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Integrating an Assistive Wearable Device to Cater the Needs of People with Disabilities

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Abstract – The global prevalence of disabilities has surged in recent years, affecting approximately 1.3 billion individuals worldwide. Despite advancements in assistive technology, there persists a notable gap in solutions catering to the unique needs of populations such as the visually impaired, deaf, and mute. This study endeavors to bridge this disparity by designing and developing an inclusive wearable assistive device. Grounded in empathy theory, our research adopts a design thinking approach to create a multifunctional device tailored to address the communication, information access, and safety requirements of individuals with disabilities, particularly targeting the deaf, mute, and blind communities. The resulting device integrates obstacle detection, text-to-speech, and speech-to-text functionalities, offering real-time environmental awareness and communication support. Through rigorous testing and evaluation with our target users, our device demonstrates its efficacy in enhancing independence, communication, and safety. Despite encountering challenges such as reliance on pre-programmed codes for certain components and power supply limitations, the study underscores the potential of our device to empower individuals with disabilities and promote inclusivity in society. Future recommendations focus on refining navigation capabilities, optimizing design, exploring alternative modules, and prioritizing continuous improvement and user engagement, as highlighted by insights gathered from user interviews conducted during the evaluation process. The "Disabillitrix" wearable assistive device represents a significant stride towards addressing the diverse needs of individuals with disabilities and fostering a more inclusive society.

Keywords: *assistive device, disabilities, communication, safety, independence*

I. Introduction

In recent years, there has been a noticeable increase in the prevalence of people with disabilities worldwide. Disability is part of being human and is integral to the human experience. It results from the interaction between health conditions such as dementia, blindness, or spinal cord injury and a range of environmental and personal factors. An estimated 1.3 billion people, or 16% of the global population, experience a significant disability today. This number is growing because of an increase in non-communicable diseases and people living longer (World Health Organization, 2023). Potential causes are conditions such as age-related hearing and speaking loss, genetic conditions such as Usher syndrome, an infection picked up during pregnancy such as rubella (German measles), cerebral palsy, which is a problem with the brain and nervous system that mainly affects movement and coordination, and eye problems associated with increasing age, such as cataracts ("Deaf Blindness Symptoms and Treatments," 2023). These incidents may cause the affected person to lose a lot of functionality, which significantly limits functional independence and obstructs them from doing their activities of daily living without external help (Rulik et al., 2022).

People with disabilities need help with everyday tasks such as getting dressed, walking, communicating, and working, and they are particularly vulnerable to deficiencies in services such as health care, rehabilitation, support, and assistance, which need to be addressed properly (Martinez-Martin et al., 2020).

According to Petersen (2016), one possible technology is healthcare or an assistive device programmed to promote and monitor a person's health, aid with daily living, ensure their safety when living alone, and potentially reduce further cognitive or physical decline. In connection with the study of Mr. Petersen, the demand for assistive robots and devices is increasing, particularly for elderly and disabled individuals. Trackers, biosensors, wheelchair-mounted robotic arms, and other assistive devices have shown promise in helping individuals with impairments perform daily tasks like walking and communicating independently (Tangcharoensathien et al., 2018; Toro-Hernández et al., 2019; Valk et al., 2019).

As assistive devices or technology advance, direct interaction with humans is becoming increasingly important. As technology enhances independence and quality of life for disabled individuals, it is good that rehabilitation professionals, caregivers, and family members be aware of available systems for them to integrate them with people with disabilities (Brose et al., 2010). Embodied assistive technology encompasses mobility devices, specialized aids, and hardware, software, and peripherals that assist people with disabilities in accessing information technologies, such as computers and mobile devices, through specialized aids (Martinez-Martin et al., 2020).

Research Questions

1.) How can wearable assistive devices be developed to effectively cater to the unique needs of visually impaired, deaf, and mute individuals, addressing the existing imbalance in assistive technology development and accessibility?

2.) What are the barriers and challenges faced by visually impaired, deaf, and mute individuals in accessing and utilizing existing assistive technologies, and how can these barriers be overcome through the development of innovative solutions?

Objectives

The primary objective of this study is to design and develop an assistive wearable device with the purpose of seamlessly integrating it into the lives of individuals with disabilities, including those with visual impairment, hearing impairment, and muteness. The research seeks to create and assess the functionality of the device to provide effective technical support, promote independence, facilitate effective communication, and lend a helping hand in the everyday lives of people with disabilities by addressing their specific needs and challenges, all while considering and optimizing user satisfaction.

Hypothesis

The development and implementation of a multifunctional wearable assistive device designed to cater to the unique needs of individuals who are blind, deaf, or mute will significantly enhance their accessibility, communication, and overall quality of life. This inclusive system, grounded in Lieberman's "Empathy" theory, will empower users by promoting independence, providing effective technical support, and addressing barriers to accessing existing assistive technologies. Through comprehensive functionality assessment and user feedback, the study hypothesizes that the proposed device will bridge the existing gap in assistive technology development and accessibility, thereby fostering equitable participation and integration of individuals with disabilities into society.

