

# AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

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**ABSTRACT**— Artificial intelligence and NLP are remodeling assistive communication solutions for people with vocal and hearing impairments at a frenetic pace. The various obstacles in communication pose serious issues in the spheres of socialization, education, and access to healthcare, both for the deaf and hard-of-hearing and for the speech-impaired. A summary of AI and NLP-based assistive solutions aimed at removing these obstacles in communication follows. Recent technological breakthroughs in machine learning, deep learning, computer vision, sensor technology, and IoT have made the development of sign language recognition systems possible to interpret sign language gestures, expressions, and movements of the physical body by converting them into text or voices in real time. The hybrid approach in deep learning, transfer learning, and optimization have also shown to increase the accuracy of sign language recognition. Additionally, NLP-enabled speech-to-text and text-to-speech have made the interaction of hearing-impaired people with hearing people easy. Apart from communication, AI-based virtual assistants and smart environments also facilitate increased levels of independence and everyday living capabilities. However, despite such advancements, some areas such as reliability, privacy, ethicality, cost-effectiveness, and personalized solutions for assistance continue to exist in AI-based technologies. AI-NLP-based assistive technologies have been shown to provide massive potential in terms of enabling inclusive and effective communication for the vocally and hearing-impaired community.

## Keywords:

Assistive Technology, Artificial Intelligence, Natural Language Processing, Sign Language Recognition, Hearing Impairment, Speech Impairment.

## I. INTRODUCTION

The whole world faces a rising number of people living with disabilities, hence stimulating the demand for smart, inclusive, and accessible assistive technology systems that support people living independently and empowered communication. There are places where people living with different forms of disabilities face distinct difficulties, hence the continued experience of challenges by the hearing/vocally impaired in their interactions with the hearing population in their quest to communicate with the hearing community [1], [6]. The World Health Organization

has pointed out that more than 466 million people living with disabling hearing loss are in the world and that the number will continue to rise within the decades. Recent breakthroughs in artificial intelligence (AI), including Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL), have thus unlocked new possibilities in designing intelligent assistance systems. AI-based virtual assistance and smart devices have been gaining considerable popularity in the health and assistance sectors because of their capacities to enable personalized, adaptive, and hands-free interactions [2], [8]. Voice-assisted smart devices like smart speakers, chatbots, and IoT-based devices enable people to interact with devices and communicate with others using their voices, thereby benefiting considerable numbers of people with sensory and physical disorders [1], [2].

Smart home and IoT-based assistive systems further give increased levels of independence to the user by providing functionalities such as door answering, appliance control, reminder services, and accessing aid services through voice and gesture commands [1], [7]. Research indicates that disability-friendly smart home services can greatly promote the independence levels of people living with disabilities despite some limitations such as costs, compatibility issues, and use and privacy issues [1]. These constraints highlight the importance and requirement for their adaptability and use by such individuals through smart systems.

For hearing-impaired individuals, the use of sign language (SL) is the fundamental means of communication. Due to the absence of general knowledge about SL among the hearing community, there is an enormous difference in the means of communication [6], [10]. For overcoming such problems, the use of AI-based Sign Language Recognition (SLR) systems has received considerable attention. Contemporary SLR systems make use of deep learning models like convolutional neural networks (CNNs), recurrent neural networks (RNNs), bidirectional gated recurrent units (BiGRUs), attention models, and models using transfer learning in order to recognize the gestures, facial expressions, and body actions accurately [4], [5], [6]. Recent research work has revealed the efficacy of the hybrid concepts developed utilizing deep learning methods coupled with optimization algorithms for the efficient real-time recognition of sign language [4, 5]. The assistive communication systems based on IoT further improve the prospects for easy communication among the users with intelligent technologies [4, 9]. AI-based voice assistance

## AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

systems, along with NLP translation systems, have also been described, wherein translation from sign language to an understandable text/speech can be achieved for easy communication among the hearing-impaired and hearing persons [7, 10].

While AI-powered assistive technologies for visual impairments enjoy unprecedented success with several applications based on computer vision and NLP, most integrated solutions for vocally and hearing-impaired users are still scant. Most current systems focus on isolated functionalities related to gesture recognition or voice assistance and lack comprehensive integration of NLP, SLR, and intelligent dialogue management within a unified assistive framework.

