International Journal of Current Trends in Engineering and Technology
www.ijctet.org, ISSN: 2395-3152
Volume: 11, Issue: 01 (January -February, 2025)

Assistive Technology Solution for Visually Impaired/Low Vision Students for Their Schooling

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Abstract- Nowadays, visually impaired students face many challenges during their schooling. Due to their low vision, they are unable to compete with others to their full potential. In certain situations where visual attention is necessary, such as chemistry lab practicals, reading notices on notice boards, and detecting hurdles in their path, these students encounter significant difficulties. Therefore, our intention is to assist students with visual impairments or low vision in their schooling through the use of assistive technology. Assistive technology refers to any device, software, or equipment that helps individuals overcome their challenges. This report aims to discuss the development of assistive devices that will serve as effective solutions for visually impaired students.

Keywords:- Assistive Technology, Visually Impaired, Accessibility, Obstacle Detection, Smart Devices, Education Technology

1. Introduction

The World Health Organization (WHO) states that there are 285 million visually impaired people worldwide, including 39 million who are blind [1]. In the United States alone, more than 1.3 million people are completely blind, and approximately 8.7 million are visually impaired [2]. Among them, 100,000 are students, according to the American Foundation for the Blind [2] and the National Federation of the Blind [3]. Over the past years, the incidence of blindness caused by diseases has decreased due to successful public health initiatives. However, the number of blind individuals over the age of 60 is increasing by 2 million per decade. Unfortunately, these numbers were estimated to double in 2020 [4].

Globally, a large number of visually impaired people suffer from low vision, with India having the highest number of such individuals. According to [13], India accounts for 21% of the total blind population worldwide. Within India, approximately 8 million out of 39 million visually impaired people are blind. Among every 1 million people, 53,000 are visually impaired, 46,000 have low vision, and 6,800 experience complete vision loss. Unfortunately, due to a lack of awareness, many of these individuals have been labelled as blind or partially blind and were provided with Braille training. In reality, their vision could have been improved with the help of low-vision aids.

Assistive technology can be used to help visually impaired individuals, particularly in navigation and orientation. The simplest and most affordable navigation tools currently available are trained guide dogs and white canes [5]. Although these tools are widely used, they do not provide blind individuals with all the necessary information and features for safe mobility that are available to sighted people [6, 7]. Therefore, there is a need to develop a smart assistive device based on assistive technology that can support the daily activities of visually impaired individuals. We believe this will contribute to the development of low-vision services in the country and strengthen programs designed to meet the needs of individuals with low vision. “Low vision” is defined as a chronic visual impairment that causes functional limitations or disability. It is considered chronic because it cannot be corrected through medical or surgical intervention or by refractive error correction. Visual impairment refers to the loss of visual acuity, reduced contrast sensitivity, loss of peripheral vision, or the presence of central blind spots. These impairments lead to functional limitations, such as increased difficulty with reading, mobility, visual-motor activities, interpreting visual information, and night blindness. As a result, individuals with low vision may experience disability, which affects their ability to perform usual or customary daily activities. People with disabilities use all systems, services, equipment and devices to help them in their daily lives, make their activities easier, and provide safer mobility under one umbrella term: Assistive Technology [8]. Visual assistive technology is divided into three categories: vision enhancement, vision substitution, and vision replacement [12]. This assistive technology became available for blind people through electronic devices, which provide the users with detection and localisation of objects in order to offer those people a sense of the external environment using the functions of sensors. The sensors also aid the user with mobility tasks based on the determination of the dimensions, range, and height of the objects [6]. The vision replacement category is more complex than the other two categories; it deals with medical and technology issues. Vision replacement includes displaying information directly to the visual cortex of the brain or through an ocular nerve [12]. However, vision enhancement and vision substitution are similar in concept; the difference is that in vision enhancement, the camera input is processed, and then the results will be visually displayed. Vision substitution is similar to vision enhancement, yet the result constitutes a non-visual display, which can be vibration, auditory or both based on the hearing and touch senses that can be easily controlled and felt by the blind user.