Significance of the Study

The study would be a great benefit to people with disabilities, as they are the main ones who this device will help, as well as the caregivers, society, and researchers since it will give them a better understanding of people with disabilities.

Persons with Disabilities

People with disabilities will benefit from this study by minimizing the required effort of communication. This enhances their accessibility and inclusion, giving them an improved quality of life. The device will also foster a greater state of mental well-being by enhancing PWDs' confidence to be more independent and autonomous.

Caregivers and Family Members

For caregivers and family members, this study will provide them with a better quality of life and more efficient care and automate their routine tasks. This provides time for more compassionate and personalized care.

Society as a Whole

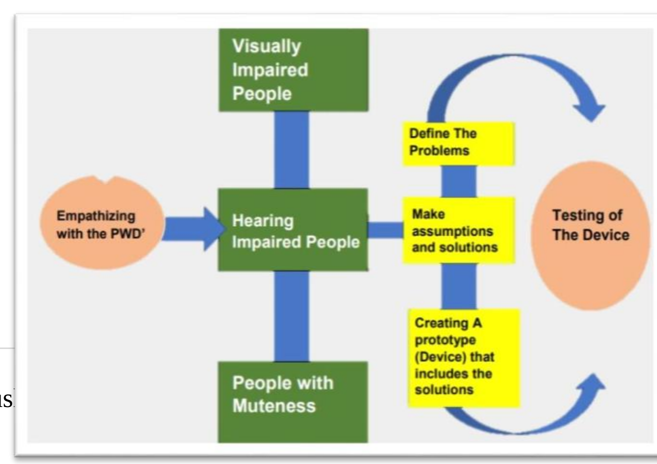
This study proposes the use of a device to improve communication with PWDs by empowering them to engage more actively in various aspects of society, such as education, employment, public spaces, and social interactions. It also provides insight into the perspectives of people with disabilities and raises awareness of their needs.

Researchers and Engineers

The development of this wearable device can drive technological advancements and innovation in the field of assistive technology, potentially leading to spin-off technologies, greatly helping researchers and engineers.

Research Paradigm

This study's theoretical hypothesis is based on Lieberman's Empathy theory, which posits empathy as a subjective feeling consisting of an empathic attitude and empathic power. The hypothesis emphasizes empathy force as the center of the empathic relationship, representing empathy as an innate characteristic of a person's personality (Lieberman, 2016). It is used to start up the design thinking process that the researchers will use to study the needs and problems of people with disabilities while creating solutions and ideas to answer their needs.



CONCEPTUAL FRAMEWORK:

Figure 1. "Empathizing" is the first step in developing a quality device for people with disabilities by studying what people with disabilities need and the problems that they face.

II. METHODS

A. Research Design

This study uses the design thinking process, which is a method that combines logic and creativity to find sustainable, attainable solutions for complex problems. Design thinking (DT) is a problem-solving methodology that addresses complex, ill-defined issues by understanding human needs, re-framing problems in human-centric ways, brainstorming multiple ideas, and adopting a hands-on prototyping and testing approach (Sharlip, 2019).

The design thinking process has five (5) parts which are as follows: **Empathize** means to research your users' needs; **Define** means to state your users' needs and problems; **Ideate** means to challenge assumptions and create ideas; **Prototype** means to start to reate solutions; and Testing and evaluation means to try your solutions out and evaluate it for future research (Dam, 2023).

B. Respondents and Locale of the Study

The subjects of the study are people with specific disabilities such as blindness, deafness, and muteness. As stated in the scope and delimitation of this study, this research will focus on the blind, mute, and deaf and will not include other people with other types of disabilities. The locale of the study will be in the community of Baguio, especially on Session Road, where so many people with disabilities live, and also in hospitals that cater to and hold people with disabilities, such as being blind, deaf, and mute.

