Smart Cane for Staircase and Water Detection

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Abstract *— The World Health Organization (WHO) reported that there are 285 million visually-impaired people worldwide. Among these individuals, there are 39 million who are totally blind. Blind people need some help in interacting with the society. Existing devices are able to detect and recognize objects that emerge on the floor, but a considerable risk is also includes when the objects that are at a sudden depth, or obstacles above waist level or stairs. The designed smart cane uses a single IR sensor to detect staircases and a water detection sensor is used to detect water pits. If there's a staircase or a water pit, user will receive an alert as a form of audio voice output informing him whether the path is clear for him to safely walk forward. This project aims at the design and implementation of a detachable unit which is robust, low cost and user friendly, thus, trying to aggrandize the functionality of the existing white cane, to concede staircase and water pit detection. The smart cane was tested for its proper functioning while operating successfully in detecting staircases and water pits.*

Keywords *—* **IR sensor, staircase, cost effective**

I. INTRODUCTION

According to the statistics of World Health Organization(WHO), 285 million people are visually-impaired. 39 million are blind and 246 have low vision. Even for the non-visually impaired the congestion of obstacles is sometimes problematic, it's even worse for the visually impaired. People with visual disabilities are often dependent on external assistance. Humans, trained dogs, or special electronic devices can be taken as support systems for visually-impaired people. Majority of visually impaired people cannot find their way autonomously in an unknown area.

Generally visionless persons use a white cane or walking cane. It is a pure mechanical device dedicated to detect static obstacles on the ground, holes, uneven surfaces, steps and other hazards via simple tactile-force feedback. Its light weightiness and the capability to be folded into a small piece can be advantageous to carry around when not required (Fig. 1). These simply designed canes are only capable of detecting below waistline obstacles like street curves and simple guidance between distances. Even though these canes are capable of detecting obstacles, receiving feedback is very low (Sakhardande et al., 2012). Therefore, visually impaired individuals still find it difficult to navigate especially in unknown environments. More high-tech devices, using different types of range finders, have been in the market and have been widely used too but they are discarded on the basis of cost and other factors.

Figure 1. White cane/walking cane

Despite various research findings to improve the mobility of the blind, there are drawbacks in the existing solutions.

The major disadvantages of these solutions are:

1) They only detect obstacle existence and distance without specifying indication about their nature which is important for the user to know.

2) They are unable or inaccurate in detecting some obstructions that are not protruding but present potential threat such as descending stairs, holes, etc.

3) The system communicates its recommendations, through intensity or frequency variations. Thus, feedback information is often sent to the user through vibration. So, a training course is needed to keep the user informed about how to understand and react in real time to alerts that are transmitted regarding the existence of obstacles as well as their recognition. On the one hand, such training can be sometimes more expensive than the product itself.

To overcome these difficulties, cost effective white cane has been designed to detect nearby stairs, water pits and alert the user about these using audio signals. This white cane is designed to guide visually impaired people when they are moving without his/her guardian. Structure of this product can be divided into three main parts as Smart cane, Detection module, IOT module and mobile app. Each part has its own inputs and a process to provide the output. This system includes four features namely staircase and water detection, IoT Module, navigation, emergency alert which provides essential aids to the visually impaired person.

II. Literature Review

A. Early Developments

In 1958 Kenneth Jernigan, the director of the then Iowa Commission for the Blind, now known as the Iowa Department for the Blind introduced the Iowa Cane. This was made from fiberglass which improved the sound produced by the cane when it was tapped on a surface. Its handle was of green plastic with a metal tip at the bottom of the cane. With time the white cane has gone through various developments which have most of the time prioritized the ease of usage. For storing purpose the telescoping and folding canes were introduced (Strong ,2017)

With the time, white cane has gone through many technological advancements and has ultimately reached the level of a smart cane which not only can serve as a mobility support but also as an obstacle detection device may it be above the knee level (Sheth et al., 2010) or below the knee level (Azigi and Hurst, 2011).

B. Recent Advancements

For the detection of the obstacles, sensors such as IR and Ultrasonic sensors (Sheth et al., 2010) have been widely used. Informing the blind of the detected obstacles has been done using methods such as vibrating the stick and sending a voice output (Sheth et al., 2010).

Detections for the stair cases, Ultra Sonic sensors have been used in some researches (Bouhamed et al., 2010; De Alwis,2016). A pair of infrared sensors has been used to detect stair-cases and other obstacles presence in the user path, within a range of two meters (Nada,2015).