Related Work

Wahab et al. [14] studied the development of the Smart Cane product for detecting objects and producing accurate instructions for navigation. It is a portable device that is equipped with a sensor system. The system consists of ultrasonic sensors, a microcontroller, a vibrator, a buzzer, and a water detector in order to guide visually impaired people. It uses servo motors, ultrasonic sensors, and a fuzzy controller to detect the obstacles in front of the user and then provide instructions through voice messages or hand vibration. An assistive device for blind people was introduced by White et al. [15] to improve the mapping of the user's location and positioning of the surrounding objects using two functions that are based on a map-matching approach and artificial vision [16]. The first function helps locate the required object and allows the user to give instructions by moving their head toward the target. The second one helps in the automatic detection of visual aims. This device is a wearable device that is mounted on the user's head, and it consists of two Bumblebee stereo cameras for video input that are installed on the helmet, a GPS receiver, headphones, a microphone, and Xsens Mti tracking device for motion sensing. The system processes the video stream using the SpikNet recognition algorithm [17] to locate the visual features that handle the 320 × 240-pixel image. A design of a tiny dipole antenna was developed in [18] to be connected to a Tongue-placed electro-tactile device (TED) to assist blind people in transmitting information and navigating. The device contains an antenna to support wireless communication in the system, a matrix of electrodes to help the blind sense through the tongue, a central processing block (CPU), a wireless transmission block, an electrode-controlling block, and a battery. A matrix of 3x3 electrodes that are distributed into eight pulses will be replaced in the blind person's tongue, and the remaining components will be fabricated into a circuit. Each pulse responds with vibration to the specific direction of navigation. This paper describes a miniature dipole antenna for a tongue-placed electro-tactile device designed to support blind and visually impaired people in information transmission and mobility assistance. A wearable aid system for blind people (named CASBlip) was proposed by Dunai et al. [19]. This design aims to provide object detection, orientation, and navigation aids for both partially and completely blind people. This system has two important modules: a sensor module and an acoustic module. The sensor module contains a pair of glasses that includes the 1X64 3D CMOS image sensors and laser light beams for object detection. In addition, it has a function implemented using a Field Programmable Gate Array (FPGA) that controls the reflection of the laser light beams after its collision with the enclosure object to the lenses of the camera, calculating the distance, acquiring the data, and controlling the application software. The other function of FPGA was implemented within the acoustic module in order to process the environmental information for locating the object and convert this information to sounds that stereophonic headphones will receive. A Radio Frequency Identification Walking Stick (RFIWS) was designed by Saaid et al. [20] in order to help blind people navigate on their sidewalks. This system helps detect and calculate the approximate distance between the sidewalk border and the blind person. Radio Frequency Identification (RFID) is used to transfer and receive information through radio wave medium.

RFID tag, reader, and middle are the main components of RFID technology. A supportive reading solution for blind people called FingerReader was introduced by Shilkrot et al. [21] to aid disabled people in reading printed texts with a real-time response. This device is a wearable device on the index finger for close-up scanning. So, the device scans the printed text one line at a time, and then the response comes in tactile feedback and audio format. FingerReader is a continuous work of EyeRing, which was presented in [22] for detecting a particular object once at a time by pointing and then scanning that item using the camera on the top of the ring. Andreas Kunz et al. [23] introduced the concept of a virtual environment that allows experiencing unknown locations by real walking while still staying in a sage-controlled environment. Since this virtual environment can be controlled in its complexity, it can be adjusted from an abstract training scenario to a real-life situation such as train stations or airports. Bharambe et al. [24] developed an embedded device to act as an eye substitution for vision-impaired people (VIP) that helps in directions and navigation. The embedded device is mainly a TI MSP 430G2553 microcontroller (Texas Instruments Incorporated, Dallas, TX, USA). The authors implemented the proposed algorithms using an Android application. The role of this application is to use GPS, improved GSM, and GPRS to get the location of the person and generate better directions. The embedded device consists of two HC-SR04 ultrasonic sensors (Yuyao Zhaohua Electric Appliance Factory, Yuyao, China) and three vibrator motors. Krishna Kumar et al. [25] deployed an ultrasonic-based cane to aid the blind people. This work aims to replace the laser with ultrasonic sensors to avoid the risk of the laser. This cane is able to detect ground and aerial obstacles. The authors claimed that this device could be a navigational aid for blind people. However, the results showed it is only an object detector within a small range. Prudhvi et al. [26] introduced an assistive navigator for blind people by adapting GSM and GPS coordinator. It helps the users detect their current location. Hence, navigating them using haptic feedback. In addition, the user can get information about time, date and even the colour of the objects in front of them in audio format. The proposed device is attached to a silicon glove to be wearable. Syed Tehzeeb Alam et al. [27] developed a smart assistive device for visually impaired individuals. The model is designed to guide blind users and prevent unwanted collisions with obstacles through pre-recorded voice commands, thereby providing active feedback. It consists of two modules—a cane unit and a shoe unit—both of which are integrated and function as a single system connected via Bluetooth. The device also provides orientation assistance using a digital compass. Infrared (IR) ranging sensors embedded in both the cane and shoe units work together to deliver real-time information to the user. Additionally, a pressure switch is incorporated to alert the user if they lose hold of the cane. An LED lighting system on the cane helps notify surrounding pedestrians of the presence of a visually impaired individual. Collectively, these features help reduce the risk of injury for blind users. B. Rajapandian et al. [28] proposed a new system prototype aimed at facilitating communication among individuals who are blind, deaf, or mute. The system utilises portable technology and Arduino circuit boards to provide an effective means of communication for individuals with one or more of these disabilities. The device allows the sender to input a message in various formats, including text, hand gestures, or Braille, depending on their specific disability and available resources. The message can then be transmitted over short or long distances as needed. Upon reaching the receiver, the message is converted into text, voice, or Braille output, depending on the receiver's abilities and available facilities. Madhura Gharat et al. [29] recommended an RFID-based system for independent navigation in a building for blind or visually impaired people. The conversion of speech to text is carried out using speech recognition software modules. This system is initiated by providing a voice command and specifying the destination to be reached by the blind person. This navigation system will guide the blind person along the path by providing audio navigation assistance to reach the desired destination. To avoid the collision, an ultrasonic sensor will be interfaced with the Raspberry Pi. By implementing the above technique, blind people can navigate independently and acquire information about their current location within the intended building.

