International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Intelligent Companion for Blind: Smart Stick

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Abstract**: *Blindness is a state of lacking the visual perception due to physiological or neurological factors. According to World Health Organization, approximately 1.3 billion people live with some form of visual impairment with 36 million people being completely blind. These people face great difficulty in independent and safe mobility. Almost 89% of such people live in low and middle income countries, and are unable to afford existing mobility aid devices. Addressing these difficulties, the proposed research aims to design a low-cost and user- friendly guidance system "Smart Stick" which serves as an Electronic travel Aid and as a Position Locator Device. It helps to improve the mobility of both blind and visually impaired people, enabling them to navigate safely by avoiding any obstacles that may encounter and providing facility to communicate its current location to any of his/her relative. This device is tested under natural environmental conditions, and has performed excellent under low and high light environments too. The proposed design achieves reduction in cost by 44% in comparison to existing devices.***

Keywords: Visually impaired, obstacle-detection, conveying position, Smart Stick, Ultrasonic ranger.

I. INTRODUCTION AND RELATED LITERATURE

With the help of a non-government organization 'Niwant', an institution dedicated to Multi Faceted Development of the Visually Challenged, it is observed that people having visual impairment or complete blindness face major problems while navigating, like obstacles on ground, disorientation, fear of falling, walking into doors, arial barriers, etc. and also safety at unknown locations

The normal cane used by visually challenged people has major limitations:

- It can only detect obstacles up to knee-level. Hence, the user cannot detect raised obstacles like elevated bars and frequently collides with them.
- The cane can only detect obstacles within 1m from the user.
- Safety.

The market study evolves that the researchers have developed Electronic Travel Aids [ETAs] to enhance obstacle detection. However, they possess limitations that have restricted their wide-spread acceptance amongst the visually impaired.

Some of the ETAs are as follows:

1) **The K-Sonar** [5, 7] gives the output in the form of auditory cues but mask other important environmental sounds e.g. sound of moving vehicles on road and of fellow pedestrians.

2) **Mini-Guide** [6] is a vibration feedback based obstacle detection system and supplements the information provided by a guide dog or a cane. But it is not to be used as a primary aid. Also since it cannot be attached to the white cane, it results in occupation of both hands.

3) **Laser Cane** [5, 7] apart from being prohibitively expensive also requires consistent movement of the user to comprehend the small cone of obstacle detection.

4) **The Ultra Cane** [8] transmits the vibration feedback through two buttons, forcing the user to modify their grip, and also does not provide any information about the user's location.

5) **The Smart Cane** [9] detects objects from knee to head height in front of a person, however conveys no information about the location of the user.

These systems available internationally cost more than 450 USD. According to WHO, of the 1.3 billion blind people in the world, 90% live in developing countries where such devices are unaffordable. India has 13 million visually challenged persons (largest for any country in the world), with a majority having no access to an affordable and effective mobility aid. Additionally, research and user experience regarding ETAs reported in the literature highlights the difficulty in demonstrating their effectiveness in enhancing safe mobility.

II. PROPOSED SYSTEM DESIGN

As per the market research, there is a need for a knee-above obstacle detection and warning system with a user-friendly design, which ensures their safety and is available at an affordable cost to users in low-income countries who presently have very limited access to electronic navigation aids.

Accordingly, proposed solution is as below:

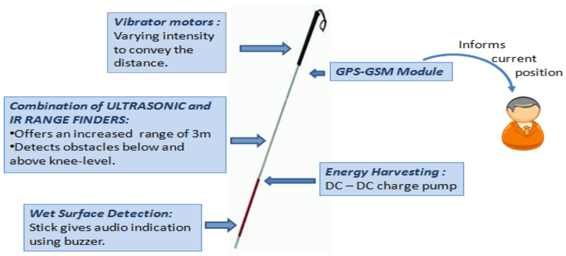

Fig. 1: System Design

The design uses a combination of ultrasonic ranger and IR range finders which offers a range from 10cm to 3m to detect obstacles below and above knee-level.