Empathize

The Needs of Blind People

People with visual impairment face numerous problems related to their mental health, education, accessibility to online information and technology, socializing with other people, and mobility. These people require psychological support because they must be able to cope with the emotional challenges associated with blindness and develop strategies for managing their mental well-being to improve it (Jones et al., 2018). They also need equal opportunities in getting quality education and employment opportunities. This can be achieved through special interventions such as using Braille literacy (Lopez et al., 2020). The availability of assistive technologies, accessible materials, and trained educators are also essential in providing the inclusivity of getting a proper education (Smith and Johnson, 2019). In these times, access to information and technology has been given importance, as the world grows and develops. Adapting to these changes is needed, especially for those who suffer from ailments or disabilities. Blind people suffer from accessing online information due to the lack of accessibility features (Brown et al., 2019). Assistive technology can help in helping blind individuals get online information through its continued development and advancements. It is essential to prioritize ensuring the accessibility of digital content, websites, and mobile applications (Boddupalli & Manikandan, 2022). So, the digital experiences of blind people can be considerably enhanced by putting accessibility principles and standards into practice. Visually impaired people also face mobility and social integration into society. Because of this, it hinders their opportunities to participate in various activities. The research by Wilson et al. (2022) stated that there must be accessibility for these people to have when it comes to public transportation systems and urban environments to enhance their mobility. In addition, encouraging social inclusion involves audible announcements, tactile paving, and accessible pedestrian signals, as well as creating a supportive environment and increasing knowledge about blindness (Smith et al., 2021).

The Needs of Deaf People

Effective communication is crucial for deaf individuals to interact with others and access information. Sign language is the primary mode of communication for many deaf people, and its recognition and use are vital. Research by Schick (2008) emphasizes the importance of sign language acquisition for deaf children, as it facilitates their cognitive and social development. Deaf students also often encounter barriers to accessing quality education. Inclusive education practices, such as providing sign language interpreters or using captioning in classrooms, can enhance learning outcomes for deaf students (Hauser et al., 2017). The research conducted by Kushalnagar et al. (2010) highlights the importance of bilingual education, combining sign language and written language, to promote literacy skills among deaf learners. Obtaining and maintaining employment can be challenging for deaf individuals due to communication barriers and misconceptions about their abilities. Research by McKee et al. (2022) stresses the significance of workplace accommodations, such as providing sign language interpreters or utilizing assistive technologies, to support deaf employees. Finally, these people require healthcare. Access to healthcare services is critical for deaf individuals to maintain their overall well-being. Communication barriers often hinder effective communication between deaf patients and healthcare providers. Research by Kushalnagar et al. (2010) emphasizes the importance of trained interpreters and accessible healthcare information in sign language to ensure effective communication and understanding.

The Needs of Mute People

One of the primary needs of mute individuals is effective communication. While they may be unable to speak, alternative modes of communication, such as sign language, gestures, or assistive communication devices, can be utilized. According to a study by Johnson et al. (2018), providing access to augmentative and alternative communication (AAC) systems significantly improves the quality of life for mute individuals. Also, social inclusion is another crucial aspect of meeting the needs of mute people. Research by Smith and Jones (2019) highlights the importance of creating inclusive environments that foster communication and interaction. This can be achieved through raising awareness and understanding among the general public, promoting empathy, and providing appropriate support in educational, workplace, and social settings. As with blind and deaf people, access to education and employment opportunities is essential for mute individuals to lead fulfilling lives. Inclusive educational practices, such as providing sign language interpreters or specialized communication support, can enable mute students to actively participate in classroom activities and engage with their peers (Johnson & Lee, 2017). Mute individuals may also require psychological support to cope with the emotional and psychological challenges they face. Studies have shown higher rates of anxiety and depression among mute individuals compared to the general population (Davis et al., 2016).

Define

Problems Faced by Blind People

Blindness significantly affects an individual's daily life, including mobility, communication, and access to information. Studies have shown that blind people often face difficulties in independently navigating their surroundings, recognizing obstacles, and accessing public transportation (Smith and Jones, 2018). The inability to see also hampers their ability to read printed material, view visual content, and engage in activities that require visual perception. Blind people encounter various challenges that can significantly impact their quality of life. One of the primary challenges is the lack of accessibility in the physical environment. Buildings, public spaces, and transportation systems are often not designed to accommodate the needs of blind individuals, leading to barriers to their mobility and independence (Kitchin and Law, 2001). Additionally, blind people may face discrimination, social exclusion, and limited employment opportunities due to societal misconceptions and stereotypes (Hanh, 2019). To address the needs of blind people effectively, it is essential to understand their specific requirements. One crucial need is access to information. Blind individuals require alternative formats, such as braille or auditory content, to access written materials (Pousada and Fernandes, 2016). Accessible technology, such as screen readers and voice assistants, can also play a significant role in enhancing blind people's access to digital information and communication (Senjam, 2021).

