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Design and Implementation of Arduino and Ultrasonic Sensors based Smart Cane for Visually Challenged:A Practical approach

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***Abstract*—**According to the WHO there is 39 million blind present across the globe. These visually challenged group faces lot of difficulties in various task including basic orientation and mobility. We worked in two phase. In phase one this paper describes the design and implementation of a smart cane which is consists of Arduino and Ultrasonic Sensor. The stick is made up of a microcontroller, GPS Module, Buzzer, Vibrator, Vibrator goggles, Bluetooth and head phone connections. The Arduino can control the surroundings environmental obstacles by receiving the input signals. A buzzer is operated by a transducer and it converts an electric, oscillating signal in the audible range of 20Hz to 20 kHz. A vibrator motor is included along with buzzer to enhance its capacity to receive information's from the environment in various formats. In addition to this the sound signal can also be transferred to the user's ears with the help of output to an earphone. This walking stick can give response in various conditions like obstacle detections, wet surface detection, Heat detection, IR sensor, LDR sensor. In phase two we used our newly made smart cane for the practical demonstration. For this, we have used National Orientation and Mobility checklist (NOMA) pre and post usage of the cane among 20 blind individuals. Paired t test results shows there is significant changes ($p<0.0001$) in their mobility performances with this newly made cane. The features of light weight, easy to use and cheaper cost will make it more acceptable to the users.

***Keywords*—** Visually Challenged, Smart Cane, Arduino, Ultrasonic Sensor, NOMA

I. INTRODUCTION

According to the estimates from the World Health Organizations blindness program there is about 285 million blind people in all over the world and among them 246 million have low vision and rest of the 39 million are considered to blind. Globally it has been notified that the condition is quiet alarming in developing countries. Therefore these large numbers of populations are not only increasing the economic burden globally but also they are dependable for many small and big tasks in their daily activities [1]. Apart from all other daily basis needs, proper orientation including where you are, whether you are moving from one place to another place, where you want to go or walking through a complete new environment is always challenging for a blind individuals. People who have difficulty seeing are always afraid to go outside by themselves. They sit at home because they do not know how to travel alone. They have to wait for someone to take them to the bathroom or to visit a neighbor's house. They cannot travel by themselves and must rely upon help from their friends and family. However, with training these people can learn to move safely around their needy places [2]. There are four major techniques which has been followed globally by the visually challenged to travel safely in familiar surroundings where they can become more active in family and community activities. Those techniques are the use of sighted guide, the use of cane, the use of guide dog and the use of electronic aid. The first three methods of mobility is already followed by almost a large number of visually challenged populations but some of the systems are only for indoor navigations ,limited outdoor usage, has no location detection and hurdle determination features. This limitations in the existing technique is indirectly opposes them from interacting with people, social activities and binding them under a limited types of jobs they can do. So that in last decades researcher have concentrated more on the fourth major technique of mobility i.e, the development of a smart electronic stick which will alert them about the obstacles and they can navigate safely around their environment. Over the last decades there are many varieties of smart cane design has been proposed to help and assist the blind individuals. These cane techniques have some advantages and some drawbacks also in terms of used technology, features, cost and application [3].

In this paper we have proposed a smart Arduino and Ultrasonic Sensors based cane which not only overcome the earlier proposed drawbacks of the existing cane technique but also we have added few more new features to make the design more compact. Additionally we have done one practical based experiments with this newly made cane to show its efficiency and the acceptance to the users.

II. OBJECTIVES

The main aim of our work is to provide a better technology to help the visually impaired people so that they can develop good spatial and environmental concepts-building an understanding of the layout of the environment in which the individual can travels safely, independently. The specific features of lightweight, easy usage technique and low cost gives a visually impaired a new lease of life, a new dimension of independence and enables him to become fully contributing members of society.

III. REVIEW OF LITERATURE

Over the last decades there are few smart sticks made by various groups for the purpose of orientation and navigation. Though the designs are good and reliable but it has some deficiencies as well.

A work done by Somnath and Ravi group (2012) is one of the major works in this field. They constructed one navigation system where the sound out facility is present. The stick consists of an Ultrasonic system and Global positioning system (GPS). The GPS system is also attached with a SD card memory chip which store different locations. User can set the desired destination according to his requirements. This cane technique also tells the distance and remaining distance left while walking along with the stick. This system has also the facility of buzzer, vibrations, and talk back which operates as per the environmental changes. But the major drawback of this system is it navigates only 5 meters radios so that its usage is also bit limited. This device also has not much use in indoors as there will be no signals for the GPS in indoors. Over that the blind person also has to be familiar with the using method of this complicated operating system [4].