Manuscript published on 30 August 2019.
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The information of distance of obstacle from user is conveyed through vibratory patterns composed of vibrator motors that vary incrementally with changing obstacle distance. The stick on touching wet surface gives audio indication using buzzer. The GPS-GSM module informs the current position of blind person to his relative. Two modes implemented are

- The blind person can himself/herself send the location on pressing a switch.
- When the relative of user calls on the GSM number, the current location is messaged to the relative's number.

Using the ultra-low power MSP430 MCU ensures efficient utilization of energy. Further energy can be conserved by using energy harvesting technique through DC-DC charge pump.

A. Obstacle Detection

Continuously detect obstacles using infrared & ultrasonic sensors and avoid collision with objects coming in its way.

Components used:

1) IR sensors (Sharp IR GP2D12 (10-80 cm))

An infrared sensor consists of 2 parts- emitter and receiver. Emitter is an IR LED and the detector is an IR photodiode. The IR photodiode is sensitive to the IR light emitted by an IR LED. The photo-diodes resistance and output voltage change in proportion to the IR light received. The type of incidence can be direct incidence or indirect incidence. In direct incidence, the IR LED is placed in front of a photodiode with no obstacle in between. In indirect incidence, both the diodes are placed side by side with an opaque object in front of the sensor. The light from the IR LED hits the opaque surface and reflects back to the photodiode.

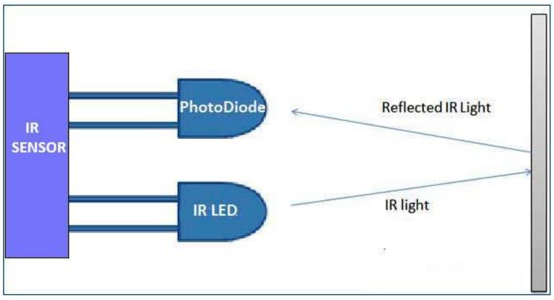

Fig. 2: Working of IR Sensor
Photo courtesy: electronicsforu.com

The design uses indirect incidence IR sensor from sharp - GP2D12 with an effective range of 10 cm to 80 cm having integrated signal processing to give analog voltage output. The sensor design has apt packaging for the emitter and detector to avoid noisy output. Interfacing Sharp IR Range Finder with uC ADC:

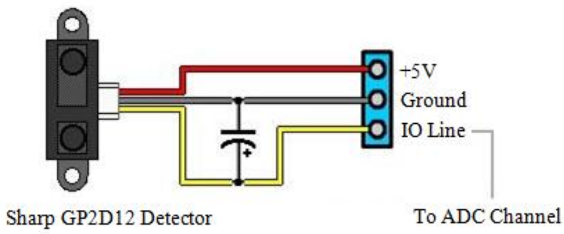

Fig. 3: Interfacing IR Sensor

Since the output of sensor is analog, it is connected to analog-to-digital converter of microcontroller. The output voltage ranges from 0V to 3V for a 5V DC power supply, with around 2.7V output when the obstacle is 10 cm apart and 0.7V when the obstacle distance from sensor is above 70cm. These readings were constant when experimented with obstacle as white paper and gray paper.

2) Parallax Ultrasonic distance sensor (HCSR04)

An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the object. It works with the simple formula:

Distance = Speed X Time

Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception. Since the speed of ultrasonic wave at room conditions is 330m/s, knowing the time elapsed between emission and reception, distance can be calculated.

