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Paper 29

ARTIFICIAL INTELLIGENCE AND SENSORS BASED ASSISTIVE SYSTEM FOR THE VISUALLY IMPAIRED PEOPLE

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Abstract :
The need for developing a low-cost assistive system for the visually impaired and blind people has increased with steady increase in their population worldwide. The stick system presented in the paper uses artificial intelligence along with various sensors in real time to help the visually disabled people to navigate their environment independently. Image recognition, collision detection and obstacle detection are the three tasks performed by the system. The image recognition task was performed using a smartphone application powered by artificial intelligence. The tasks of collision detection and obstacle detection utilized ultrasonic sensors to alert the user of the obstacles appearing in his route. The stick system also managed to demonstrate the important characteristics of affordability, high efficiency, mobility and ease of use.

Keywords: visually impaired; image recognition; collision detection; obstacle detection; artificial intelligence; real-time system

I. INTRODUCTION

According to the reliable estimates of WHO (World Health Organization), about 40 to 45 million people are blind from the global population of 285 million visually impaired people [1]. With the staggering number of visually disabled people around the world, providing care for such a large population results in an enormous socio- economic stress on the countries. About 90% of global visually impaired people belong to low-income households with highest numbers in developing countries like India [1, 2]. This trend will continue to grow because of widespread chronic eye diseases, population growth as well as rising ageing population around the world with developing countries bearing most of the brunt [1].

People with visual disability have a constant need of assistance in their daily lives. It can range from relying on other people for help to using various Electronic Travel Aid (ETA) assistive devices whenever needed. People also use Guide dogs and white canes but the restriction on the allowance of guide dogs in certain places and short range of white canes serve as their shortcomings. Similarly, most of the ETAs also have drawbacks of being unaffordable and inefficient. Keeping a tab on the various drawbacks of traditional and common methods of providing assistance to the blind and visually impaired people, we decided to develop and design our system with a novel approach. Past few years have seen wide scale applications of artificial intelligence ranging from national defence, scientific research, automated vehicles to space exploration. Taking advantage of the monumental

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advances in artificial intelligence and helping visually impaired people was our main goal. For the features we desired and the tasks which we intended our system to perform, depending solely on artificial intelligence was not feasible. So using a microcontroller and sensors based hardware in addition to artificial intelligence was decided upon. The system thus not only makes use of artificial intelligence capabilities but also gathers precise readings from the various sensors to become a real-time assistive system. This enables the visually impaired people to navigate the world independently with confidence.

II. RELATED WORK

A significant quantity of research has been published previously for helping the visually impaired and blind people. One such work described Artificial Vision System for Blind (AVSB) [3], consisted of ultrasonic sensors and a microcontroller that anticipated the distance of the obstacles around the user and to advise him towards an alternative available route via an audio feedback. The disadvantage of this system was that it blocked the daily routine hearing of the visually impaired individuals. Tactile Vision System [4] was another published work that was studied for our paper. The system converted visual information into a tactile signal using a tractor-belt with 14 vibrators and a camera belt with two webcams. The drawback of this system was the prototype being heavy and its failure to differentiate between hanging and ground obstacles. The Navbelt system [5] used 8 ultrasonic sensors to create a map of angle and distances of objects around the user. The limitations of having a bulky prototype and use of audio feedback exclusively for functioning plagued this work.

All the work mentioned before lacked enthusiasm towards using AI in their systems along with consideration for mobility and affordability of the system. Focus on implementing obstacle detection, collision detection and image recognition together was also absent. Learning from the drawbacks and building upon the positives of these earlier works helped us design a better system. In an earlier version of our work [6] on this subject, we presented a brief explanation of our idea of developing a cost-effective assistive system for the visually impaired and blind people. The earlier system lacked the prowess of artificial intelligence and its capabilities of computer vision, machine learning and natural language processing. The implementation of image processing techniques of edge detection and texture detection for image recognition purpose often ended with error-prone results. The previous system hardware implementation also required numerous iterations of fine tuning and calibration to work seamlessly. A significant change in the use of accelerometer and improvements to the prior collision detection algorithm were also made in this work.

III. PROPOSED SYSTEM

Two thirds of the estimated 285 million visually impaired people globally will become smartphone users in the next five years [7] with Android based smartphones having the highest user base around the world especially in developing countries [8]. The stick system was developed to leverage this estimate and consists of a 1 foot long PVC cable raceway stick and a smartphone application. The stick houses a Arduino Nano microcontroller, two ultrasonic sensors, an accelerometer and a Bluetooth module as shown in Fig. 1. The smartphone application resides on the user's Android smartphone.

