors that monitor the positions and orientations of fingers can capture motions. With a 96% recognition accuracy, the system as it is now can interpret 20 of the 26 letters [10]. Sign language is a communication system that combines body language, face expressions, and hand gestures. Fingerspelling or word-level signs make up a sign language. For the deaf-dumb community, it is their only form of communication. However, those who are deaf never attempt to learn sign language. Therefore, without a sign language translator, deaf people cannot communicate with regular people. Deaf persons become more isolated in society as a result of this. Therefore, a system that can interpret sign language automatically is required. When such a system is put into place, hearing-impaired people can communicate with the outside world without the need for an interpreter. In this research, we offer an automatic technique for Indian sign language fingerspelling recognition. The suggested approach recognizes various indicators by utilizing artificial neural networks and digital image processing techniques [11]. In order to facilitate communication with individuals who are hard of hearing, computer recognition of sign language is a crucial research topic. In order to detect the number of fingers opened in a gesture that represents an alphabet of American Sign Language, this research presents an effective and quick method. The ideas of border tracing and fingertip detection are the foundation for finger detection. The hand does not need to be precisely positioned in front of the camera, nor does it need to wear input gloves or specific markers [12]. Individuals who are deaf or dumb use sign languages to communicate with each other, but they have a hard time interacting with others. This research suggests a way to translate hand motions used in Indian Sign Language (ISL) into suitable text messages. This work uses a webcam to record the hand motions that correlate to the ISL English alphabets. The hand is split in the collected frames, and the alphabet is recognized based on the condition of the fingers. Recognition is based on characteristics such the angle formed between fingers, the number of fully opened, fully closed, or semi-closed fingers, and the identification of each finger. Single-handed alphabets were the subject of experimentation, and the findings were compiled [13]. The development and analysis of a real-time stereo vision hand tracking system for interaction is presented in this paper. Without the need for extra markers or gloves, the system is able to track the thumb and index finger of each hand in real time, as well as their 2D orientation. It is hard for a hearing person to comprehend what it is like to be deaf. It's a common misconception that "deaf people are handicapped," however this is untrue. A disabled person, such as a blind person, finds it difficult to live their life on their own. This is not an issue for deaf people; they can drive, ride a bike, go shopping, and go on vacation just like everyone else. A deaf person's biggest issue is "communication." The primary goal of the paper is to facilitate communication between hearing and non-hearing individuals and integrate them into society as a whole. Segmenting finger spelling hand motions from image sequences is the initial step in the finger spelling recognition assignment. This work aims to translate finger-spelled words into speech and text (character by character). The process of converting text to image is part of the second phase. The alphabet separation module scans and enters the characters in this sentence, extracts the alphabets from the sentences, and shows viewers the relevant image. These are just alphabets that can be spelled with the fingers [14]. For aphasics with disabilities who can only communicate through "finger language," this paper offers a system for recognizing finger language. In contrast to sign language, finger language is made up of basic hand motions that each have a predetermined meaning. The system is composed of a commercial text-to-speech (TTS) subsystem, a small-scale finger language recognition subsystem, and an inexpensive fiber data glove. The recognition subsystem interprets the intended meaning of a specific hand gesture after the data glove receives the optical fiber signals linked to it. The TTS subsystem receives the understood meaning and translates it into voice signals. According to our experiment, the accuracy rate of the system can reach 99.97% [15]. The language used by Georgia's Deaf and Hard of Hearing (DHH) community is called Georgian Sign Language (GESL). The number of DHH in the nation is roughly 2,500. GESL and spoken Georgian are their two native languages, making them multilingual. They anticipate bilingual education in schools as a result. All languages use morphological numerals to indicate the number, order, or component. As a result, numerals might be distributive, fractional, ordinal, or cardinal. The universal way that languages approach numbers is repeated by GESL. Cardinal numbers are represented by fingers arranged in predictable ways in almost all sign languages. While many spoken languages utilize the decimal system or system of twenty, as spoken in Georgian, sign languages use pentagram systems, which are the most practical method of transmitting numbers using the fingers of the hand [16]. The primary goals of robotic hand development are activities involving grasping and manipulation. Specifically, the under actuation in grabbing involves the employment of a clever mechanical system that can automatically adjust to the shape of the object. The necessity to improve these systems' mechanical benefits has been brought to light by recent investigations. The performance of the linkage-driven three-phalanx fingers has been determined by the ratio of the output link to the input link lengths of the four-bar linkage mechanism. In this paper, a transmission ratio of the underactuated linkage robotic finger has been formulated using finger geometric parameters. A three-finger, multi-finger robotic hand mechanism with proposed design and manufacture is under development. The finger is made up of series links with two to four bars. Every robotic finger has a DC motor fastened to the coupler link of its second phalanx. In order to get the necessary length for either grabbing or pinching configurations, the link length has been changed. The entire hand mechanism has been accelerated by a single actuator. To control grabbing and pinching of items, the proportional, integral, and derivative (PID) control technique has been applied. The outcomes of the experiment demonstrate that the robotic hand's movement can be successfully controlled to accomplish the desired goal [17].