The ultrasonic ranging module HC-SR04 which provides range up to 350cm is used. The timing diagram as taken from datasheet of HC-SR04 is as follows:

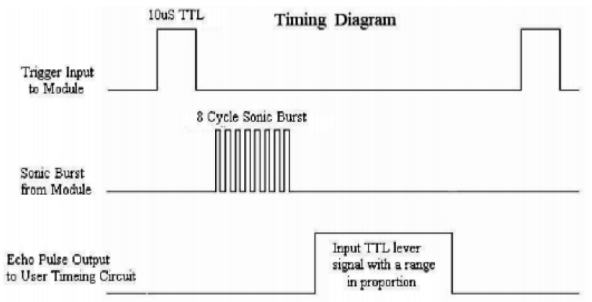

Fig. 4: Timing Diagram

On supplying a short 10uS pulse to the trigger input to start the ranging, the module sends out an 8 cycle burst of ultrasound at 40 kHz and raises its echo pulse output. The distance is calculated using formula:

Range = high level time * velocity (340m/s) / 2

Interfacing Ultrasonic Ranger with MSP430 uC:

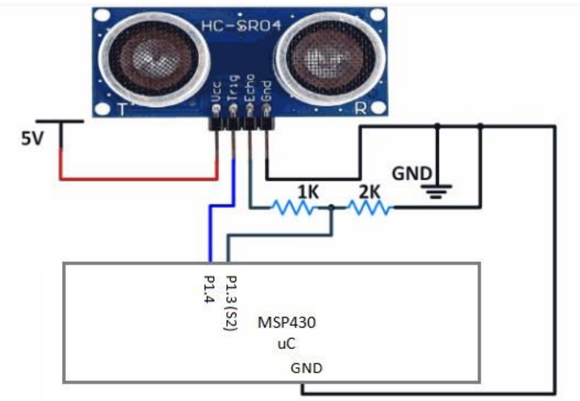

Fig. 5: Interfacing HCSR04

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The sensor HC-SR04 requires 5V for power. The Trigger and the Echo pins are both I/O pins and hence are connected to I/O pins of the microcontroller. To start the measurement, the trigger pin is made high for 10uS and then turned off. The amount of time during which the Echo pin stays high is measured by the microcontroller using its internal timer. Also the sensor outputs 5V signal on echo pin to 3.3V of MSP430. A voltage divider on ECHO wire scales down 5V output from sensor to be interpreted as 3.3V by the controller.

B. Vibratory Patterns

Varying the intensity of vibrations to convey the distance.

Components used:

1) Coin vibrator motors

A vibration motor is a simple motor which vibrates when given sufficient power. To make a vibration motor vibrate it needs voltage difference in its 2 terminals. The polarity does not matter for this motor. The vibration motor by Precision Micro-drives is used. This motor has an operating voltage range of 2.5-3.8V to be powered.

Interfacing Coin Vibrator Motor with uC:

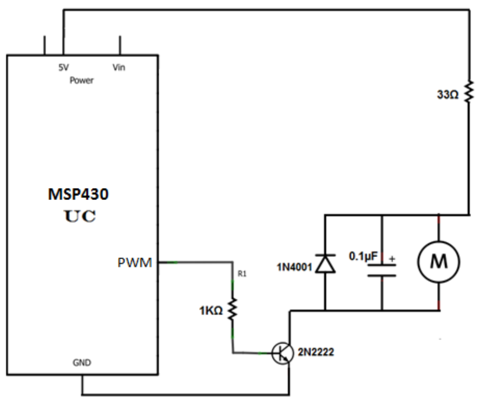

Fig. 6: Interfacing Vibrator motor

Photo courtesy: www.learningaboutelectronics.com

The motor may produce voltage spikes which could destroy the microcontroller. Hence a reverse biased diode is connected in parallel to the motor as a surge protector against the voltage spikes. The 0.1F capacitor absorbs voltage spikes produced when the brushes, which are contacts connecting electric current to the motor windings, open and close. The transistor 2N2222 provides current amplification. The vibration motor needs about 75mA of current to be driven. The input to vibration motor through the transistor circuitry is given by the PWM pin of the uC. By varying the PWM output, the average voltage to the motor can be changed. However, in this design, the PWM value is kept constant to give average voltage of 3V to the motor, enough to make it vibrate whenever required.

C. Wet Surface Indication

Audio indication using buzzer.

Components used:

1) Timer (NE555)

NE555 timer IC is used in astable mode to generate frequency of around 62 Hz.