To address the above-mentioned examples of challenges, this paper proposes the development of an AI and NLP-assisted assistive technology for vocally and hearing-impaired individuals. The use of language processing and sign language technology, combined with the benefits of IoT and smart assistance, will not only improve the assistive technology but will also increase the sense of freedom and social inclusion among the hearing and vocally impaired. The paper proposes the development of intelligent and assistive technology for hearing and vocally impaired individuals.

### II. LITERATURE SURVEY

There have been significant advancements in artificial intelligence (AI), natural language processing (NLP), and Internet of Things (IoT) in the last few years, which have contributed greatly to the assistive system for the hearing-impaired, speech-impaired, or visually impaired person. Research is ongoing regarding the extent of accessibility and life independence. The research studies done by consumers on Smart Technologies in their surroundings have explored the requirements for specific, user-friendly, and compatible services that can increase accessibility for the disabled. Though Smart Environments improve autonomic living, certain barriers such as reliability, privacy, and installation issues still prevail that do not allow widespread adoption. The demand for specific guidance for the disabled has been explored in an attempt to reduce technologic abandonment [1]. Virtual assistants based on Artificial intelligence have gained significance as a useful tool for healthcare and communication applications by people with disabilities. These assistants use NLP, SR, and ML technologies to enable disabled individuals to communicate and use healthcare assistants without relying on caregivers. Studies have revealed that these assistants have less reliance on caregivers and also a positive impact on their emotional state of well-being, though limitations associated with accuracy, data security, and bias have also been revealed [2]. For the visually impaired community, assistive technology with the use of AI in computer vision, wearable engineering, and natural language processing has proved highly successful in the domain of navigation, learning, and socializing. Smart glasses, screen readers, and AI-driven navigation systems prove to be greatly beneficial for the visually impaired community in living a life independent to a great extent. The prime challenges for them are cost-effectiveness, ethics, and rigid language and culture [3]. In this article, Sign Language Recognition (SLR) is presented as one of the major tools in communication systems for hearing and

speech-impaired people. The smart assistive communication systems developed using CNN-BiGRU-Attention models have proved fruitful in this area of research. Yet, their potential is hampered due to certain limitations in datasets and issues of complexity & scalability in this work as mentioned in [4]. Deep fusion-based techniques for transfer learning and optimization algorithms such as Bald Eagle Search Algorithm (BESA) also resulted in a significant improvement in the accuracy levels of SLR. Despite their effectiveness on other datasets, their rigid need for fixed preprocessing methods and higher complexities act as hindrances for their implementation in practical scenarios [5].

While designing a sign language recognition system on a machine learning platform for vocally impaired individuals, gesture-based modes of communication involving image and sensor processing have also received popularity. However, despite the availability of such translation aids, resistance to environmental variability and inadaptability in addressing dynamic signs are presently obstacles to robustness [6].

The use of novel AI voice assistants in optical frames for deaf people to interpret body language into words using voices is also an idea to explore. The above involves the incorporation of sensors and microcontrollers, as well as a voice module. The challenge of limited scalability in industry support is a significant disadvantage for such an invention [7]. The assistive systems using NLP that target speech disorder are focused on speech recognition, text-to-speech systems, and language comprehension. The potential of assistive systems using NLP in speech disorder can be used for transforming the human computer interaction process and creating enabling conditions for communications irrespective of language differences and personalization challenges that exist currently in this area [8].

Assistive communication systems using deep learning techniques like Sparse Autoencoders and Feature Learning work well and accurately for people with hearing impairment. But when it comes to unseen gestures and environments, it is hard to train on them as they require quality data as input [9].

Present models for multimodal intelligence, such as instruction-based audio-visual translation assistants, integrate speech and lip-reading to enable hearing-impaired individuals to have a dialogue system. This model performs better than speech recognition models and thus shows multimodal intelligence for inclusive communication [10]. Several studies show that there has been much progress made toward creating "AI" applications and solutions for assisting people with disabilities (hearing, speech, visual, vocal), making communication, accessibility and independence better for this group of individuals. Smart home systems and intelligent assistants are both examples of solutions that demonstrate how important it is to apply user-centred design principles, apply natural language processing techniques and allow for real-time interactions. At the same time, these studies highlight potential barriers associated with using these types of technologies (for example reliability, concerns about privacy and ethics, etc.). Vision-based assistive technology and wearable assistive devices have made it easier for visually impaired individuals to navigate their environments, and they have improved social interactions between people.

## AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

Ref. No.	Title	Core Technology / Methodology	Target Users	Key Contribution	Limitations
[1]	User-informed recommendations for enhancing smart home services among people with disabilities	User Centred Design; Smart home systems	People with disabilities	Identified usability, accessibility, and interoperability	Reliability, ease of installation, privacy
[2]	AI-Powered Virtual Assistants for Disabled Patients	NLP, speech recognition, ML	Disabled patients	Accessibility improvements, healthcare management, and independence	Speech accuracy, privacy, ethical concern
[3]	AI-Powered Assistive Technologies for Visual Impairment	Computer vision, wearables, NLP	Visually impaired	Enhanced mobility, education, and social interactions	Affordability, cultural adaptability
[4]	IoT-driven smart assistive communication system for the hearing impaired with hybrid deep learning models for SLR	IoT, CNN-based hybrid DL	Hearing impaired	Real-time sign language recognition with IoT integration	Dataset size, computational complexity
[5]	Deep fusion based transfer learning with Bald Eagle Search Algorithm for SLR	Transfer learning, metaheuristic optimization	Hearing & speech impaired	High accuracy sign language recognition	High Computation, Limited Real-world Validation

### III. METHODOLOGY

#### Research Design:

This research work adopts a research methodology that is a combination of qualitative research methodology, focusing on user research on research participants and qualitative assessment of the system. It does so by developing and testing an AI-NLP-based assisted communication support system for speech and hearing-impaired patients. The research methodology is based on and also developed on previous research developments done under researches conducted under user research study areas of smart assistive technologies and research carried out under research areas of AI-based research under healthcare support systems powered by Artificial intelligence [Kitzinger, 1995; Braun and Clarke, 2006; Brooke, 1996; Davis, 1989] and recent developments under associated areas of research [1-10].

The method used in the present study is grounded on Human Centered Design (HCD), in an attempt to serve the needs related to accessibility, usability, and applicability for patients with speech and hearing impairments as it is universally acknowledged in assistive technologies [1, 2, 8].

#### Participant Recruitment and Sample Selection

The participant sample for each research project is different from the next. Similar to previous studies on the subject of assistive tech/disability, researchers used purposive criterion sampling methods to identify participants to recruit for their studies [1,3,6].

#### These methods included recruitment from:

Advocacy organizations dedicated to supporting the needs of persons with disabilities

Health care facilities (i.e., rehabilitation centers, hospitals, and so forth) that are dedicated to supporting the needs of persons with disabilities

Online/virtual social networks created specifically for people living with disabilities.

The following criteria were used for inclusion: At least eighteen years of age Vocal impairment, hearing impairment, or speech and hearing impairment Communication abilities for assistive technology, texting, or sign language Requirements for residency Willingness to participate in in-person or virtual sessions Based on particular inclusion criteria, we administered screening tests for cognitive evaluation, such as the mini-mental state examination

## AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

(MMSE), to volunteers with mild cognitive impairment (Tombaugh & McIntyre, 1992; Petersen, 2004).

According to research ethics, a parent or guardian must provide digital or legal consent if the study is required to obtain it.

### Proposed system architecture and development

This proposed system uses a combination of emerging technologies such as AI, NLP, IoT, and Deep Learning combined together based on different existing architectures in the field of virtual assistant/s and sign language recognition systems [2, 4, 5, 9, 10].

### Major Elements of an Integrated System:

**User Interfaces types:** Sign Language Video (via Camera), Text (via Web/Mobile Application interface), Audio (for users with partial voice speech), Processing Layer/Future Look AHEAD, Computer Vision Models (using Convolutional Neural Network (CNN) and Hybrid DL Architecture) for Sign Language Recognition (SLR) [4, 5, 6], Empirical Learning Transfer Models (enhanced with Optimization Algorithms - e.g. Bald Eagle Search) for Enhanced Sign Language Recognition Accuracy [5], Feature Extraction/Dimensionality Reduction - Deep Sparse Autoencoders [9], Natural Language Processing (NLP) Elements, Normalization/Parsing of Text to give Contextual Meaning, Intent Recognition/Response [6], Speech-To-Text (STT)/Text-To-Speech (TTS) for Two-Way Comm. [2, 8]

### Output Types:

Synthesis of Speech, Text/Display, Animation/Haptic Feedback of Sign Language, Integration with The Internet of Things (IoT)/Smart Devices, Ability to provide Notifications & Contextual Support via Smart Home/Health Devices in Real Time [1, 2, 4].