Some researches has been using Kinet sensor and 3D image processing in indoor scenarios in different lighting conditions and the results showed it can identify walls, doors, stairs, and a residual class that covers loose obstacles on the floor accurately (Pham et al.,2016).

Water sensors have used to detect puddles, water pits and water spreads (Nada et al.,2015).

For the IoT equipped smart cane we have used the IR sensor technology to detect obstacles, stair cases and the water sensor to detect puddles, water pits as the project name suggests IoT technology, MIT App Inventor to build the code and google maps for navigation purposes.IR sensor technology uses infrared waves (near IR region) for object detection. The first practical IR detector sensitive to IR wavelengths up to 3m employed lead sulphide (PbS) as the IR sensitive material. During the last four decades, different types of detectors have been combined with electronic readouts to form detector focal plane arrays (FPA) revolutionizing the field of infrared imaging. Progress in integrated circuit design and fabrication techniques too have contributed to the rapid growth and performance of these solid-state devices (Rogalksi,2012).

III. Methodology and Experimental design

A. Data Gathering

Qualitative and quantitative data required for designing the requirement specification for the IoT equipped smart cane was gathered through interviews, questionnaires and document review techniques which were carried out at the Ceylon School for Deaf and Blind. Face to face interviews were conducted with the Principal of the Deaf and Blind school, teachers and students. Questionnaires were distributed among students and teachers' and answers were gathered accordingly.

B. Data Analysis

The data which were gathered during the data gathering phase were analysed by using various analysing techniques. Through analysing the data, the group could reveal the extent procedure, problems, limitations, suggestions of the students and teachers for the smart cane. Drawbacks in the existing solutions are the lack of ability to use traffic signals and to get real time updates of the surroundings of a specific location, lack of information provided to the visually impaired people to get details about public transport, lack of ability to cross the road safely without getting disturbed by obstacles laying around the road, lack of ability to get to know about puddles, lack of ability to use staircases. Concluding the analysis section, the authors finally decided to design an IoT equipped smart cane with the ability to alleviate all the above- mentioned drawbacks.

C. Approach

The users of this system are visually impaired people who need to navigate between places for various tasks for their daily needs. There are five main inputs such as pairing request by the mobile app to the smart cane, pairing request by the mobile app to the IoT module, data collected by the smart cane and IoT module to the mobile app, triggering a navigation voice input "navigation" should be given and send an emergency message with the location voice input "help". The readings are sent to the mobile app of the smart cane using the IR sensors and water sensor, giving audio feedback to the user about the sensor data and traffic light data by the mobile app. With the voice input "navigation" Google maps opens and with the voice input "help" emergency message is sent to the guardian.

D. Technology Adopted

Four important state of the art technologies were used in developing the IoT equipped smart cane. Arduino open source hardware/software platform was used to make the prototyping phase faster. In developing the hardware part an Arduino UNO and Arduino Mega2560 were used. Arduino IDE was used to program the hardware parts.

In order to develop the Mobile application MIT App Inventor was used (Fig. 2). It is an open source, web-based system developed by Google that allows people to create android apps for prototyping purpose.

IoT is a novel concept used in order to incorporate with the smart cane for better functionality and it is the key feature in this solution. IoT modules are installed in smart cities and certain specific places and the smart cane is designed in such a way as to enable communication with such installed IoT modules.

Three IR sensors were used in this cane. They are placed in order to detect barriers to the right, left and at the center of the user. When an obstacle is detected by any of these sensors, instructions are given to the user by a voice output alerting the user to avoid the barrier ahead. He will also receive updates about the barrier when it is too close to him.

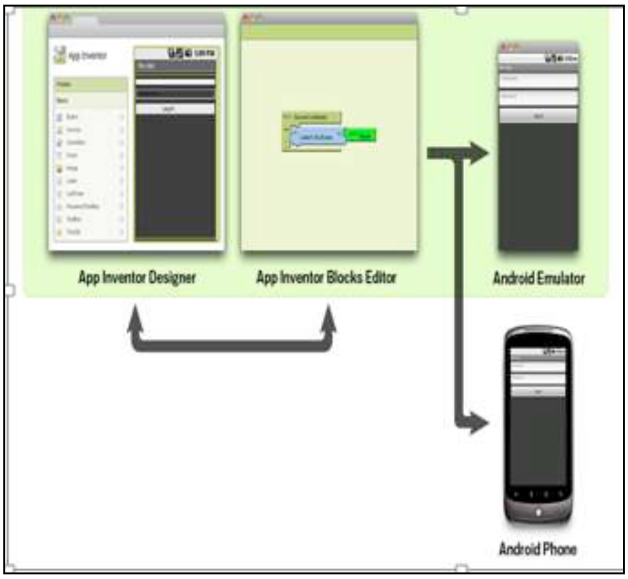

Figure 2. Use of App Inventor with Android phones

E. Hardware Design

1) Design of the smart cane: The smart cane basically carries out two functions. They are detecting barriers ahead of the user and transmitting the relevant data to the android application. In order to execute these functions the following items were used.