Another smart stick technology has been proposed by other group have incorporated the features of ultrasonic sensor to detect the obstacle in front of the user at a particular distance, Buzzer produces beep sound to alert the user about the presence of an obstacle, push button facility helps the user to use it in an emergency situation, GPS module is applicable for outdoor navigation, GSM module will help to send message to the number saved in raspberry pi when the push button will be pressed, vibratory motor works along with the buzzer to alert the user about the presence of an obstacle, water sensor differentiate the wet and dry floor, Raspberry Pi in their stick works along with the GSM module. It has also the advantages of orientation and navigations in outdoor mostly but the GPS system has the limited use in the indoor. It does not contain the heat sensor, LDR sensor which are the two major part of the smart cane technique [5].

Another work is done by (C.S.Kher et.al) group. They made an intelligent stick by using the CPU called MELDOG which uses artificial intelligence system. It contains both ultrasonic sensors and LASER sensors to detect the obstacle. This system also includes an ultrasonic DC motor controller which connects the encoder. This stick can detect the obstacle in between 0 to 18 degree. However the design and uses method is complex for this stick. The user needs much training before to operate the system. Also it has few other disadvantages like heavyweight, limited distance working and costlier options as compared to other existing navigation devices [6].

A smart cane for distance measurement using infrared sensors features, have been proposed by S. Innet and N. Ritnoom. This stick has features of different vibrations for different distance. The many ranges of vibrations sometimes confuse the user to judge the exact location of the obstacle. This process is also complex and time consuming and it needs some more sessions of training by the experts to be familiar with it [7].

Another group proposed an interactive guide system for indoor navigation, which can't detect the obstacles and hurdles properly in the outdoor environment. For that this system has less usage [8].

(R Radhika et al. 2016) designed and implemented a Smart Stick for Obstacle Detection and safe orientation and mobility. This system includes infrared system, water and ultrasonic sensors. This system also has GPS and GSM facility along with the rechargeable battery. The major drawback of this system is the cane is not foldable so it is very problematic to carry in every place [9].

(M.H. Mahmud et al. 2013) designed a Smart Walking cane which is an Electronic Approach to Assist Visually challenged Persons. Their cane is made up of a microcontroller based automated hardware that can assist a blind to detect obstacles in front of him very quickly. The hardware consists of a microcontroller PIC16F690 incorporated with ping sonar Sensor, proximity sensor, wet detector, a GH311 Ultrasonic obstacle sensor, a micro pager motor and few others additional equipment. The simple design makes it easy to use by any person also to be familiar with it and at the same time the manufacturing cost is quiet low so that it has an extra advantage of affordability. The

proposed stick design is not bendable therefore keeping it and carrying it in every place might be challenging [10].
This group proposed a Voice Enabled Smart Walking Stick for Visually Impaired persons. Their proposed design consists of a simple walking stick equipped with ultrasonic sensors to give information about the environment such as object detection, pit detection and water sensing capacity. GPS technology is incorporated with preprogrammed locations to determine the optimal route map that the blind person should navigate. It has the disadvantages that it cannot judge the speed of the object and also some improvement needs to be made to implement the range of the ultrasonic sensor. The hardware requires an alternative to the battery [11].

[R Seth et al.] Proposed Smart White Cane which is an economic Walking stick. The components of the devices are ATMega328PU microcontroller, 4 HC-SR04 Ultrasonic Sensor Modules, Sound IC-APR33a3, Vibration Motor, headphones and battery. The stick can detect holes, potholes, Staircase (up and down), low lying and lower level obstacles. This is a moderate budget mobility cane for the visually impaired. The major disadvantages are it does not contain the GPS system. The stick does not have the ability to detect
Moving objects, wet floor, and there is no heat sensor [12].

IV. METHODOLOGY

The study was divided into two phases. Broadly, phase I involved in the design and implementation of smart cane by using Arduino and Ultrasonic sensor based technique .In phase II we have assessed the practical approach of the newly made smart cane. We have included 20 blind patients and assessed their pre and post usage of cane skills. To evaluate their performances we used National Orientation and Mobility checklist.