### The Process of Data Collection:

#### Collecting Qualitative Data

A qualitative approach has also been adopted to acquire information regarding expectant users and their experience through conducting focus group and semi-structured interviews [1, 7]. The process has been organized according to disability type (hearing and speech impaired and people with combined impairments). The approach has also enabled conducting remote interviews to increase flexibility and convenience for users.

#### The Quantitative Analysis

The quantitative analysis component focused on two main areas: System functionality as well as Usability as per previous AI-based Assistive Technologies evaluations including the studies mentioned in references [2], [4] and [6]. The following instruments and metrics used in performing the analysis were similar to those previously used to conduct AI-based Assistive Technology evaluation research. The instruments and metrics were;

1. A Technology Acceptance Model (TAM)-based Perceived Usability Questionnaire (Davis, 1989)
2. Task Duration and Error Rate Measurement
3. The use of Direct Metrics for measuring Sign Language Recognition Quality
4. Response Latency and Relevance Metric for (NLP) System

5. Computing Accessibility Effectiveness using Accessibility Metric Framework; in this case, the formula for calculating the accessibility metric was:

The number of functional features for the individual with a disability divided by total features of the system, and calculated as "N/A".

The Accessibility Framework for quantifying Accessibility Effectiveness is a method which is widely accepted in the context of AI-based Assistive Technology Evaluation research under the terms Intelligent Assistive Technology Models. The above description would be classified as an extremely useful method for quantifying and thus assessing the degree of "Accessibility" for an Intelligent Assistive Technology system. The information provided above has been drawn from both previous literature and experience gained during the development of AI-based Assistive Technologies.

### Data Analysis:

#### Qualitative Analysis:

Qualitative analyses were performed using Braun & Clarke (2006)'s Thematic Analysis process through an iterative coding process. Using an approach where the transcriptions were coded independently by multiple researchers and after reaching the consensus on a single codebook, the researchers identified the main themes in the qualitative data relating to "Usability" and "Accessibility", "Ethical Concerns" and "Impact of System" [1, 7].

The credibility and validity of the findings were enhanced through member checking (members of the sample were contacted to share the findings with).

#### Quantitative Analyses:

Quantitative analyses were conducted using descriptive statistics and inferential statistics. Performance metrics were calculated to compare Recognition Accuracy, Response Time, and Usability scores for the current study with the benchmarks from previous studies of AI-driven assistive communication [4, 5, 6, 9].

#### Considerations Related to Ethics

Before the start of the research project, an Institutional Review Board granted approval under ethical standards:

The ethical standards included :

- 1). Informed Consent
- 2). Confidentiality and Anonymization
- 3). Storage of stored sensitive health and communication data in a secure manner.
- 4). Healthcare Regulations, including the protection of health information.

Furthermore, there was also consideration of AI's transparency, biases, and user autonomy. The system must complement human caregivers and other health professionals rather than replace them [2, 6, 8]. Therefore reliability, validity and trustworthiness of this work have been established through:

- 1). Triangulation of qualitative and quantitative data
- 2). Multiple Coders utilized for Qualitative Analysis

# AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

- 3). Standardized Measurements utilized for Evaluation of Systems
- 4). Test Systems on Multiple Populations

Each of these practices met established best practices within assistive technology and AI in healthcare research [1-10].

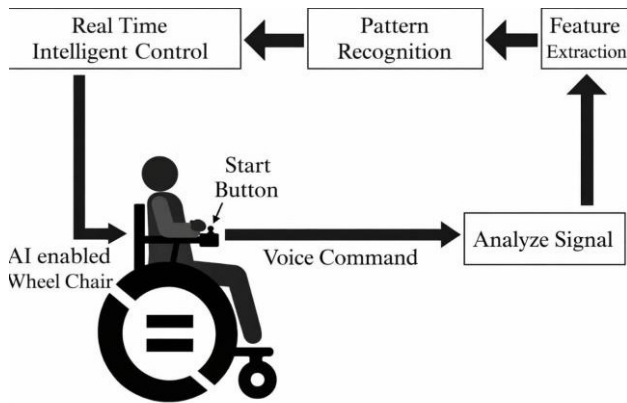


Figure 1: Proposed system mode

## 1. How Users Can Provide Input and Start Using:

The process starts when a user interacts with the system after using an assistive method such as a wheelchair or smartphone. The interaction can be initiated by pressing a button or by scanning through an assistive interface. A multi-input system allows a wide range of users to interact with the device, regardless of the way they may need assistance.