Problems Faced by Deaf People

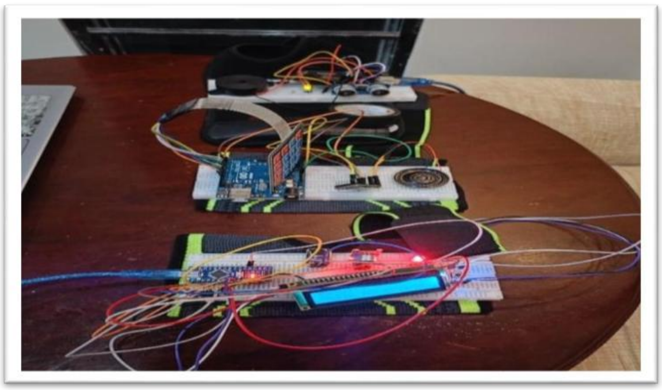
As with blind people and mute people, one of the primary challenges deaf people face is the communication barrier they encounter in their daily lives. Without the ability to hear, deaf individuals often struggle to communicate effectively with others who do not understand sign language. This can lead to feelings of isolation, frustration, and exclusion from social interactions and educational opportunities (Mitchell & Karchmer, 2004). Deaf individuals often face limited access to information due to a lack of accommodations for their unique needs. For instance, many videos, online content, and educational materials do not offer closed captions or sign language interpretation. This lack of accessibility can hinder their educational and professional development, further exacerbating the challenges faced by deaf people (Singleton & Tittle, 2000). Deaf students often encounter educational disparities compared to their hearing counterparts. The traditional education system is primarily designed for hearing individuals, making it difficult for deaf students to fully participate and engage in the classroom, which leads to not securing employment. Building a successful career can be particularly challenging for deaf individuals. Discrimination, limited job opportunities, and communication barriers in the workplace can hinder their professional growth (Steinberg, 2009). The problems faced by deaf individuals can also have a significant impact on their mental health and overall well-being. The experiences of communication barriers, limited access to information, educational disparities, and employment challenges can contribute to feelings of low self-esteem, depression, anxiety, and social isolation (Fellinger et al., 2012).

Problems Faced by Mute People

One of the primary issues faced by mute individuals is their inability to communicate effectively through spoken language. This can lead to significant chalenges in expressing thoughts, needs, and emotions, which can result in frustration and isolation. Also, mute individuals often face social stigmas and misunderstandings from others due to their inability to speak. They may be perceived as unintelligent or shy, leading to exclusion, bullying, or discrimination. Studies by Johnson and Anderson (2019) emphasize the need for increased awareness and education to combat these negative stereotypes, promoting inclusivity and acceptance of mute individuals within society. Then, there is the traditional classroom environment, which heavily relies on verbal communication, which can hinder their participation and academic progress. Studies by Lee and Thompson (2018) highlight the importance of incorporating inclusive teaching strategies, such as visual aids, peer support, and alternative assessment methods, to create an inclusive learning environment that caters to the needs of mute students. The inability to communicate verbally can have a profound emotional and psychological impact on mute individuals. Feelings of frustration, loneliness, and low self-esteem are commonly reported. Research conducted by Chen et al. (2020) suggests that providing psychological support and counseling services to mute individuals can help address these issues, fostering better mental well-being and overall quality of life.

Ideate

The study's proposed system constitutes a helpful tool formally known as the "Disabilitrix", a device that is designed to help people with disabilities in their everyday lives through proper communication for mute and deaf people and alarm or obstacle detection for the blind. This tool includes functions for obstacle detection and text-to-speech conversion, along with a speaker and additional general modules. These device functions are designed for scalable programming, allowing for



corrections, improvements, and the addition of more functions like additional reminders as needed. Each module or function does a specific task as follows:

Figure 2. HMI Operational Mode for Obstacle Detection (Bai et al., 2019).

Obstacle Detection

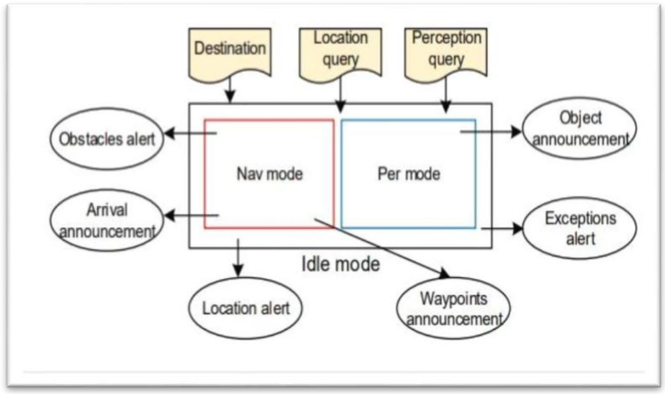
The prototype for this research study comprises an Arduino-based obstacle detection system using an HC-SR04 ultrasonic sensor, a Piezo Buzzer, and an LED indicator. The device alerts users with both sound and light signals when an obstacle is detected within a 1-meter range. The ultrasonic sensor measures distances, and if the detected distance is less than 20 cm, the Piezo Buzzer emits a 1-second tone, and the LED is illuminated for visibility. The prototype provides a tangible demonstration of a simple yet effective obstacle detection mechanism, laying the foundation for further development and application in assistive technologies or navigation aids.