This study was carried out in two places. The Phase I part of the study was done at Pailan College of Management and Technology, Bachelor in Optometry Department, Computer lab and phase II was carried at Behala special school for the blind, Kolkata. All procedures and protocols were standardized across the two centers. This was ensured by video recording and proper instructions to the examiners involved in the study. Single blinded technique has been followed during the assessment of National Orientation and Mobility checklist. The study was approved by the institutional review board and informed written consent was obtained from all the participants.

Phase-I
Design and implementation of smart cane

The proposed smart cane is made up of the following units:

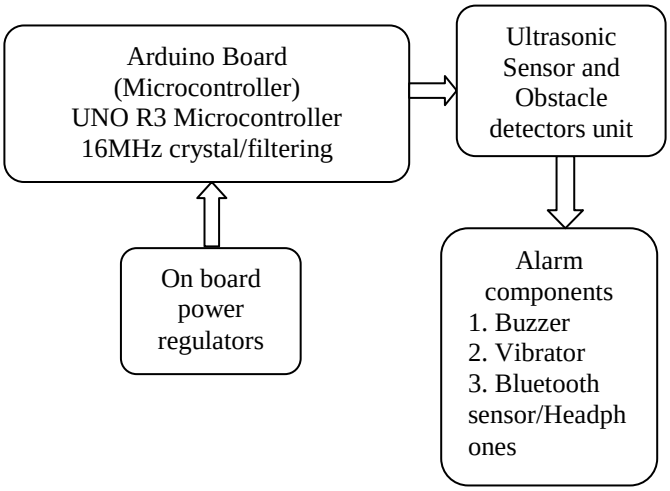
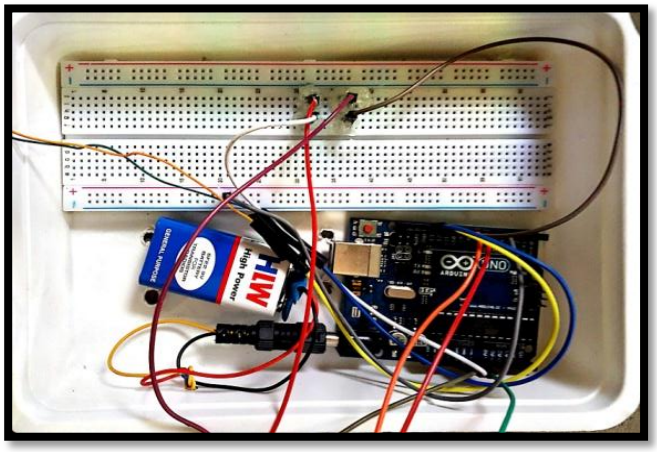


Figure: 1 *Design of a proposed Smart cane*

(i) Arduino Board microcontroller
Arduino board with UNO R_3 Microcontroller is used as the main part of the sensory cane. The Arduino can control the surroundings environmental obstacles by receiving the input signals. Arduino board designs use a variety of microprocessors and Microcontrollers. The Arduino boards are equipped with sets of digital and analog input/output (I/O) pins that may be connected to various expansion boards and other circuits.



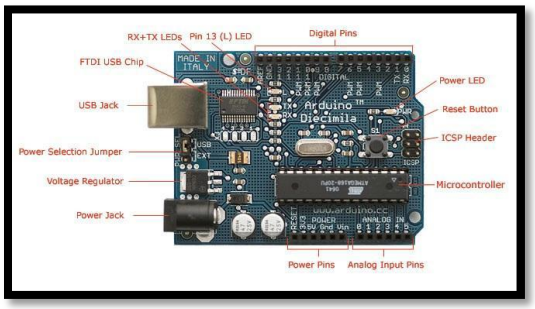


Figure: 2 *Components of Arduino Board used in smart cane*

(ii) Power regulators

The input voltage to the Arduino board has been used with 9volts battery regulated power source. This also can be used with the help of Power bank facility in case of any emergency or it the battery is not working due to any cause.

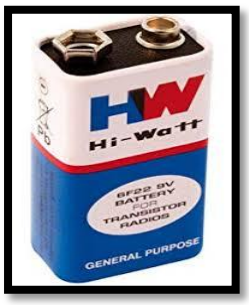


Figure: 3 *9 V battery used for on board power regulators*

(iii) Ultrasonic Sensor and Obstacle detectors unit

This unit consists of 5 components.

1. Ultrasound transducer

The ultrasonic sensor determines the distance of an object just like the bats do. It offers excellent non-contact range detection with high accuracy and stable readings for various distances. It generates, detects and processes the ultrasonic signals.