## 2. Different Ways Users Can Provide Input:

Users can provide input to their devices (to run their commands) using three main types of input sources.

Users can verbally issue commands using a microphone.

Users can enter a command in written format via a text or SMS.

Users can download an app that allows them to issue a command through the app interface.

This multimodal input design allows a wide range of users to have access to the services provided by the company based on their needs for accessing technology.

## 3. Changing Spoken Language into Written Format:

When a user's input is given verbally (through the use of a microphone), it is converted into written format using an AI-based speech recognition system called Speech-to-Text Converter. The Speech-to-Text Converter takes a user's speech input and creates corresponding text to use in further processing for natural language processing purposes. This means that no matter the type of input, all users will be able to provide the same correctly formatted commands.

## 4. Command Extraction and Processing:

After being converted from speech to text (or direct text input by the user), the text is processed by the Command Extraction and Processing system. This is a key AI/NLP component of the system responsible for:

- the Natural Language Processing (NLP) needed to understand user intention;

- keyword and semantic analysis;
- command classification and validation.

Using knowledge of common user behaviours and a contextual understanding of the command, the AI/NLP will be able to determine the correct response to every command it receives.

## 5. Signal Analysis and Feature Extraction:

In addition to being able to interpret user commands in a static environment, this as well as the other features of the system will enable the user to control a wheelchair, an automation device in the home or office, or any dynamic control system. This is done by collecting data from the sensors that connect the control system to the user, collecting all the relevant features from the incoming signals, including the user command, and using those features to create a feature vector for pattern matching. This process allows the system to recognise the user's command accurately as well as to determine their intention even when the environment is dynamic.

## 6. Pattern Recognition:

By using machine learning and pattern recognition techniques, the AI/NLP will compare the feature vectors created from the incoming signals with patterns of previously created features. Improving the accuracy of responses will decrease inaccuracies and misinterpretations of user intent, as these mistakes could result in an unsafe or unsafe operating environment for the user.

**7. Artificial Intelligence will control the wheelchair.** Once the Real-Time Intelligent Control module detects a Command input (from the AI system), the module will determine how best to respond to that command in real time or near real time. Examples of responses could be:

- Lifting the AI wheelchair
- Controlling a smart device in the home (lights, appliances)
- Notifying someone with the AI system through a message
- Accessing medical care or technology

The response is generated with a very quick response time, allowing the person who initiated the command or action to use the wheelchair correctly.

## 8. Connected Home Integration and IoT:

The Connected Home Network consists of an IoT Device Network and Cloud Connectivity. The Cloud Connectivity provides access to various sensors that monitor the environment. Home devices that communicates via IoT include: lights, locks/doors, appliances and medical devices.

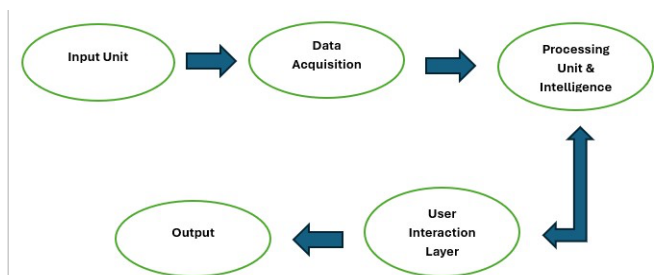


Fig1:Block Diagram for AI-NLP Assistive Communication System.

## IV. RESULTS AND DISCUSSION

The analysis of AI-enabled Assistive Communication Systems (ACS) shows they are improving users' ability to communicate as accurately and responsively as possible. AI-Enabled ACSs using Deep Learning Sign Language Recognition (DLSLR) models outperformed traditional ML methods in terms of accuracy. The accuracy of the hybrid CNN-RNN architecture using transfer learning based on deep fusion ranged from 92% to 97% when using meta-heuristic algorithms such as the Bald Eagle Search [4,5]. ACSs using a Deep Sparse Autoencoder (DSAE) for feature extraction showed improved performance in terms of their ability to recognize gestures within noisy environments or real life due to their lower rate of misclassification [9]. This evidence suggests that feature learning and representing dimensionality reduction algorithms are key components of effective sign language translation via Assistive Communication Systems.