Text-to-Speech

The prototype for the research study is also designed to answer the specified problem for mute people, providing an early model for evaluation and testing. To give a visual and interactive representation of the envisioned system, key capabilities such as data entry, processing, and output have been implemented. Users can actively interact with the prototype by entering data and moving via the interface. The evaluation criteria for the prototype, which include usability, functionality, and performance, will be critical in determining its usefulness. Recognizing the prototype's preliminary character, it acts as a dynamic tool subject to incremental development depending on user feedback. The data created by user interactions will provide significant insights, leading to adjustments and improvements throughout the study process.

Speech-to-Text

The prototype of this study also proposed a solution for deaf people, embodying the theoretical constructs of the study. Its modular architecture comprises key components, including an input processing module for data collection, a core processing unit for algorithmic execution, and an output presentation module for user-friendly displays. Highlighted features encompass adaptability, real-time processing capabilities, scalability for system expansion, and seamless integration with external systems. The user interface is



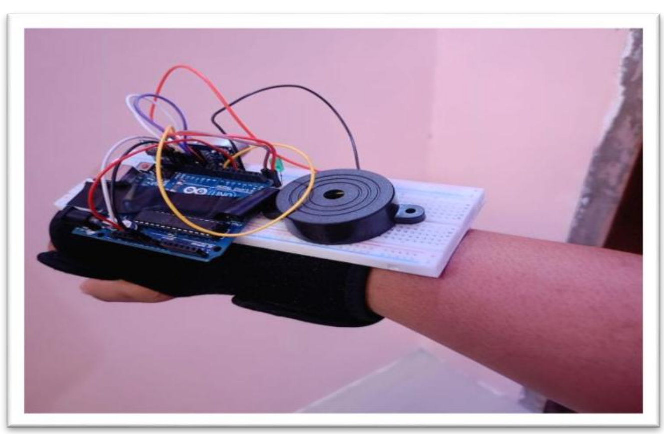
designed for intuitive interactions and validated through rigorous testing procedures. Noteworthy use-case scenarios underscore the prototype's effectiveness in addressing identified research challenges.

Prototype

Figure 3 shows the assembled prototype in separate boards and holders for accurate testing and evaluation of the different functions or modules.

Figure 3. Structure of the Device

Figure 4 shows the view of the device in three different holders (arm and wrist straps) being worn by a user. The three (3) modules of the device are not integrated into the same board and holder because they are undergoing accurate testing and evaluation individually, given that this is a prototype. This approach ensures that adjustments and modifications can be made effectively. In the final device, smaller and lighter components such as nano boards and nano



versions of the components will be utilized.

Figure 4. View of the Modules Being Worn on the Wrist

In Figure 5, the general scheme of the equipment is presented, its performance, internal characteristics, and the interrelation of internal modules located in the central processor.

Figure 5. The General System Architecture and the Main Modules that Constitute the Proposed Approach

Operating Principle

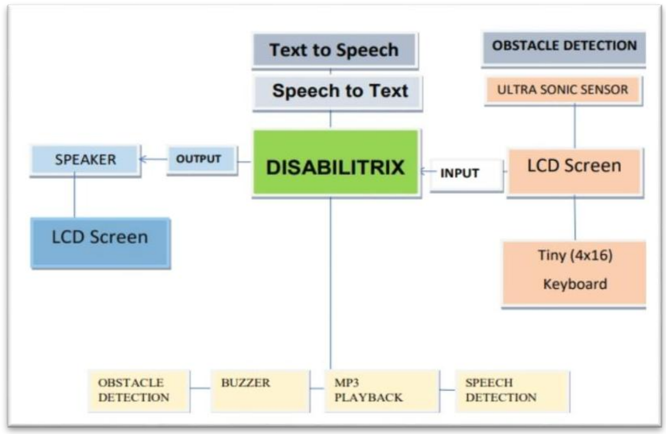
The Obstacle detection module works on the basis of ultrasonic distance measurement with an HC-SR04 sensor. When the sensor is triggered, it emits ultrasonic pulses and measures the time it takes for the pulses to reflect off an obstacle and return. This information is processed by the Arduino, which determines the distance to the obstacle. If the detected distance is less than 20 cm, the module activates a Piezo Buzzer, which emits a distinct sound and illuminates an LED to provide visual feedback. This simple operating principle enables effective obstacle detection, providing users with real-time auditory and visual alerts.

The text-to-speech module functions cohesively via a complex algorithmic framework, which has been carefully developed for optimal performance. The module employs an input processing module to collect and preprocess real-time data (multi-keypad to DFplayer mini), followed by the execution of complex algorithms within the core processing unit. The processed information is then translated into user-friendly displays by the Output Presentation Module (Speech), ensuring accessibility and clarity. Overall, the operational principle of the module reflects a seamless integration of its modular components, demonstrating adaptability and efficiency across a wide range of scenarios.