2) Buzzer

Circuit diagram to detect water:

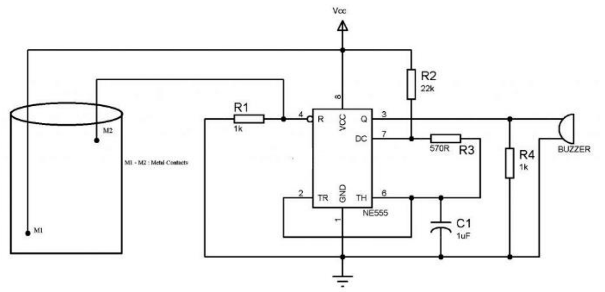

Fig. 7: Water detector circuit

Photo courtesy: www.electronicshub.org The distance between the two probes which will come in contact with the wet surface is kept 5cm heuristically. The water acts as a conductor to complete the circuit. The 555 timer is connected such that it is enabled when its reset pin is connected to logic high. But initially it is connected to ground. When the probes touch water, this pin is enabled and this drives the 555 timer into astable mode and a square wave output with a frequency of about 62 Hz is produced. This output is given to the buzzer.

D. Location Tracking

Informs the current position of blind person to his relative to ensure safety.

Components used:

1) GSM module SIM900A

SIM900A GSM/GPRS module is used to send the location coordinates of the user to his/her relative's number. The GSM/GPRS module uses USART communication to communicate with microcontroller. SIM900 modem supports features like voice call, SMS, Data/Fax, GPRS etc. It uses AT commands to work with supported features. This module requires 12V to power for its working.

2) GPS receiver module NEO-6M

To fetch the current location of the user, NEO-6M GPS module is used. It is a well-performing complete GPS receiver with a built-in 25 x 25 x 4mm ceramic antenna, which provides a strong satellite search capability. It has a built-in EEPROM to save configuration parameter data along with data backup battery. This module works has a default baud rate of 9600bps and uses USART communication to interact with microcontroller. It receives information like latitude, longitude, altitude, UTC time, etc. from the satellites in the form of NMEA string. This string is parsed to extract latitude and longitude coordinate information of the user. 5V is used to power GPS Module.

Interfacing GPS and GSM with uC:

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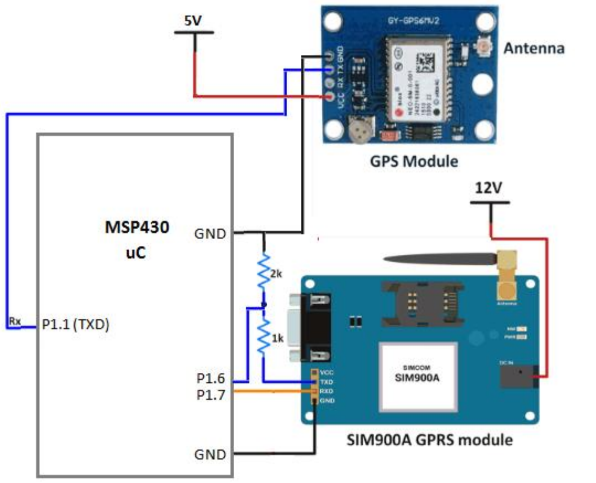

Fig. 8: Interfacing GPS-GSM

The Tx pin of GPS module is directly connected to digital pin number P1.1 of MSP430 Launch pad which is hardware serial port. Pins P1.6 (Rx) and P1.7 (Tx) are converted to software serial ports to allow serial communication for the GSM module. This location tracking feature of the system is implemented in 2 modes:

- User voluntarily sends location information. Hardware interrupt is connected to switch using which this mode is operated.
- Location information is automatically sent to number of user's relative when he/she gives miscall. Software interrupt is triggered when the relative's miscall is received.

In both modes, information from GPS is fetched by parsing the NMEA string, only when hardware interrupt connected to switch or the software interrupt for mode 2 is triggered. This information is then passed through Tx port connected to the GSM module.