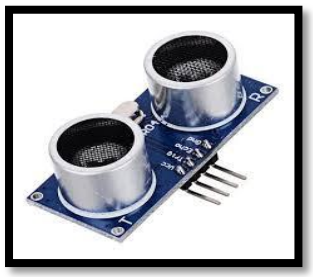


Figure: *4 Ultrasonic Sensor used in our study*

2. Water sensor

The facility of water sensor has been installed at the bottom of the stick to get the information's of the presence of wet surface so that the blind person can take precautions earlier as he may fall on the slippery floor and thus can hurt. When the base part of the stick comes in contact of the wet surface, the electrical signals will be produced and the buzzer and vibrator will be enabled to make the person aware.

3. Heat Sensor

The smart cane can detect the heat radiations and sends the electrical impulse to the controller which sends the information's to the person by buzzer and vibrator.

4. IR sensor

It can detect any size of objects even the smallest stone also at the lower end of the stick. After detecting the small obstacles on floor, IR sensor will send the signal to the Arduino and it will enable the buzzer for informing the blind person about presence of obstacles on floor.

5. LDR Sensor

We have also incorporated light dependent Resistor and it has been connected with a Flash LED light so that when it illuminates it will easily catch the notice of the other sighted person. So that one can be careful of the blind person to let him to pass the way

(iv) Alarm Components

This components will aware the person about the presence of obstacle by the method of either Beep sounds or vibrations.

It is made up of two components:

1. Buzzer

Buzzer is used to make a blind person aware of the presence of any obstacle which is coming in the coverage of the sensor. A buzzer is operated by a transducer and it converts an electric, oscillating signal in the audible range of 20Hz to 20 kHz. The audible range of the cane changes as per the distance of the obstacle from the cane. If the distance between is less the frequency of sound will be very high to alert the user on a very high seriousness. The transducer converts electrical energy into mechanical energy in the form of audible waves. The major disadvantage of the buzzer is sometimes it may not be audible the place is very crowdies specially the bus stops and railway stations where the frequency of sounds are quiet high.

Figure: *5 a buzzer that is used in smart cane as sound Components*

2. Vibrator & Vibrator goggles

A vibrator motor is included along with the buzzer to enhance its capacity to receive information's from the environment in various formats. Vibrator is mainly useful in the conditions where the beep sound is still not audible even if it is sounding in a highest frequency also specially the crowed area. The vibrations mode also kept considering the people who are deaf and mute along with the visual problem. In our stick we have connected the vibrator mode in stick and also it has been attached in goggles. Blind person can take the facility vice versa. The idea of attaching it in a spectacle frame is the person will be more alerted once it will vibrate near both the ear. Another thing is it is notices that the technique used to use a cane is, it always touch the floor and the person always moves it in a arc directions to

detect the obstacle at the center as well as the sideways. Once this technique will be followed in a very uneven surface the movement of the stick itself can give an appearance of vibrations because of the contexture of the surface. So, that if anyone can get confused because of this vibration other way the spectacle vibrations will be another clue. Another unavoidable cause is that, the spectacle itself will be used as eye protectors for the blind person and also it gives some clues to the other normal individuals also about the presence of a blind person who may need some assistance for the safe navigation.

Figure: *6 Vibrator Goggles*

3. Bluetooth Sensor/Head phones/Ear Phones

In addition with buzzer and vibrator the sound signal can also be transferred to the user's ears with the help of output to an earphone. To avoid wires with the stick the earphone can also be used as a wireless one. For this we have attached a Bluetooth Arduino with the sensor. This is an alternative technique to use the sense from the cane.

(v) Global Positioning system (GPS)

We have incorporated the GPS system also which will be beneficial for outdoor navigation, root mapping, road tracking and timing services. The information's would be provided via a sound output. We used Skylab UART GPS Module (For Arduino and Microcontroller)

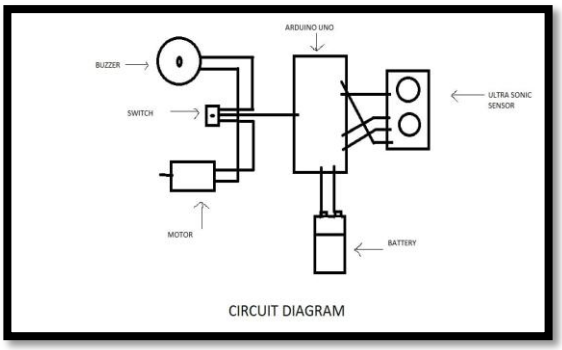


Figure: 7 *Circuit diagram of the proposed cane technique*

Figure: 8 & 9 *showing outdoor and Indoor mobility*

Phase-II

Practical approach

In this phase we have used our newly made smart cane for the practical demonstration. This part of the study was carried out in Behala School for the blind, Kolkata, We have