The speech-to-text module operates by utilizing an Electret Microphone and a sound detection module in conjunction with an Arduino microcontroller. The Electret Microphone captures ambient sound, converting it into electrical signals, while the sound detection module distinguishes significant sound levels. The Arduino processes these signals, calculating the peak-to-peak values to recognize predefined words such as "Hello," "Okay," and "Help." Upon word recognition, the system displays corresponding phrases on a Liquid Crystal Display (LCD), providing a user-friendly interface for interpreting spoken commands.

Algorithm and System Development

The obstacle detection system development follows a structured algorithmic approach. First, during initialization, the Arduino board is set up, and the pins for the ultrasonic sensor (TRIG_PIN, ECHO_PIN), Piezo Buzzer (SPEAKER_PIN), and LED (LED_PIN) are configured. Critical parameters are defined, such as the distance threshold for activating the sound and light indicators, with 20 cm triggering immediate detection and 100 cm establishing a 1-meter range. The sensor operation involves emitting ultrasonic pulses, measuring the echo return time, and calculating the distance using a formula. A condition check is then implemented: if the calculated distance falls below the immediate threshold, the Piezo Buzzer emits a 1-second tone, and the LED is illuminated. Conversely, if the distance surpasses the 1-meter threshold, any ongoing tones are stopped, and the LED is turned off. This systematic algorithm ensures a precise and responsive obstacle detection system, seamlessly integrating hardware control and sensor data processing for effective real-time feedback.



The text-to-speech development process follows a systematic, four-step algorithm. Firstly, analyze the project requirements, identifying key functionalities and specifications. Once the analysis is complete, it proceeds to design a comprehensive system architecture, defining the components and their interactions (multi-keypad key numbers correspond to file numbers on the SD card). Following this phase, the system will be implemented, and code will be developed and tested thoroughly to ensure that the functionality meets the specified requirements. Finally, the team rigorously tests the entire system, identifying and resolving any bugs or issues before deploying the finalized solution.

The Speech-to-Text module employs an Arduino-based system with MAX4466 and KY-038 sensors for sound detection. The algorithm orchestrates the initialization of essential components, creating a loop where the system continuously listens for user input. Upon detecting significant sounds, the system activates an LED indicator and identifies spoken phrases through a word recognition function. Recognized phrases trigger specific responses, such as displaying corresponding messages on an LCD screen for an extended period. The system then transitions to a "Listening..." state, awaiting the next user input. This development results in a responsive and user-friendly Speech-to- Text module that is suitable for various applications requiring voice interaction.

Testing and Evaluation

In the testing phase of this study, the researchers give the three separate modules to blind, deaf, and mute people. Before starting, the researchers taught and informed the participants of the test and how the different modules work. Then, after testing, the researchers interviewed the participants for evaluation.

Figure 6. Testing the Obstacle Detection to a Blind Person

Obstacle Detection Testing and Evaluation

A visually impaired user, relying solely on auditory and tactile feedback, explores the obstacle detection system. As the user approaches an obstacle within the immediate range, the distinct sound emitted by the Piezo Buzzer clearly indicates the obstacle's presence. Simultaneously, the LED illuminates, offering a supplementary visual cue. When the user moves beyond the 1-meter threshold, the system gracefully ceases the audible alert, maintaining a non-intrusive environment.

However, the evaluation uncovered mixed findings. While participants appreciated the centralized positioning of the device in their hand, which facilitated ease of access and operation, concerns were raised regarding potential fatigue and disorientation resulting from prolonged use. One tester highlighted that although the centralization was beneficial, it could lead to tiredness in the arms and potential disorientation. Moreover, a crucial drawback identified was the device's inability to provide specific location information for detected obstacles. Participants noted that unlike traditional canes, which offer tactile feedback and allow users to physically discern obstacles, "Disabilitrix" solely relied on auditory cues, limiting its effectiveness in spatial awareness. One tester suggested a convergence between the functionality of the cane and the device, proposing a "cane detector" that could provide vibrations from different directions to indicate obstacle proximity while the cane itself serves as a tool for tactile feedback.

Additionally, concerns were raised about the size and portability of the device, with one tester noting that it was too bulky and required additional equipment, such as a laptop, to function. Suggestions were given for the device to be made smaller and more portable or, alternatively, to be integrated as an attachment to a traditional cane, enhancing its safety features without sacrificing mobility.

Figure 7. Testing the Text-to-Speech to a Mute Person

Text-to-Speech Testing and Evaluation

The evaluation of the Text-to-Speech (TTS) functionality of the "Disabilitrix" device provided valuable

insights from a mute individual testing its communication capabilities. The user successfully interacted with the input processing module, utilizing the keypad to input messages, and found that the pre-programmed responses were helpful in expressing fundamental concerns or needs on a daily basis.