III. COMPLETE BLOCK DIAGRAM OF SYSTEM AND EXPERIMENTAL RESULTS

A. Obstacle Detection prototype module

To cover knee-above and knee-below obstacles, a prototype to fix the position of obstacle detection sensors (Ultrasonic and IR) was fabricated for testing. The image of the same is as below:

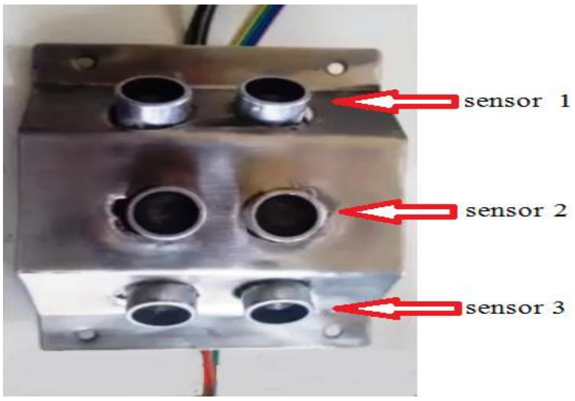

Fig. 9: Obstacle Detection Module

The ultrasonic sensor 1 detects obstacles above knee-level, sensor 2 detects obstacles in front and sensor 3 detects obstacles below knee level upto 3 meters. The IR range sensors are placed beside ultrasonic sensor 2 to detect obstacles closer than 50cms. IR sensors are most affected by surrounding light. However, SHARP IR sensors come with a covering that reduces noisy input. Additionally, averaging algorithm to filter noisy output is implemented. The prototype is tested under natural environmental conditions, and has performed excellent under low and high light environments too.

B. Vibration motor array module

Below is the image of vibration motor array on raw PCB used for testing of prototype:

Fig. 10: **Coin Vibrators module**

This array of 3 is placed where the user holds the stick, in order to convey obstacle distance to the user. 3 coin vibrators are used to ensure that the vibration spikes generated would be efficient enough to user's acknowledgement.

C. Complete setup as mounted on the normal cane

The coin vibrators and obstacle detection setup along with GPS-GSM module interfaced with controller is mounted on the existing white cane as below:

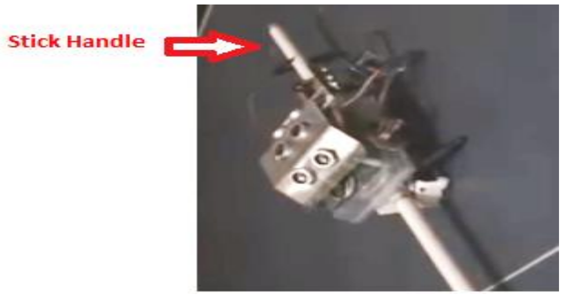

Fig. 11: Complete module (1)

The water detection circuit is placed at the bottom of the stick. The complete image of the prototype smart stick on mounting all the electronic aids is as below:

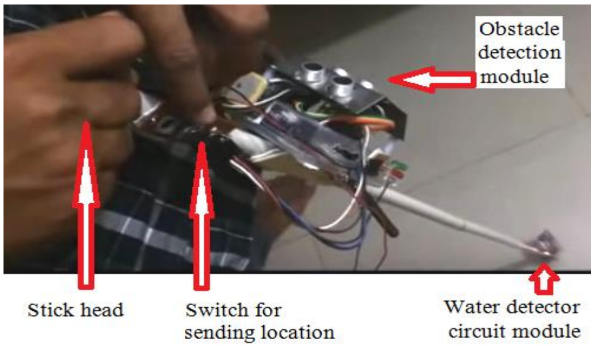

Fig. 12: Complete module (2)

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D. System Response

Following image tabulates the results of response of the system to obstacles at varying distance.

