Real-Time Accessibility Tool For Specially Abled People

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Abstract: Over the years, many technologies have been realized to aid people who suffer from sensory and physical disabilities. Real-time assistance is offered by these technologies, which use artificial intelligence, machine learning, and mobile computing. For their users who are presumably visually challenged, object-detection models coupled with image processing give audio feedback for easy navigation. Speech-to- text applications and text-to-speech applications cover the communication gap for deaf and mute persons. Some of these systems also perform sign language recognition, OCR, and voice synthesis to make life interactable. Hardware tools include ultrasonic sensors and smart gloves for specific impairments. However, these solutions are mostly class-wise and least integrated with one another. This survey paper goes into the depth of past developments and stresses the need for inclusive, multipurpose, user-friendly platforms that cater to as many differently abled users as possible.

Index Terms - Assistive Technology, Artificial Intelligence, Object Detection.

I. INTRODUCTION

Accessibility tools have come to symbolize a branch of modern technology that improves life for people with disabilities. People with impairments of the eyes, those with impairments of hearing, and those with impaired speech suffer greatly when attempting to communicate, using transportation, or accessing information. For that purpose, researchers and developers have built countless assistive technologies over the most recent decade. These vary from hardware solutions that include smart canes, wearable sensors, haptic feedback systems, among others, to software solutions that depend on computer vision, natural language processing, or mobile applications.

Deep-learning-based object detection systems such as YOLO, through a mobile camera, could help the visually impaired with navigation by converting visual data into audio prompts in real time. Other technologies such as speech-to- text and text-to-speech have been found most apt to support individuals with hearing and speech impairments and are often inculcated into mobile applications that further allow for two-way communication. Research efforts are also being carried out into sign language recognition, OCR for reading printed text, and voice-based alerts.

Despite these advancements, most solutions remain narrow in scope, often designed to address one form of impairment. Furthermore, these solutions are hampered with limitations concerning language support, hardware price, competition, and integration, preventing their broad adoption by people of the rural setting, resource-poor environments in general. In this survey paper, we review and analyze the technologies developed earlier, investigating their methodology, impact, and limitations. The objective is to highlight the strengths and weaknesses with the existing means and significance of building an inclusive, real-time, a united platform for a broader range of disabilities.

II. LITERATURE REVIEW

Researchers have focused on developing assistive technologies that help bridge the communication gap for people with disabilities, particularly those who are blind, deaf, or mute. One of the earliest developments in this domain was the use of flex sensor-based gloves. Anbarasi et al. [2] proposed a sensor-based system to assist deaf-mute communication by interpreting gestures using accelerometers and flex sensors, providing a foundational approach to wearable gesture recognition interfaces. Kuldeep Singh Rajput et al. [30] further enhanced this idea by introducing an interactive accelerometric glove, enabling real-time sign recognition for hearing-impaired individuals.

To cater to users with both hearing and visual impairments, Jayatilake et al. [3] introduced a multi-modal interface that converted images into natural language text using wearable camera systems. This allowed users with different sensory impairments to communicate through a shared language medium. Building on this idea, Tanyawiwat and Thiemjarus [4], [25] designed a glove using combined sensory channels— accelerometers, tactile, and flex sensors—for more accurate gesture-based communication. Samonte et al. [5], [24] also proposed an SPNG-based approach for converting images into natural language, which enhanced multimodal accessibility.

Ghosh et al. [6], [23] developed the Data Entry Glove, which is considered a landmark in wearable input devices, offering ASCII character entry using sensor-dense gloves. The glove included flex, tactile, and inertial sensors that laid the groundwork for interpreting sign language alphabets. This was followed by surveys by Vaidya et al. [7], [26], highlighting the potential of glove-based interfaces across accessibility domains. Mocanu and Tapu [8], [27] extended these ideas by automating Arabic Sign Language recognition using PowerGlove technology, which provided insights into language-specific adaptations.