included 20 blind students in this phase those who are studying in college and who needs to move regularly in various places to maintain their active lifestyle. We have included all type of blind students including congenital and acquired blindness. The age group of the subjects were above 18 years and those who were using the conventional long smart cane. These group were quiet familiar with the manual cane technique but never used any kind of Smart cane or any electronic navigation aids. We have excluded those subjects who were already using any type of electronic navigators. The subjects those who were unwilling to participate in this study were excluded. In the beginning part of our study we visited the special school and proposed our proposal to them. The interested subjects were examined clinically to confirm about their blindness. The examination process were included the vision assessment, hand held slit lamp examination and fundus check-up if media is clear. The visual acuity of less than 6/60 in better eye after best possible corrections were considered as blind as per the World Health Organisations guidelines. The included subjects were provided with an informed consent form and also the verbal explanations were made. We have used the "National Orientation and Mobility checklist" for the pre and post smart cane usage to get the practical feedback of our subjects about our cane. After the pre questionnaire sessions we have given a short training sessions to all of our subjects to become familiar with our newly made cane and its operating systems. The cane was handed over the group for a period of 2 months and suggested them to use it in all the environmental conditions wherever they need to face challenges for safe and independent mobility. Each participant was advised to take experiences with the cane during this time period. All the participants were also asked to maintain a record of the time for cane usage on daily basis. Though this has been done on subjective basis but it may enhance the compliance of this study. A post assessment of the questionnaire has been done after two months. Double Blinded process has been followed to enhance the transparency of data collections and to increase the strength of this study.

The National Orientation and Mobility (NOMA) Assessment checklist includes five components. Screening, Self assessment, General mobility skills, Orientation skills and travel confidence skills.

Table:1 Five components of NOMA scoring and scoring pattern

SCREENING							
Num	Behavior	AA	O	S	R	AN	N/O
1	Does not move freely						
2	Hesitates or become fearful						
	when moving in familiar or unfamiliar places						
3	Become easily lost						
4	Bumps into door frames and obstacles in familiar and unfamiliar places						
CONCEPTUAL SKILLS							
1	Knows concept of up and down						
2	Knows concept of forward and backward						
3	Understands cardinal directions						
4	Understanding of mental mapping						
5	Understands conceptual uses of traffic cues						
GENERAL MOBILITY SKILLS							
1	Maintains good posture						
2	Can ascend stair without assistance						
3	Can follow a line without bumping into other students						
4	Can cross a drive way without losing line of travel						
5	Can handle shopping in a store, using only a reader or store employee						
ORIENTATION SKILLS							
1	Knows when he/she is inside versus outside						
2	Is aware of changes in own direction of travel						
3	Can locate classroom without assistance from primary drop off points						

4	Can use traffic cues for orientations						
5	Can locate a particular store in a strip mall						
TRAVEL CONFIDENCE							
1	Is not hesitate to initiate movement in familiar areas						
2	Is not fearful of getting loss in familiar places						
3	Exhibits confidence shopping in a store, using a reader or store employee						
AA- Almost always (5) O-Often (4) S-Sometimes (3) R-Rarely (2) AN-Almost never (1) N/O-Not observed (-5)		Scoring pattern					

Table: 2 NOMA scoring card

Standardized Score range	Interpretation Scores
80-100	Very significant mobility deficiencies exists; referral for O & M services should be made immediately
60-79	Significant mobility deficiencies exist; a referral for O & M services is recommended
45-59	Moderate mobility deficiencies exists; a more thorough assessment by a qualified mobility specialist should be sought
20-44	Mild to minor mobility deficiencies were detected; if visual acuity /diagnosis/prognosis are stable

In the screening part the pre smart cane score was 85% which indicates that the extremely significant mobility deficiencies exicts;a referral for orientation and mobility services recommended as per the NOMA scoring card interpretation guidelines.

When we assessed the data of conceptual skills including the concept of up and down,concept of forward and backward,cardinal directions,mental maping and traffic cues we got the score of 78% which also indicates the extremely significant mobility deficiencies exicts;a referral for orientation and mobility services recommended as per the NOMA scoring card .

The third assessment were done for general mobility skills.In which we got the score of 93% which again is indicating for a extreme mobility deficiencies as per the NOMA scoring.