Table- I: System Response

Distance of obstacle from stick(cm)	Sensor involved	Output signal from system
300	Ultrasonic	1 time vibration
200	Ultrasonic	2 times vibration
100	Ultrasonic	3 times vibration
50 to 80	IR	Buzzer for 2 seconds
below 40	IR	Continuous Buzzer + Vibrations

E. Block Diagram:

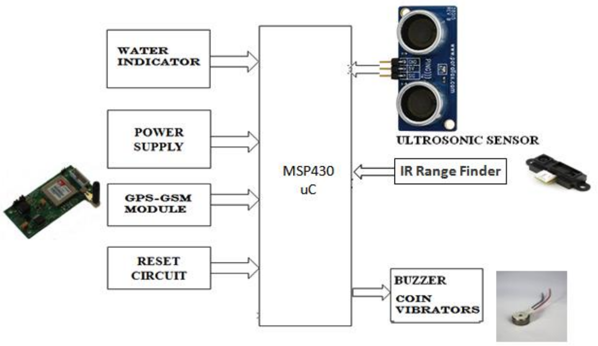

Fig. 13: Block Diagram

It is known that the visual assistive technology for blind is divided into three categories: vision enhancement, vision substitution, and vision replacement. Of that vision substitution category includes three subcategories; Electronic Travel Aid (ETAs), Electronic Orientation Aid (EOAs), and Position Locator Devices (PLDs). The proposed system design as seen from the complete block diagram is thus a combination of ETA and PLD.

IV. DISCUSSION AND CONCLUSION

Rough bill of materials used is as follows:

TABLE- II: SYSTEM COST

Part	Function	Quantity	Cost
MSP-EXP430FG4618	Development Kit	1	$117
MSP-EXP430G2	Supporting Controller	1	$10
NE555	Driving buzzer	1	$0.15
LM7805	Voltage Regulator	5	$3.63
LM358	Signal Conditioning	5	$0.75
Sharp IR - GP2D12	Obstacle detection	1	$12
Ultrasonic Sensor - HC05	Obstacle detection	3	$6
GPS Module NEO-6M	Location fetching	1	$12
GSM Module SIM900A	Location sending	1	$12.3
TPS40200EVM-002	Supply Regulator	1	$49
BOOSTXL-BATTPACK	DC Battery	1	$27

The total cost of the system is around 250 USD. Cost of existing devices is as below:

Miniguide - $545
Laser cane - $2650
Ultra cane - $635
Smart Cane - $53

Of the available devices, only Smart Cane costs less than $100, which is an ETA but not a PLD. Despite the disadvantages of these devices, their cost is much higher than the proposed design - Smart Stick.The proposed solution, serving as an ETA as well as a PLD, also ensures minimum 44% reduction in cost as compared to existing saleable devices.

The unique selection of components, with ease of availability in market adds to easy maintenance of this design. Since this cost represents engineering cost, the actual price of the device will further reduce on production.

To conclude, in relation with Market Study the major objectives achieved are as follows:

- Developed an affordable knee-above and below obstacle-detection and warning system for the visually impaired employing ultrasound based ranging to enhance the horizontal and vertical range of the cane.
- Improvement in personal safety ensured by employing the following metrics: a) obstacle awareness (perception), b) reduction in obstacle collision-rate, c) distance of obstacle detection, d) tracking position of person.
- The standalone module can be mounted on the stick in use with some initial calibration which can be done by the user himself.
- All of these design functionalities are made available at cost 44% less than average market price of such devices.
- Thus this system would help in independent mobility for the visually challenged and will be available at reduced cost and thereby suggests applicability in real life scenarios.

Future Scope

- MSP-EXP430 board has a RAM of 512 bytes which is easily filled. Thus times when large Serial buffer is needed to contain the data; the buffer size for the Serial library is to be modified. While doing such things, it is must to ensure that the code does not utilize more than 70% RAM.
- This could lead to the code working in an erratic manner. RAM extension can be done to make code enhancements easy.
- Implementation of DC-DC charge pump to reduce the energy consumption to improve battery life.
- Database of Red Zone areas in the city to be stored with the user, so that, mistakenly or forcefully, if the user enters such areas, his/her relative is informed immediately.
- Machine learning algorithms could be implemented to tune the device to recognize the obstacle type, so that the user can modify reactions accordingly. MSP-EXP430 would not suffice for this approach and thus might increase the cost of the design.

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