Amitha M. Lokeshwar et al. [9] introduced "Glove Talk," a neural network model for translating sign language gestures directly into synthesized speech, significantly improving human-computer interaction for differently abled users. Furthermore, the integration of Braille systems [10], [22] offered a tactile reading solution for the visually impaired, supporting non-audio modes of communication. As part of standard sign communication, American Sign Language (ASL) [11] has been extensively referenced and adopted in sensor-glove systems.

The advent of microcontrollers like the Arduino platform [12] has revolutionized the development of lightweight assistive tools. Arduino boards provide flexibility and modularity, making them suitable for wearable communication systems. When combined with GSM Shields [13], these devices can transmit data or alerts over mobile networks, facilitating long-distance communication.

For more complex processing, Texas Instruments' BeagleBone Black [14], [15] has been used in systems like SHAROJAN BRIDGE to integrate audio-visual inputs with analog and digital signal conversion. The Arduino UNO together with vibrating motors form essential hardware elements which provide haptic feedback needed for deaf-blind users, as demonstrated by Ruthvik Srinivasa et al. [16] and Sasikala and Shaik [17]. These components work together to form bi-directional communication systems like SHAROJAN BRIDGE, which adjust messages based on sender and receiver capabilities.

The Raspberry Pi system by Rithika and Nithya [1] enabled language flexibility through its ability to convert image text into speech across fifty languages. Their system employed Tesseract OCR and Google Text To Speech to provide real-time interaction capabilities for both visually impaired and non-English speaking users. Recent works like those by Namita Shah et al. [18] and Sartha Tambe et al. [29] demonstrate a steady movement towards hybrid, accessible communication solutions which scale to meet complex user requirements.

III. TOOLS USED

Researchers have employed a variety of hardware and software tools to develop assistive technologies that enable communication for individuals with sensory impairments, especially those who are deaf, mute, or blind. These tools have evolved from basic sensor-based systems to advanced AI- integrated platforms.

Sensor-Based Gloves were among the earliest tools. Researchers such as Anbarasi et al. [2] and Kuldeep Singh Rajput et al. [30] used flex sensors and accelerometers in wearable gloves to detect hand and finger

movements. These gloves translated sign language gestures into digital signals, enabling communication for hearing-impaired individuals. The inclusion of tactile sensors and gyroscopes in later models improved accuracy by detecting wrist rotation and pressure, as demonstrated by Tanyawiwat and Thiemjarus [4].

To address the needs of both visually and hearing-impaired users, researchers integrated wearable cameras with Optical Character Recognition (OCR) technology. Jayatilake et al. [3] employed such systems to convert images into text, which was then processed into speech using Text-to-Speech (TTS) tools like Google TTS. Similarly, Rithika and Nithya [1] used Tesseract OCR in combination with Raspberry Pi boards to translate image text into speech (fig – 1)in over fifty languages.

Microcontroller platforms played a crucial role in these developments. Arduino boards, especially Arduino UNO, were widely adopted due to their modularity, low power consumption, and ease of integration with sensors. Researchers such as Hesham et al. [12] built wearable systems using Arduino to detect and interpret gestures. When combined with GSM Shields, these systems could transmit alerts and messages over mobile networks [13], enabling remote communication.

In more complex systems like SHAROJAN BRIDGE, researchers utilized the Beagle Bone Black microcontroller for its advanced processing capabilities. This allowed integration of audio-visual inputs with real-time digital and analog signal processing [14], [15].

To support communication for deaf-blind individuals, tools such as vibration motors and haptic feedback systems were implemented. These components provided tactile feedback, allowing users to receive responses through vibrations. Ruthvik et al. [16] demonstrated the effectiveness of such systems in enabling bi-directional communication.