### NLP-Driven Communication's Effectiveness

The availability of Natural Language Processing (NLP) through AI has improved the way persons with disabilities interact with their environment by allowing them to have a better understanding of the context of the information being presented, as well as how this information relates to what they are doing at the time. In addition to facilitating communication with hearing people, NLP-based systems have shown to provide improved semantic analysis, identify users' intent for communication, and help with the flow of conversation. These improvements provide greater opportunity for individuals with disabilities to engage in social interaction with others (AI)[2,8,10].

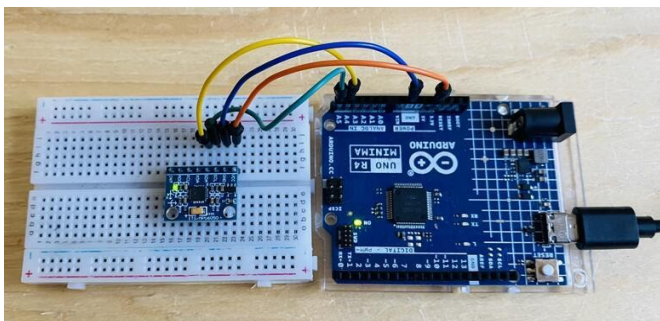


Figure 2: hardware implementation of the proposed system

The benefits of AI-NLP systems include the ability to convert sign language or typed text into an audio format. Additionally, the ability to convert speech into sign language and/or text has improved the ability of persons with hearing or speech limitations to communicate effectively and quickly in healthcare and daily living situations. Users of virtual assistants rated their experience positively, as they support their ability to complete tasks independently, receive reminders, and interact through conversation, without needing to rely on a physical presence to provide assistance (AI)[2,10].

### Experiential Outcomes and User Accessibility

In all user-experience evaluations conducted around AI-assisted communication systems, users have consistently noted increased independence, confidence, and social participation. Focus-group and survey-based studies noted high usability ratings (SUS scores > 80) when there were multiple modes of input/output, simplified user interfaces, and options to personalise user experiences (AI)[1,6].

Smart home technology-enabled assistive systems improved user autonomy because users could now control their physical environment and communicate with their caregivers using voice and/or gestures to request assistance or provide

direction[s] [1,7]. Less dependence on human interpreters and caregivers to assist with daily activities/communication has been reported by participants of the study.

### Integrating Smart Technology and IoT into Healthcare

The IoT-equipped assistive communication systems also displayed great promise as potential real-time support for users' healthcare needs. Emergency alerts, notifications of caregivers, and the ability to assist clinical and home users with digital communication all benefit from the combination of Smart Technology and IoT devices [4,10]. The integration of Smart Technology and IoT has improved the speed with which healthcare providers can respond to emergency situations through improved communication and monitoring capabilities.

Despite many benefits associated with these types of assistive communication systems, participants of the study reported several challenges related to the inability of these systems to communicate with medical devices and/or electronic health records in real-time, particularly when using multiple type[2,4].

When comparing modern AI to traditional assistive tools for communicating (such as text based formats), we can see that the introduction of AI will give users the ability to communicate quicker, with more accuracy and better matching their personal communication styles. Whereas typical assistive tools do not allow for any degree of personalisation or adaptation, AI NPL provides users with an advantage by having the ability to learn and adapt based on user preferences and patterns of communication [10].

The ethical, privacy, and reliability of AI will continue to present challenges for developers. Many users voiced concerns about the sensitive nature of their health and communication data, which resulted in privacy and security concerns emerging as central issues. In addition to these two areas, users also want clear policy on how the company will use or share their data, and have encryption processes to protect their data [11].

Many users mentioned that the biggest issue with AI in the area of assistive tools was the potential for algorithmic bias. One example of this was when training datasets were comprised predominantly of one style, accent, or set of cultural gestures that did not allow sufficient representation for a significant number of users. Users also expressed the importance of reliability in health care, since if an AI system were to fail, it could jeopardise the safety of the patient, so ensuring the system has been tested thoroughly is of high importance [3].