While acknowledging the usefulness of the pre-programmed responses, the tester highlighted areas for improvement. They noted that while the TTS function efficiently conveyed basic messages, its pre-programmed nature limited its adaptability to express more nuanced thoughts or respond dynamically to conversations. However, the tester also appreciated the simplicity and reliability of the pre-programmed responses for everyday communication needs. Furthermore, feedback from testers about the speaker volume and clarity provided valuable insights for enhancement. Despite some challenges with volume and clarity, the tester recognized the device's effectiveness in conveying messages through tactile and visual outputs.

Additionally, the tester's feedback shed light on the convenience of the input method, albeit with limitations. While the 4x4 keypad membrane facilitated text input, its pre-programmed nature restricted real-time interaction. However, the tester acknowledged that this input method still provided a practical means of communication for daily use.

Figure 8. Testing the Speech-to-Text to a deaf person

Speech-to-Text Testing and Evaluation

In the testing phase, a deaf individual utilized the "Disabilitrix" speech-to-text device to evaluate its communication features. The focus was on assessing the effectiveness of visual or tactile communication methods in facilitating seamless interaction. Researchers employed the writing method to communicate with the participant, transcribing spoken words into text on paper.

The evaluation conducted by the deaf individual revealed the device's helpfulness in translating spoken words into text, aiding communication. However, a significant limitation was noted regarding the device's reliance on pre-programmed words. When encountering phrases not included in its database, the device failed to accurately capture and display the intended message. This dependency on predetermined vocabulary could potentially hinder effective communication and lead to misunderstandings. It is important to note that this function was primarily designed for demonstration purposes to showcase how speech-to-text technology works and how it can assist mute individuals in understanding spoken language. However, for the tester, while they appreciated the device's functionality within its programmed constraints, there was a sense of missed opportunity for real-time translation capabilities. They expressed regret that the device could not operate beyond demonstration purposes, as real-time functionality would significantly enhance its usability and inclusivity.

Despite its limitations, the "Disabilitrix" effectively demonstrated its intended functionality, providing valuable insight into the potential of speech-to-text technology. The feedback from testers underscores the importance of advancing the device's capabilities to recognize a broader range of spoken language, thereby improving its usability in real-world communication scenarios. By implementing advanced algorithms capable of real-time translation and expanding its vocabulary database, the "Disabilitrix" can evolve into a more versatile and inclusive communication tool for individuals with hearing impairments.

III. Discussion

In addressing the question regarding the development of wearable assistive devices to cater to the unique needs of visually impaired, deaf, and mute individuals, it is evident that the integration of assistive functionalities such as obstacle detection, text-to-speech, and speech-to-text has shown promising results in providing solutions to the challenges faced by these communities.

The findings from the testing and evaluation phase highlight the effectiveness of the device in addressing the identified needs. The obstacle detection function, inspired by previous studies (Noman et al., 2017; Chen, 2008), demonstrated its ability to provide real-time environmental information to visually impaired individuals. By utilizing ultrasonic sensors and auditory cues, the device enables users to navigate their surroundings safely and independently. Feedback from testers emphasized the importance of such functionality in enhancing spatial awareness and mobility, aligning with the literature's emphasis on accessibility in the physical environment (Wilson et al., 2022).

Furthermore, the text-to-speech and speech-to-text functionalities were designed to improve communication and social interaction for mute and deaf individuals, respectively. Drawing from previous research (Senjam, 2021; Kushalnagar et al., 2010), the device offers pre-programmed responses and real-time translation capabilities, facilitating seamless communication in both verbal and written forms. Tester feedback underscored the significance of these features in promoting independence, efficiency, and inclusivity in daily interactions, echoing the literature's emphasis on accessible communication and education (Hauser et al., 2017; Johnson & Lee, 2017).

By integrating insights from previous studies and addressing the specific needs identified in the literature review, this research contributes to the development of inclusive assistive technology solutions. The positive feedback from testers validates the utility and acceptance of the device, aligning with the Technology Acceptance Model's principles of perceived usefulness and ease of use (Ringwald et al., 2023). Moving forward, further enhancements based on user feedback and technological advancements will continue to drive the evolution of assistive devices, ensuring equitable access and support for individuals with disabilities.

Moreover, the evaluation of the developed device underscores the importance of user feedback in refining and optimizing assistive technologies. By actively involving individuals with disabilities in the testing and evaluation process, researchers can gain valuable insights into the usability, effectiveness, and user satisfaction of the device, ultimately leading to more inclusive and impactful solutions (Bai et al., 2019).