On the software side, machine learning and neural networks were integrated into systems like Glove Talk by Amitha M. Lokeshwar et al. [9], where gestures were recognized and directly translated into speech. This marked a shift towards intelligent, adaptive communication tools. Overall, earlier researchers combined embedded systems, sensors, and AI tools to lay the groundwork for modern assistive technologies. These tools continue to evolve to meet the diverse and complex needs of users with sensory impairments.
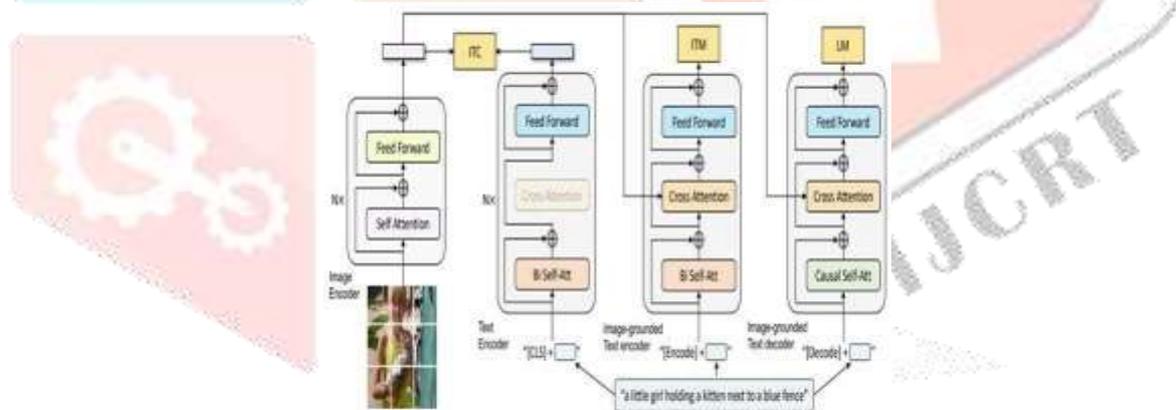

Figure 1: Image to Speech flow diagram

IV. SYSTEMS CHARACTERISTICS AND CHALLENGES

Assistive technology systems developed for individuals with sensory disabilities possess a range of unique characteristics that determine their effectiveness, usability, and adaptability. These systems are typically designed to be wearable, portable, and lightweight, ensuring that users can carry them throughout daily activities without discomfort. Many devices, especially gloves and tactile feedback systems, emphasize real-time processing, allowing immediate translation of gestures, text, or audio inputs into understandable formats such as speech, vibration, or visual displays.

Another defining characteristic is multi-modal integration. Advanced systems combine various input sources like accelerometers, cameras, microphones, and OCR modules—to capture and process diverse signals. For example, a device might convert hand gestures into speech while also providing image- to-text conversion for the visually impaired. Language flexibility is also a critical trait, enabling systems to function across multiple regional or global languages through TTS and STT modules.

Despite these strengths, assistive systems face several challenges. One primary challenge is gesture and speech recognition accuracy. Variability in hand size, signing speed, pronunciation, and background noise can lead to misinterpretations. Systems must be trained on large, diverse datasets to enhance recognition and reduce false positives. Power consumption and hardware limitations also pose significant barriers. Wearable devices, especially those using microcontrollers like Arduino or Raspberry Pi, often struggle to balance processing power with battery life and form factor. Ensuring continuous operation without frequent recharging remains a hurdle.

Affordability and scalability are additional concerns. High- quality sensors, vibration motors, and microcontrollers can raise production costs, limiting access for economically disadvantaged users. Moreover, systems must be designed for inclusive usability, accommodating varying degrees of disability, including complete deaf-blindness, which requires advanced tactile or Braille-based interfaces. Lastly, privacy and data security are emerging concerns as these systems begin to integrate cloud-based AI services, requiring protection of sensitive user data.

V. METHODOLOGY

Earlier research in assistive technologies for sensory disabilities followed a structured methodology combining hardware design, software integration, and user-centered evaluation. Most studies adopted an engineering-based design approach where prototypes were developed iteratively based on functional requirements and user needs.

The initial phase of most methodologies involved identifying the type and extent of disability being addressed. For instance, studies targeting hearing or speech-impaired individuals, like those by Anbarasi et al. [2] and Amitha M. Lokeshwar et al. [9], began by analyzing sign language gestures or facial movements. These gestures were broken down into measurable parameters such as finger bends, orientation, and position using flex sensors, gyroscopes, and accelerometers embedded in gloves or wearable devices.