Our Objectives

Assistive technology (AT) refers to any adaptive device or service that enhances participation, achievement, or independence for students with disabilities. It plays a crucial role in supporting visually impaired students, with or without additional disabilities, by increasing their access to the general curriculum and improving their academic performance. It is essential to carefully consider the most suitable devices, tools, and technologies to meet each student's unique learning needs. AT devices should not provide undue advantages but rather empower students with the independence to compete effectively with their peers. The primary goal of assistive technology is to ensure that children with disabilities have access to literacy and communication in school, at home, and within the community. This report aims to introduce assistive technology solutions designed to support visually impaired students in situations where vision is essential. The primary objectives include enhancing traditional notice boards to assist blind and low-vision individuals, providing aid to blind and low-vision students performing chemistry practicals, and developing a smart assistive device for hurdle detection. These innovations aim to improve accessibility, promote independence, and create a more inclusive learning environment for visually impaired students.

Objective 1: Improving traditional notice boards to help blind and low-vision people

Institutions and organisations use notice boards to keep their students and members informed about important updates. However, these notice boards primarily rely on printed material or text to convey messages, which can be inaccessible to individuals who are blind, have low vision, are illiterate, or do not understand the local language. This inability to read prevents them from receiving crucial information in a timely manner. Organisations strive to maintain inclusivity by fostering diversity and encouraging different perspectives, which ultimately benefits their overall growth. Promoting inclusivity also involves ensuring that blind and low-vision individuals can access information in a format that suits them best. To address this challenge, we propose developing a vision-substitution-based system that delivers notifications through audio output.

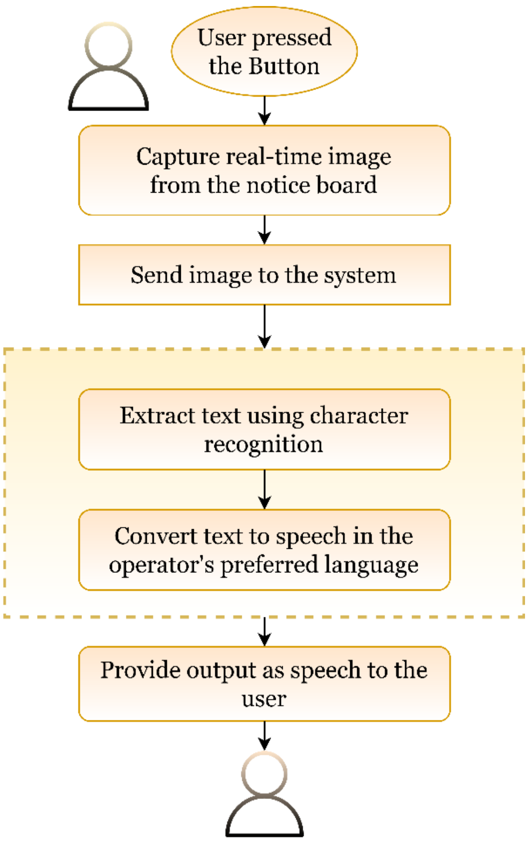

Figure 1. Block diagram for developing the audio-based notice board

International Journal of Current Trends in Engineering and Technology
www.ijctet.org, ISSN: 2395-3152
Volume: 11, Issue: 01 (January -February, 2025)

Suggested Solution: In order to overcome this issue, traditional notice boards can be enhanced with cameras that capture real-time images of posted notices. These images will be processed by a trained model that converts the text into speech. The system will be designed so that whenever a visually impaired individual stands in front of the notice board, they can press a push button to receive the notice as an audio message. By simply listening to the information, they can stay updated without relying on visual reading. The block diagram for this proposed system is illustrated in Figure 1.