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Fig. 1. The stick hardware setup

After powering on the stick and opening the smartphone application, the user starts walking by holding the stick in one hand and smartphone in the other. The smartphone application and the sensors on the stick then start a continuous analysis of the environment in the user's route.
In order to get some perception of his surroundings, the user captures images of his environment through his smartphone. These images are then processed by the artificial intelligence in the smartphone application leading to caption generation for each image which describes their contents. These captions are then conveyed to the user by the smartphone reading them aloud through its speakers. The ultrasonic sensor mounted on the front side of the stick detects the location of the obstacles appearing in the front of the user and an audio feedback is provided to the user so that he alters his route to avoid colliding with the obstacles. The other ultrasonic sensor mounted at the bottom of the stick along with the accelerometer detects the presence of potholes and bumps in the user’s route eventually alerting the user via haptic feedback to make the user change his route. The flowchart of the proposed system is as shown below.

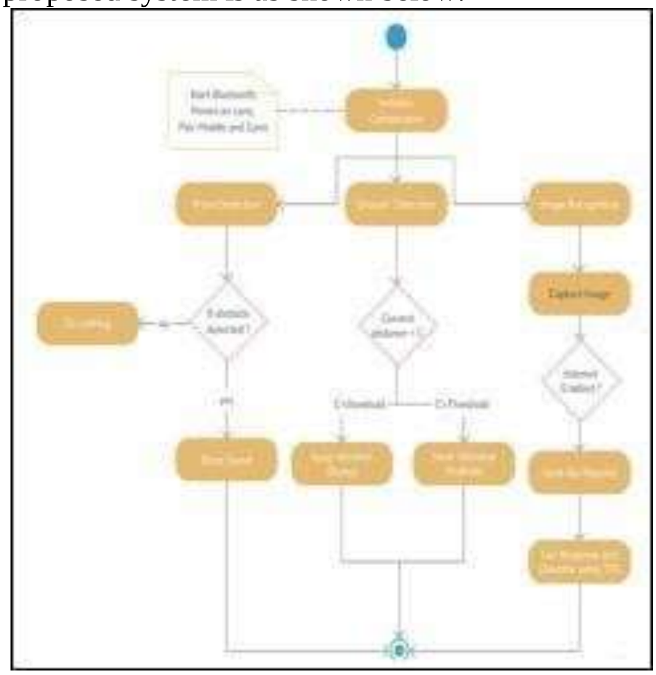

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Fig. 2. Flowchart of the system

A. System Architecture

The Arduino Nano microcontroller acts as the brain of the system, taking readings from the two ultrasonic sensors and the accelerometer to compute various the distance values. The Arduino board then sends these values to the smartphone using a Bluetooth connection. The two HC-SR04 ultrasonic sensors are tasked with identifying the recurring obstacles coming in the user's route by sending and receiving ultrasonic waves. One sensor is located at the bottom and the other on the front side of the stick.

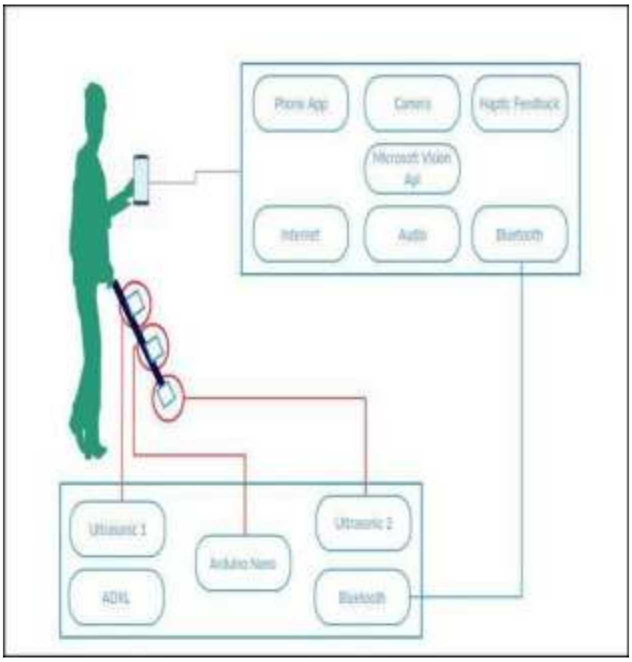

Fig. 3. Overview of the system

The ADXL345 MEMS accelerometer provides supplementary information of the angles at which the distance between the ground and the stick were measured by the bottom ultrasonic sensor. Bluetooth HC-06 is a short range wireless communication module. This module sends all the computed distance values from the Arduino board to the user's smartphone. The smartphone application performs image recognition as one of its main tasks and makes use of the smartphone's rear camera, speakers, cellular internet connection and Bluetooth connection. It also provides audio and haptic feedback to the user.