- Arduino UNO
- Breadboard
- HC-06 Bluetooth Module
- 5 IR Sensors – (GP2Y0A21YK0F)
- Arduino Water Sensor
- Toggle
- Switch
- 1 LED (On/Off State Indicator)
- 9V battery
- Jumper Wires
- Project Box

HC-06 Bluetooth module is paired with the android mobile phone which transmits the data gathered through the sensors to the android mobile phone.

Three IR sensors are used to detect any barrier or obstacle and send that information to the Arduino software platform. Two other IR sensors are used in order to detect steps (staircases) or puddles on the ground. Water sensor is used in order to detect puddles by the way. Toggle switch is used to turn the circuit On/Off and an LED is used to display the On/Off status in the circuit. A 9V battery supplies power to all the electronic items in the smart cane and a project box is used to house all the components. Jumper wires are used to interconnect the components. (Fig.3)

UNO board is powered by a 9V battery which is connected to the DC (direct current) input terminal of the Arduino UNO board.

The bread board is given a +5V by connecting its positive power rail to the +5V pin in the Arduino UNO board (shown by the black wire connecting the bread board and the Arduino UNO board). The black wire connects the GND (ground) pin of the Arduino UNO board to the bread board.

Each IR sensor has three main outputs:

- VCC, the positive voltage terminal (indicated in red) is given a +5V by connecting it to the +5V power rail in the bread board.
- GND, the negative terminal (indicated in black) is grounded by connecting it to the negative power rail of the bread board.
- Analog terminals of the three IR sensors (indicated in yellow) are connected to the A0, A1 and A2 Analog input pins of the Arduino UNO board. These Analog terminals transmit sensor data collected by the IR sensor to the Arduino UNO board.

The Bluetooth module HC-06 has four main outputs:

- VCC, the positive voltage terminal (indicated in red) is given a +5V by connecting it to the +5V power rail in the bread board.
- GND, the negative terminal (indicated in black) is grounded by connecting it to the negative power rail of the bread board.
- TX, the transmitter of the Bluetooth module (indicated in orange) is connected to the RX, the receiver of the Arduino UNO board.
- RX, receiver of the Bluetooth module (indicated in green) is connected to the TX, transmitter of the Arduino UNO board.

Water sensor has 3 main outputs :

- VCC, the positive voltage terminal (indicated in red) is given a +5V by connecting it to the +5V power rail in the bread board.
- GND, the negative terminal (indicated in black) is grounded by connecting it to the negative power rail of the bread board.

- Signal, this terminal is used to send the analog data in regard to the water level.

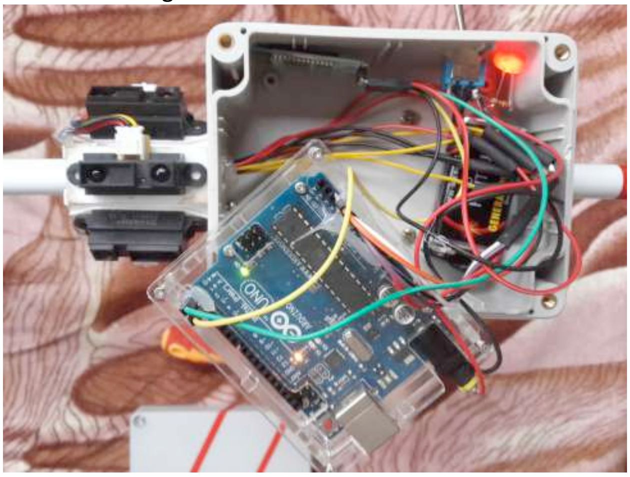

Figure 3. Hardware Design

2) Design of the IOT module: IoT module basically consists of the functionality which demonstrates the process of the traffic light sequence. To achieve this functionality, the following items are used:

- Arduino Mega 2560 Board
- HC-05 Bluetooth Module
- Vari Board soldered with 3 LED bulbs (Red, Orange, Green)

Again, in designing the IoT module the Arduino prototyping platform is used in order to make the prototyping process easier. Arduino provides the triggering to light up the LED's in the traffic light sequence with the usage of the code written. This data of the traffic light sequence is then transferred to the android application via the Bluetooth module HC-05. Android application then informs the blind person of the status of the traffic lights accordingly by giving an audio feedback of the present color of the light and whether it is safe to cross the road. Fig. 4 shows the main components of the IOT module setup.