Orientation skills and travel confidance were also assessed as a part of NOMA assessment checklist.The scoring for both the category was respectively 92% and 95% which indicates that only the manual cane is not serving the purpose of safe mobility.

We have assessed the post cane usage NOMA checklist which shows a significant changes in their response to their mobility skills.

Table:3 NOMA scoring for pre and post assessment with smart cane

Category	Scoring		NOMA Interpretation
Screening	Pre	85%	Significant Mobility deficiencies exists
	Post	59%	In the borderline of significant problem
Conceptual skills	Pre	78%	Moderate mobility deficiencies exisets
	Post	45%	Moderate mobility deficiencies exisets
General Mobility skills	Pre	93%	Significant Mobility deficiencies exists
	Post	59%	Moderate mobility deficiencies exisets
Orientation skills	Pre	92%	Significant Mobility deficiencies exists
	Post	58%	Moderate mobility deficiencies exisets
Travel Confidance	Pre	95%	Very Significant Mobility deficiencies exists
	Post	58%	Moderate mobility deficiencies exisets

The average scoring was done by the NOMA recommended formulla (Total :X/4*100 =X%

Table :4 Average scoring for Pre and Post cane use

Scoring status	Percentage	P value	NOMA interpretation
Pre scoring average	97.5%	**P<0.0001**	Very significant mobility deficiencies exist
Post scoring Average	75.25%		Mobility deficiencies is there but less serious

			situation as compared to the pre scoring

V. RESULTS AND DISCUSSION

It is worth mentioning that at this point the aim of our study fulfilled as per our objectives. We started our work with two objectives; first one is to design and implementation of a sensory smart cane. We have designed our cane with all the possible features of Ultrasonic sensor, GPS detector, LDR sensor, IR sensor, water detector, heat sensor. The buzzer system has the unique features of increasing sounds when one will be approaching very near to the obstacle. We have done some modifications in vibrator part also. We have included this features in a goggles which will be wore by the user and he/she can feel the sense of vibrations very nearer to his ear lobe which is definitely adding some extra benefits to the user in sense of attentiveness while using it and also it would be effective in a very crowd place where the buzzer may not be very audible. The water detector capacity will differentiate the wet and dry floor and also be useful during the rainy season when person need to be move through the wet, muddy path. The LDR sensor will produce a bright LED flashlight so that when it illuminates it will easily catch the notice of the other sighted person. So that one can be careful of the blind person and will allow him to pass the way. We have incorporated the GPS system also which will be beneficial for outdoor navigation, root mapping, road tracking and timing services. The GPS information's would be provided via a sound output. In addition with buzzer and vibrator the sound signal can also be transferred to the user's ears with the help of output to an earphone. To avoid wires with the stick the earphone can also be used as a wireless one. For this we have attached a Bluetooth Arduino with the sensor. This is an alternative technique to use the sense from the cane. We have done few additional things in the phase II part of our study. This is completely a new approach which has never been done in previous work. The previous researches show only the constructions and implementations of an electronic cane with multiple features but no studies are showing results in real world situations. So there will be a bit doubt for the reader about the effectiveness of this cane in a real world situations and how it is operated by the actual blind individuals. We have done a small survey study in the real world situations with 20 blind students. They used it for a two months time period and gave a feedback of the newly made device. The feedback was taken with the help of National Orientation and Mobility checklist. The results shows that there is a significant changes ($p<0.0001$) in the orientation and mobility performances before and after using the cane. These results must be a positive indicator to choose this cane for all the users. However still we have find there is some area we can modified further. We are planning to attach it with the smart phone connections and also other emergency services provider like GSM module need to be incorporated with it. The subjects we have taken a very small number for the survey study. A large scale of subjects with some categorizations like congenital or Acquired blind, all age groups either children or adult will definitely increase the strength of the study. Moreover instead of only survey practical performances based scale needs to be developed to assess the cane performance in proper basis. However, in presence of all the demerits also the phase II part of our study added an extra effort to prove our work and the cane efficiency.

VI. CONCLUSION

The smart cane will definitely add an extra platform for the next generations who are hindering the barriers of blindness and are become the part of the inclusive and integrated education system. It leads to good results for obstacle detection for the user at a range of 3 meters. This is reliable, light weight, portable, low power consumption and low cost. The effectiveness and affordability make it more acceptable to the users. This new improvisation in cane technique will surely added an extra benefit the blind community for safe and independent move.

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