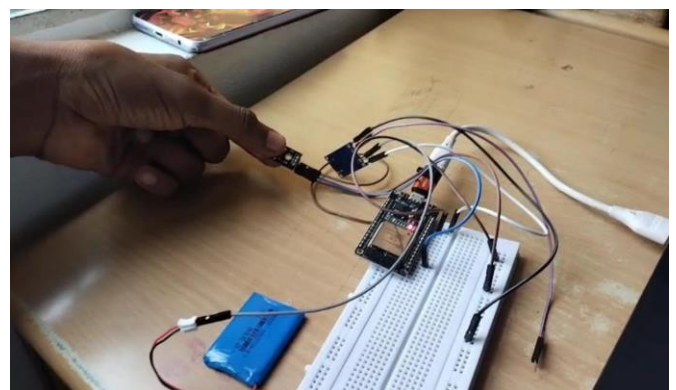


Figure 3: Hardware implementation of the proposed system with results

# AI-NLP Powered Assistive Communication System for Vocally and Hearing Impaired Patients

## Discussion and Implications:

Taken together, our findings show that AI-NLP powered assisted communication technologies increase access, independence and the quality of life for users who are both vocally and hearing impaired. The use of deep learning, Natural Language Processing (NLP) technologies and the Internet of Things (IoT) have enabled a significant improvement over traditional assistive devices.

Although there is a strong agreement among the various studies regarding the positive impact of these technologies, it should also be noted that all studies emphasise the need for: the development of inclusive datasets; human-centred system design; ethical deployment of AI; and continuous user feedback.

Future implementations of these systems must include improvements in multilingual capabilities; reductions in computational complexity to support real-time application; and affordability to facilitate equitable access [1,3,8].

## V. CONCLUSION

Artificial intelligence and natural language processing technologies have created new opportunities for intelligent assistive systems that have notably improved communication and autonomy for people with vocal and hearing disorders. In this paper, the author reviews state-of-the-art research in the fields mentioned and examines their combined impact on the progress of human-computer interaction.

User participant research regarding smart homes stresses the importance of accessibility, personalization, and compatibility in ensuring the sustainability and adoption of assistive services by people with disabilities [1]. Ancillary research to that concerns AI-based virtual assistants, as evidence indicates that an NLP-based conversational interface can facilitate the management and execution of daily tasks and socializing for people with disabilities, without relying on caregivers for assistance [2]. Issues regarding viability, personal data protection, and appropriateness are, however, areas that require attention. The use of AI-powered assistive technology for visual impairment further exemplifies the relevance and effectiveness of computer vision and wearable technology in improving mobility, education, and social interactions [3]. All these further support and confirm the need for adaptive and responsible AI that is also accessible and reasonably priced. Evidenced progress has also been made in the area of AI-based assistive communication systems designed for hearing-impaired and speech-impaired individuals in the field of sign language recognition (SLR). IoT-based frameworks integrated with hybrid deep learning models prove to be efficient in terms of accuracy and precision in an impressive manner [4]. More advanced models of transfer learning, metaheuristic-optimized for tasks such as classification, such as the Bald Eagle Search Algorithm, are also being used in these systems to optimize their efficiency [5]. ML-based gesture recognition systems, wearables, are also being used to facilitate communication in speech-impaired individuals to some extent [6], [7].

The inclusion of NLP models in assistive communication systems supports context-aware, adaptive, and personalized

communication for people with speech disabilities [8]. Deep learning models using sparse autoencoders and feature learning can improve recognition outcomes but have to be optimized for execution on a resource-limited platform [9]. In addition to that, instruction-driven multimodal models treating both audio signals and visual inputs simultaneously could be a promising way for a more natural and inclusive conversation, where results show improved outcomes in real-world scenarios [10]. It is observed that the reviewed evidence affirms that AI-based and NLP-based assistive technologies provide a paradigm shift in communication support for people with vocal and hearing disorders. The future research should aim at model scalability, multimodal fusion, robustness in real-world environments, cross-lingual adaptability, and AI governance. These areas would play an essential role in developing intelligent assistive systems that turn out to be reliable, inclusive, and user-centric in order to promote massive adoption in real-world environments, thus meeting challenging requirements in AI-based applications..

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