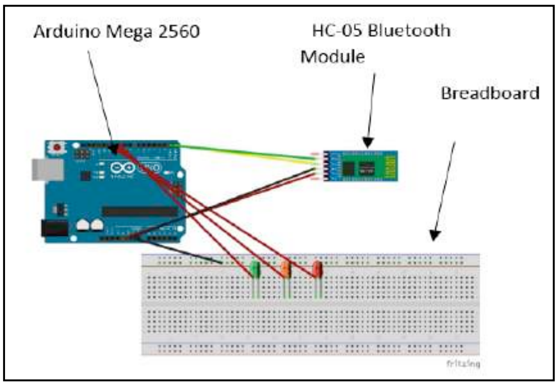

Figure 4. IoT module setup

In all three LEDs (Green, Orange and Red) the positive end of each LED is connected to the digital pins 10,11 and 12 of the Arduino board respectively while the negative end is grounded by connecting a GND pin of the Arduino to the positive power rail of the bread board.

The Bluetooth module HC-05 has four main outputs:

- VCC, the positive voltage terminal (indicated in red) is given a +5V by connecting it to the +5V pin in the Arduino board.
- GND, the negative terminal (indicated in black) is grounded by connecting it to a GND pin in the Arduino board.
- TX, the transmitter of the Bluetooth module (indicated in yellow) is connected to RX, the receiver of the Arduino board. RX, receiver of the Bluetooth module (indicated in green) is connected to the TX, transmitter of the Arduino board.

Figure 5. Final Implemented System

F. Software Design

1) Programming the Arduino: Programming of the Arduino UNO focuses on the code in the smart cane in which the function of barrier detection is prioritized. It consists of the coding of the three IR sensors (left, center and right). The detected distance to the barrier from the IR sensors will be received by the Arduino UNO with the guidance of this coding. This programming part also helps the selection of the correct output which should be conveyed to the blind person via the smart phone. Programming of the Arduino Mega2560 focuses on the code of the IOT module. The traffic lights are shown in a sequence provided by the program written. It also assists in selecting the correct output regarding the status of the traffic lights which should be conveyed to the blind person.

2) Programming the Android App: For the programming of the Android App, the MIT App Inventor 2 is used. This App is equipped with the voice recognition capabilities which can be identified as the primary input method of the android application (Fig.6). This App is also capable of giving an audio feedback to the user which can be declared as the primary output of the android application. First of all, the Android App pairs up with the Bluetooth module. When paired up with the Bluetooth module HC-06 which is installed in the smart cane, the Android App is programmed to receive the data regarding the IR sensors and barrier detection. Then the

App notifies the obstacles ahead by giving an audio feedback. When paired up with the Bluetooth module HC-05 which is a part of the IOT module, the Android App is programmed to receive the data regarding the status of the traffic lights. Then the App conveys the data by an audio output which helps the blind person to prepare himself to cross the road safely.

When the blind person needs to travel with the help of Google Maps, he has to give a voice command by saying "navigation". Because of the voice recognition capability, the App opens Google Maps on the user's smart phone. The removed areas of the screen protector used in the smart phone will enable the user to sense the icons that should be touched to give a voice command to the google maps of the destination that he wants to travel to and to make the google maps give an audio feedback of the turn by turn navigation of the path.

When the blind person needs to contact his/her guardian he just has to give a voice command saying "help". This will send an SMS alert to a predefined number (the number of the guardian can be used) asking for help. This enhances the blind person's safety.