IV. IMPLEMENTATION AND RESULTS

This system basically performs three tasks i.e. image recognition, collision detection and obstacle detection. Image recognition helps the visually impaired user to listen to a brief description of his surroundings. Collision detection focuses on instructing the user of avoiding possible collision with an obstacles upfront in his route. Obstacle detection identifies potholes and bumps on the ground in the user's route, guiding the user to avoid it. These three tasks are explained as follows:-

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A. *Image Recognition*

Image recognition deals with extracting information from the user captured images and narrate this information back to the user. For this purpose, the user holds the smartphone in front of him and captures images via the rear camera using the volume down button on his smartphone. The images are then analyzed by the application's artificial intelligence eventually generating captions for every user captured image. These captions describe the contents of the images which are then conveyed to the user using Google TalkBackThe smartphone application uses a cellular internet connection to perform artificial intelligence related tasks. The Computer Vision API of Microsoft Cognitive Services is what really powers the artificial intelligence in our system [10]. Whenever the need to analyze an image arises our system application code invokes a call to this API. Image analysis by the API is done using computer vision, machine learning and neural networks whereas natural language processing is used to generate the caption in a human understandable language [11]. Leveraging the power of the API, the smartphone application can analyze an image, read texts and handwritten texts from an image, identify landmarks and celebrities and also perform video analysis in near real -time [10]. For the image caption speaking feature, we decided to use Google TalkBack service since it comes preinstalled on most Android devices [9].

B. *Obstacle Detection*

The ultrasonic sensors generate high frequency sound waves and evaluate the echoes received back by the sensors. For the task of obstacle detection, the ultrasonic sensor mounted at the bottom of the stick sends ultrasonic waves towards the below ground and starts the timer. The timer is stopped when the waves reflected from the ground are received. Using the time required by the waves to return back to the sensor, the distance value between the stick and the ground is calculated in the Arduino board using the following formula:

Approx. speed of sound c =

331.5 + [0 · 6 × (air temperature in degree Celsius)]

at 20 degree

$c = 331 \cdot 5 + (0 \cdot 6 \times 20) = 343 \cdot 5\ m/s$

$c = 343 \cdot 5 \times 100\ cm/\mu S = 0 \cdot 03435\ cm/\mu S$ 10

1

accessibility service [9]. Google TalkBack identifies the generated captions and speaks it to the user via the smartphone speakers or through the earphones connected to the smartphone. This allows the user to get a good perception of his surrounding environment and helps him to better navigate his route.

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Fig. 4. Result of image recognition

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speed of sound = $c = 29 \cdot 1$
The time interval between ultrasonic waves sent by the sensor is in µS.

$$\text{distance} = \frac{\frac{\text{duration}}{2}}{29 \cdot 1}$$

The Bluetooth connection between the Arduino and the smartphone is used to transfer the computed distance value from the Arduino board. The smartphone application then processes this value and marks this reading as actual distance value (i.e. Calibrated value). Henceforth, all the incoming computed distance values and the angle values from the accelerometer are marked as the current distance values. Using all these values, the smartphone application detects the presence of bumps and potholes in the user's current route. If the current distance value is found to be less than the calibrated value then detection of a bump is inferred and the smartphone gives out a long vibration as feedback so as to caution the user. If the current distance value is found to be more than the calibrated value then the detection of a pothole is inferred with a short vibration as feedback.

C. Collision Detection

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Identifying the presence of an obstacles upfront in the user's route and warning him of a possible collision with the obstacles by providing an audio feedback are the tasks performed in collision detection. The second ultrasonic sensor, mounted on the front side of the stick is utilized for this task. A distance of 4 feet has been set as the default safe distance in front of the stick wherein if any obstacle is detected inside the safe distance, the collision detection system starts warning the user. For this task, the sensor transmits ultrasonic waves towards the front direction of the user along with starting a timer to keep a track of time. Once the waves reflected from the obstacle are received by the sensor, the timer is stopped. Using the time difference between the moment the ultrasonic waves were sent from and received back by the sensor along with the distance formula used in the obstacle detection algorithm, the distance between the user and the obstacle in the user's route is calculated. These calculations are performed by the Arduino board unit. The computed distance value is then sent from the Arduino board to the user's smartphone using a Bluetooth connection in the same way as observed in the obstacle detection task. The smartphone application then processes these readings and generates a series of beeping sounds thus alerting the user and causing him to alter his current route.

Fig. 5. Result of obstacle and collision detection

All these tasks from calculating the distance of obstacles from the user to generating warning sounds happen in real time so that the user can act quickly and be safely away from a potentially dangerous situation. Fig. 5 shows the calculated values generated by the obstacle and collision detection tasks.

V. CONCLUSION

In this paper, design and development of a real-time artificial intelligence system for assisting visually impaired and blind people has been discussed. The system performed three main tasks of image recognition, collision detection and obstacle detection allowing the user to navigate his route independently. Using incumbent devices like a smartphone and a compact but high quality hardware, our system managed to overcome the hurdle of developing an

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assistive system which was both efficient and affordable enough for the visually impaired people especially belonging to the low-income households. Future research work involves refining our system so that a more hands-free assistive system experience can be provided for the visually disabled people.

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