III. CHALLENGES OF ROBOTIC HAND FOR THE DEAF OR DEAF-BLIND INDIVIDUAL USING ASSISTIVE TECHNOLOGY

Robotic hands, though beneficial, present several challenges for deaf or deaf-blind individuals using assistive technology. These challenges include cost, complexity, potential for harm, and the need for specialized training. The rigid structure of robotic hands can also be uncomfortable and restrict natural movement, requiring adaptations for deaf-blind users who rely on tactile feedback. Furthermore, access to these technologies and their integration into daily life can be limited by affordability, lack of awareness, and inadequate policy, according to the World Health Organization (WHO).

Here's a more detailed look at the challenges:

I. **Cost and Accessibility:**
Robotic hands, especially advanced ones, can be expensive, making them inaccessible to many individuals, according to the Assistive Technology Industry Association.

II. **Complexity and Training:**
Many robotic hands require intricate control systems and specialized training, which can be time-consuming and daunting for individuals unfamiliar with technology, according to a Weebly article.

III. **Safety Concerns:**
The rigid components and mechanisms in some robotic hands pose a risk of pinching or injury, particularly for deaf-blind individuals who rely on tactile feedback for communication and navigation, according to ResearchGate.

IV. **Limited Natural Movement:**
The rigid structure of some robotic hands can restrict natural hand movements and make them uncomfortable, requiring adaptations for deaf-blind users who rely on tactile signing.

V. **Lack of Awareness and Support:**
There's a need for increased awareness and support to help individuals learn about and access assistive technology, including robotic hands, according to the World Health Organization (WHO).

VI. **Integration into Daily Life:**
Adapting robotic hands for use in various daily activities, like personal care, work, and social interaction, can be challenging, especially for individuals with significant communication and mobility limitations.

VII. **Maintenance and Reliability:**
Robotic hands require regular maintenance and can be prone to malfunctions, which can disrupt daily life and create challenges for individuals who rely on them, according to a Weebly article [19].

IV. CAUSES OF HEARING LOSS AND DEAFNESS

While these influences may arise at many stages of life, people are more vulnerable to their impact during pivotal moments in their lives.

1. Prenatal period
   i. Genetic factors including hereditary and non-hereditary hearing loss.
   ii. Intrauterine infections – such as rubella and cytomegalovirus infection.
2. Perinatal period
   i. Birth asphyxia (a lack of oxygen at the time of birth
   ii. hyperbilirubinemia (severe jaundice in the neonatal period)
   iii. Low-birth weight
   iv. Other perinatal morbidities and their management.
3. Childhood and adolescence
   i. Chronic ear infections (chronic suppurative otitis media)

ii. Collection of fluid in the ear (chronic nonsuppurative otitis media)
iii. Meningitis and other infections.
4. Adulthood and older age
i. Chronic diseases
ii. Smoking
iii. Otosclerosis
iv. Age-related sensorineural degeneration
v. Sudden sensorineural hearing loss.
5. Factors across the life span
i. Cerumen impaction (impacted ear wax)
ii. Trauma to the ear or head
iii. Loud noise/loud sounds
iv. Ototoxic medicines
v. Work related ototoxic chemicals
vi. Nutritional deficiencies
vii. Viral infections and other ear conditions
viii. Delayed onset or progressive genetic hearing loss [18].

CONCLUSION

Many articles about people who are silent or have difficulty speaking were reviewed in this paper. Hand speaking, also referred to as sign language, has become more and more common as a means of communication. Sign language is a language that uses hand movements to represent words and letters. People who are deaf or deaf-blind find it challenging to comprehend other people and their environment. The causes of hearing loss and deafness have also been discussed [18].

Here's a more detailed look at how artificial intelligence (AI) assists deaf learners:

1. Real-time Captioning and Transcription:

i. Automatic Speech Recognition (ASR):

AI-powered ASR systems can convert spoken words into text in real-time, providing captions for lectures, videos, and other media. This allows deaf students to follow content simultaneously with their hearing peers, even in noisy environments.

ii. Transcription of Audio Recordings:

AI can also be used to transcribe audio recordings of lectures, textbooks, and other materials, enabling students to take notes or access information at their own pace.

2. Sign Language Translation:

i. AI-powered avatars:

AI-powered computer vision systems and 3D signing avatars can be used to translate spoken language into American Sign Language (ASL) in real-time.

ii. Generative AI for sign language videos:

AI can generate ASL videos from text prompts, making learning materials more accessible.

3. Personalized Learning:

i. Virtual Tutors:

AI-powered virtual tutors can provide personalized instruction and feedback, adapting to each student's learning style and pace.

ii. Custom Learning Materials:

AI can generate personalized learning materials, such as quizzes and flashcards, tailored to a student's strengths and weaknesses.

4. Improved Communication:

i. In-person communication:

AI can help with sound isolation and lip-reading algorithms, making in-person communication more accessible.

ii. Virtual meetings:

AI-powered captioning in virtual meetings allows deaf or hard-of-hearing people to follow meetings without missing important details.

5. Enhanced Accessibility:

i. Accessibility in social media:

ASR can enable auto-generated captions on social media platforms like TikTok, Instagram, and YouTube, making digital content accessible.

ii. Assistive technologies:

AI is also being used to develop more sophisticated hearing aids and cochlear implants.

By utilizing these AI technologies, deaf learners can access a wider range of educational opportunities and participate more fully in classroom settings and other learning environments.

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