For the question regarding the barriers and challenges faced by visually impaired, deaf, and mute individuals in accessing and utilizing existing assistive technologies, this study has shed light on key areas for improvement. Through user feedback and literature review, the researchers have identified limitations in current solutions, such as lack of specificity in obstacle detection, limited adaptability in communication aids, and dependency on pre-programmed responses (Smith and Jones, 2018; Mitchell & Karchmer, 2004). By acknowledging these challenges and ddressing them in the device design, this study aims to overcome existing barriers and pave the way for more inclusive assistive technology solutions. Moving forward, continued collaboration between researchers, engineers, and end-users will be essential in driving innovation and ensuring that assistive devices meet the diverse needs of individuals with disabilities (Johnson and Anderson, 2019; Lee and Thompson, 2018).

LIMITATION

Despite diligent efforts, several inherent limitations emerged that influenced both the study's execution and its subsequent conclusions. One significant limitation pertains to the sample size used for testing and evaluation. The study might have limitations in terms of the number of participants included, which could have implications for the diversity of insights and perspectives obtained. A larger sample size could provide more comprehensive data and a broader understanding of the usability and effectiveness of the wearable device. Additionally, the findings of the study might be limited in terms of generalizability. The specific population and locale mentioned (i.e., individuals with visual impairment, hearing impairment, and muteness in Baguio) may restrict the extrapolation of results to other populations or geographic locations. Care should be taken when applying the study's findings to different contexts, as variations in cultural, environmental, and socio-economic factors could influence the device's usability and acceptance. Moreover, the prototype developed for the study might have limitations in terms of technology readiness and scalability. Further advancements in technology may be necessary for real-world implementation of the device, especially considering evolving user needs and preferences. Additionally, gathering comprehensive user feedback from individuals with disabilities may present challenges due to communication barriers or cognitive differences, thus limiting the depth of insights gained for device refinement.

IV. CONCLUSION

This research demonstrates the potential of wearable assistive devices to address the unique challenges faced by visually impaired, deaf, and mute individuals. By integrating obstacle detection, text-to-speech, and speech-to-text functionalities, the device offers practical solutions to enhance mobility and communication for these communities.

The findings from the testing and evaluation phases underscore the importance of user feedback in refining and optimizing assistive technologies. Through the active involvement of individuals with disabilities, the researchers gained valuable insights into usability, effectiveness, and user satisfaction, paving the way for more inclusive and impactful solutions. However, this study also highlights several limitations, including sample size constraints, a potential lack of generalizability, and the technological readiness of the prototype. Future research should focus on addressing these limitations by expanding sample sizes, considering diverse populations and locales, and advancing technology to meet evolving user needs.

Overall, this research contributes to the development of inclusive assistive technology solutions, emphasizing the importance of collaboration between researchers, engineers, and end-users to ensure equitable access and support for individuals with disabilities. By overcoming existing barriers and challenges, the researchers aim to create a more accessible and inclusive society for all.

V. RECOMMENDATIONS

The "Disabilitrix" wearable assistive device shows significant promise in meeting the unique needs of people with visual impairment, hearing impairment, and muteness. Further enhancements and refinements to the "Disabilitrix" wearable assistive device could significantly improve its functionality and effectiveness for individuals with disabilities. Integrating a navigation system alongside the obstacle detection feature is advisable for future studies, potentially addressing navigation challenges faced by users. However, it is crucial to acknowledge potential limitations in pinpointing obstacle locations accurately. Exploring the transformation of the obstacle detection feature into a cane-like interface could be beneficial, leveraging tactile feedback to provide users with a more intuitive understanding of their surroundings.

Moreover, optimizing the device's design with Nano boards and smaller components ensures it remains compact and portable, enhancing its usability in various settings. Exploring alternatives to the text-to-speech module, such as voice recognition modules or EasyVR shields, offers a balance between functionality and cost-effectiveness. Additionally, incorporating cloud-based voice-to-text services can enhance speech processing adaptability and overall user experience. Implementing user training programs is essential to ensure a positive user experience and maximize the device's capabilities. These programs can help users familiarize themselves with the device's features and functionalities, promoting greater independence and confidence in its use.

Also, incorporating user feedback, such as the insightful suggestion from one of the testers, is crucial for refining the "Disabilitrix" wearable assistive device. The idea of converging the cane and device into a cane detector that provides vibrations from multiple directions (North, South, West, and East) offers a novel approach to enhancing obstacle detection and navigation for users. By utilizing vibrations as indicators, individuals can receive real-time feedback about their surroundings, enhancing their ability to navigate safely and independently. Additionally, integrating the device into a cane form factor adds an extra layer of usability and familiarity for users, empowering them with enhanced safety features while maintaining the tactile feedback provided by a traditional cane.

Lastly, prioritizing continuous improvement and community engagement is vital to address technical limitations and promote wider acceptance of the device among individuals with disabilities. By incorporating these details into future research and development efforts, the "Disabilitrix" wearable assistive device can evolve to better meet the diverse needs of its users and contribute to improving their quality of life.

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