Researchers Jayatilake et al. [3] working with visually impaired individuals followed a different path—capturing visual input using Raspberry Pi cameras or similar modules. The image data was then processed using Optical Character Recognition (OCR) algorithms, often with the help of Tesseract OCR, to extract text which was then converted into speech using Google TTS (figure-2) or similar tools.

Mid-stage development involved integrating the hardware with microcontrollers such as Arduino UNO, Raspberry Pi, or Beagle Bone Black. The sensor signals were interpreted using machine learning models (e.g., decision trees or neural networks) or simple rule-based logic to produce real-time responses. For instance, in glove-based systems, sensor values were mapped to a pre-defined set of gestures, each linked to a corresponding word or sentence.

Many studies implemented bidirectional systems—especially those supporting communication with both deaf and mute users by incorporating voice recognition modules or speech- to-text (STT) conversion to allow responses from the other end. Finally, Researchers evaluated systems based on metrics like accuracy, response time, comfort, and ease of use. Feedback from differently-abled individuals or special educators was used to refine the designs in further iterations. This methodical and iterative approach ensured that the developed assistive tools were not only technologically sound but also practical and user-friendly for everyday use.
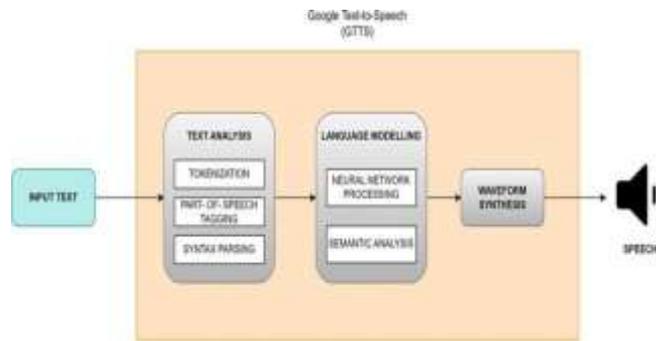
Figure 2: Text to Speech diagram

VI. PROPOSED FRAMEWORK

Based on insights drawn from previous research, the proposed assistive communication system is designed to support individuals with sensory disabilities through a real- time, modular, and adaptive framework. This system facilitates bi-directional communication by combining hardware sensors, artificial intelligence algorithms, and user- centric output interfaces.

The first component is the Input Processing Unit, which collects data based on the user's type of impairment. For hearing- or speech-impaired users, data is captured using flex sensors, accelerometers, and gyroscopes embedded in wearable devices like smart gloves to recognize hand gestures and sign language. For visually impaired individuals, a camera module captures text or object visuals from the environment, while a microphone is used to capture voice inputs for further processing.

Next, the Processing and Translation Unit interprets the collected data using embedded platforms such as Arduino or Raspberry Pi. For sign language or gesture inputs, the data is analyzed using gesture recognition algorithms and mapped to corresponding words or phrases. Visual data is processed using Optical Character Recognition (OCR) engines like Tesseract, and speech data is converted into text using speech- to-text (STT) APIs. AI integration allows for enhanced prediction accuracy and adaptability over time.

Finally, the Output Unit delivers translated content in user- friendly formats—text displayed on screens, speech via text- to-speech (TTS) tools, or haptic feedback for users with dual sensory impairments. The system is customizable, language- flexible, and can function both offline and online depending on user needs and infrastructure availability.

VII. CONCLUSION

The analysis of existing research on assistive technologies for individuals with sensory disabilities highlights the significant progress made in real-time communication systems. Through the integration of sensors, microcontrollers, and intelligent processing tools such as gesture recognition, OCR, and speech APIs, these systems have enabled smoother interaction for deaf, mute, and visually impaired users. However, challenges remain in terms of device affordability, user adaptability, and multilingual support. Future developments must focus on creating more compact, cost-effective, and scalable solutions with improved AI capabilities. A unified framework, as proposed, can bridge communication gaps and empower users by enhancing accessibility, independence, and social inclusion in real-world environments.

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