Objective 2: An aid for blind/low vision students to perform chemistry practical

Experiments give a very vivid picture of the theoretical knowledge imparted by the teacher in the classroom. Experiments are designed so that the students get a clear idea of the content of the books. In the case of chemistry, experiments result in changes in pressure, temperature, colour and state of matter. Changes in temperature and pressure are measured using a thermometer and barometer, whereas the change in state of matter and colour are just visual observations. These visual observations make it difficult for visually impaired students to conduct the experiments and hence become an obstacle in their education. With the help of an example, in this reaction, when iron reacts with copper sulphate, the copper sulphate turns from blue to green, which is called iron sulphate, as a result of displacement reaction.

$$Fe + CuSO4 \dashrightarrow FeSO4 + Cu$$

(Blue) (Green)

During laboratory experiments, visually impaired students often struggle to observe critical changes, such as colour variations, which are essential for understanding chemical reactions. This limitation prevents them from gaining the same level of comprehension as their peers. Without the ability to visually confirm outcomes, they face significant challenges in conducting experiments independently. This lack of exposure to hands-on learning further hinders their educational experience. To address this issue, we propose developing a vision-substitution-based application that will assist visually impaired students by providing real-time feedback on their experiments, ensuring they can determine whether they are performing the steps correctly.

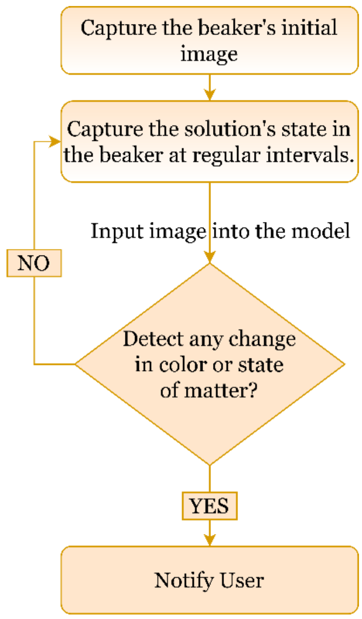

Figure 2. Block diagram to aid students in chemical experiments

Suggested Solution: To enable blind and low-vision students to conduct experiments successfully, we propose an application that utilises a camera to capture images of the beaker or test tube at fixed time intervals (e.g., every five seconds). These images will then be processed using an image recognition model or an image processing application to detect changes in colour or substance conditions relevant to the experiment. If a noticeable change occurs, the system will notify the user through an audio alert or speech output. By receiving these notifications, students will be aware that a reaction has taken place, allowing them to gain the same understanding as their sighted peers. The block diagram for this proposed system is illustrated in Figure 2.

Objective 3: Hurdle detection using a smart assistive device

This section focuses on developing a device that serves as an effective solution for visually impaired individuals. Blind or partially blind people face significant challenges in independent mobility and navigation, as their inability to perceive their surroundings hinders daily activities. The proposed model aims to assist visually impaired individuals by guiding them and preventing unwanted collisions with obstacles. This is achieved through pre-recorded voice commands and vibrations, providing active feedback and enhancing their overall mobility and safety.

Suggested Solution: A vision substitution-based assistive wearable device can be developed to support visually impaired or low-vision individuals. This device will not only detect obstacles but also help prevent unwanted collisions through audio alerts and vibrations. It will require a camera and sensors to function effectively. The camera module will capture frames from which obstacles will be detected using computer vision techniques. The obstacle recognition module will then identify and label the detected objects.

Additionally, the sensor module will measure the distance between the obstacle and the camera, ensuring accurate detection. This device can recognise a wide range of obstacles, including small objects on walkways (e.g., toys), large static barriers (e.g., building walls), stairs, and uneven surfaces. It provides multiple warnings to the user before making contact with an obstacle, enhancing safety and mobility. The block diagram for hurdle detection is illustrated in Figure 3.

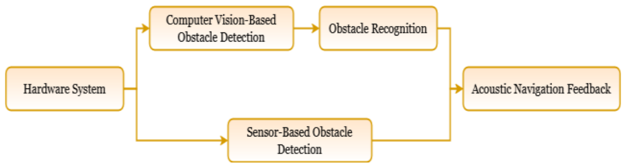

Figure 3. Block diagram for hurdle detection.

Conclusion

In this paper, we present a comparative survey of wearable and portable assistive devices for visually impaired people in order to show the progress in assistive technology for this group of people. Thus, the contribution of this literature survey is to discuss in detail the most significant devices that are presented in the literature to assist this population. Additionally, we have also discussed some suggested solutions to help visually impaired students. These suggested solutions can be formulated in the formation of wearable devices. The manufacturing cost and commercial version of these devices will be affordable for everyone.

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