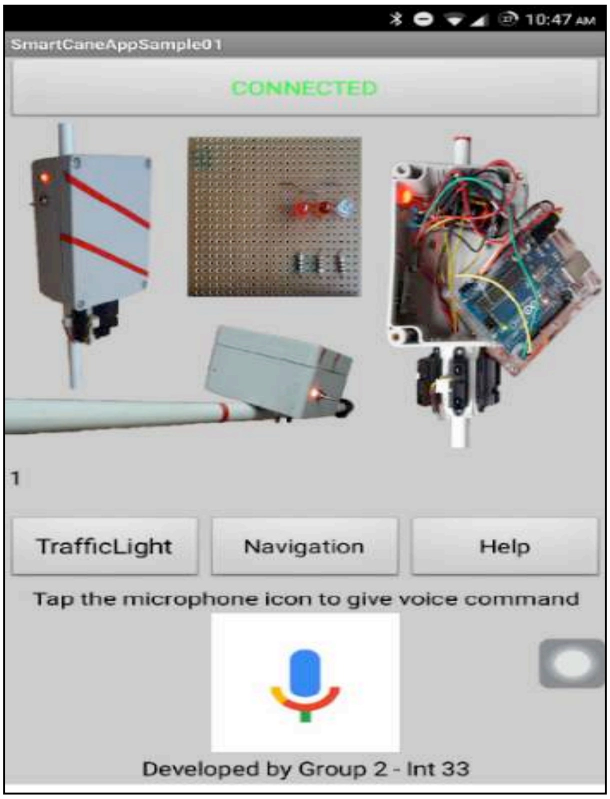

Figure 6. Interface of the Android App

IV. Evaluation

Summative evaluation was used as the evaluation method to find how the system functions and whether it is up to the expected level to fulfil the clients' requirements. At the finalizing stage this evaluation was done to evaluate the product's stability. In summative evaluation, a prototype with most stable build was shown to the client and the feedback was taken to find how far the system is success.

The intended target group of the smart cane were not employed for testing purposes as a safety measure, since the objective of this project is to design and construct a prototype smart cane. Following table and the figure depicts the overall results from the evaluation. The group reviewed the responses from 17 colleagues. According to the results, more than 95% of them have been satisfied by the below mentioned parameters taken by the group for analysing the developed system.

Table 1. Evaluation Results

Parameter	Customer Satisfaction of the Developed System
Smart Cane	15
Staircase Detection	16
IOT module	15
Water Detection	15
Android app	17
Traffic Light	9
Navigation	17
Help Option	17

Each IR sensor was tested by turning them on and sending signals directly in front of stairs as well as those within the angular range detectable by the sensors. The distance to a stair was computed by the program which was written for staircase detection of the smart cane. In this computation, the intensity of the IR signal beam reflected back to the detector by a stair was used through voltage measurements which is related to the distance to the stair and is given by the following equation:

$$\textbf{Distance} = (6762 / (i - 9)) - 4$$

where i is, an analog data collected by the IR sensor.

The water sensor was tested by turning it on and keeping it inside a water pit. The water sensor readings varied from 0-1024. Null value was indicated when there was no water. For the testing purposes, we took the range from 100-700 because, due to the humidity we might get a positive reading. When the reading was in between 100 and 700 an audio voice output was sent to the user.

As this project focused on designing and constructing a prototype of smart cane, comparatively cheap IR sensors were used which can only measure distances up to about 80 cm. Hence errors were detected in the testing process. When implementing the actual smart cane, it is recommended to use IR sensors with a higher accuracy to minimize errors in distance computations.

V. Conclusion

The project's ambition was to develop a cost effective Smart Cane to assist blind people. Detection of obstacles, stairs and puddles, water pits in the way of a smart cane user was found to be successful. However, integration of bus schedules into the App was not possible as such information is not available through the internet in Sri Lanka. This may be solved soon with technological advances expected to be incorporated by government mediation making it possible to achieve the objectives stated in the proposal regarding retrieval of transport information by the users of the smart cane. But the concept of IoT is conveyed with use of traffic light pairing.

In a similar manner traffic light signals, too are not equipped with IoT technology in Sri Lanka, making it a difficult task to incorporate such information in to the module which used in the smart cane developed in this project. This drawback too is expected to be overcome with technological advancements to be introduced in Sri Lanka soon.

Other than the above, a smart cane that can detect obstacles, puddles and the stairs in the way of a visually impaired person which can send signals to the user to enable him to navigate independently was designed and constructed in this project employing state of the art technology at a reasonable low cost.

Enhancing the functions that the smart cane already provides for the user can be done by using new advancements in technology. This approach makes it possible to overcome the shortcomings of the current smart cane. There are some certain drawbacks associated with IR sensors. With the advances in research, new IR sensors which are more accurate in determining distances are being invented which can be used in place of the sensors that were used in this project. Also, two IR sensors can be complemented with an ultrasound detector in between, which although reduces the viewing angle, would give a higher accuracy in the distance determination.

Integrating Google Maps directly into the android app will make the navigation part even easier than it is in the current smart cane. Developments of cloud computing can be used to do the processing on the cloud and instantly give the feedback to the user. This will alleviate the problem of having to do a massive amount of processing either in the phone or the smart cane. New features can be added based on IoT and Internet of Everything.

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