ELECTRONIC TRAVEL AID FOR THE BLIND

M. Moghavvemi*, T.H. Liew, C.C. Kang, H.O. Tan and M. O. Faruque
Dept. of Electrical Engineering, Faculty of Engineering,
University of Malaya, 50603 Kuala Lumpur, Malaysia.
email*: mahmoud@fk.um.edu.my

Abstract: This paper presents a simple concept and design for a travel aid for the visually impaired. The proposed device uses ultrasonic signal in sensing and detecting an object (obstacles). The aid can inform the user about the distance of the detected obstacles by means of tactile vibrations. A prototype device called the *intelligent walking stick (INSTICK)* was developed under this concept. The *INSTICK* involves four main portions, ultrasonic transmitters, ultrasonic receiver, control unit and the output portions that consists of a vibrator motor and a speech synthesizer unit. Concept of radio detection is being employed here to receive the returned echo of ultrasonic signals reflected by the obstacles. The echo travel time is used to determine the distance from the user to the obstacle. A PIC microcontroller is used to control the transceiver and process the received signal to an audible format through speech synthesizer. A few tests and survey were carried out involving visually impaired and despite some limitations satisfactory results were observed.

Keywords: Ultrasonic sensor, electronic travelling aid, visually impaired, biomedical.

I. INTRODUCTION

The most common method of range detection for the blind is the walking cane [1]. Despite its numerous advantages it has some limitations. Several electronic travel aids and obstacle avoidance devices have been proposed [2-4]. Two well-established systems are the Sonic Guide and the Sonic Pathfinder. Both electronic aids are vision substitution systems designed to provide users with a picture of the travelling route through their unimpaired senses. Both are head-mounted. There are also hand held electronics devices such as Mowat sensor. R. Gao et al [4] proposed a microprocessor based ultrasonic ranging system that is embedded in a long PVC cane resembling to the white cane used by the blind. The technique needs to use as many as four sensors integrated in the cane, however, it has the advantage of detecting protruding obstacles that is within four meter range. However, these devices failed to get well acceptance because of their high price, complexity in use and noise-prone audio output system. Realizing the shortcoming of these devices a simple and cost effective electronic travel aid is proposed here that uses ultrasound to detect immediate obstacles. The system operates by sending out a few pulses of ultrasound, and waits for the pulses to be reflected from solid obstacles. The time between the outgoing pulse being transmitted and its echo being received is used to estimate the distance of the obstacle. This information is then relayed to the user in audible or tactile way.

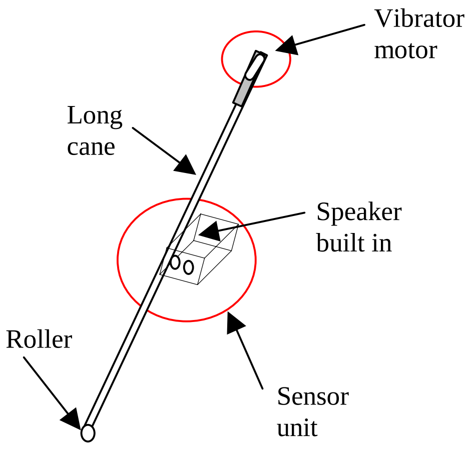


Fig.1 Sketch diagram of an INSTICK

II. INSTICK-what it is?

INSTICK is an electronic travel aid that can spatially sense the presence of an obstacle within a reasonable distance, and then display this information in an easily understandable format via the remaining senses of a visually impaired. For a blind person to follow a particular route, the person must know the obstacles of that route. In terms of operational principles, *INSTICK* is actually implementing the basic travel concept of the traditional white cane with the aid of a sensor unit, which is mounted at the center of the handle. The sensor unit works similar to a radar system. An ultrasonic beam is emitted in a certain direction in space, the beam is reflected form objects it confronts on its way, a matching receiver detects the reflected beam and the distance to the object is calculated according to the time difference between the emitting and receiving beam. *INSTICK* is designed to give warnings at three set ranges. Firstly, when an object is detected at the range of 1.0 to 2.5 meters, *INSTICK* will sound “watch out”. When an object is detected at the range of 0.5 to 1.0 meter, *INSTICK* sounds another distinct speech “beware”, and for the range of 0 to 0.5 meter, *INSTICK* will sound “dangerous”. The central control unit of the *INSTICK* will also send relevant signal of different ranges to vibration unit. The strength of vibration is inversely proportional to the distance of the user from the object detected. Most ultrasonic applications occur in the frequency range of 20 kHz to 100 kHz. In the case of *INSTICK*, 40 kHz ultrasonic signals is used. Two basic reasons for choosing ultrasonic frequency are availability of high acoustic power without causing any intolerable noise and its directivity. The ultrasonic sensor designed can detect objects in a range up to 3 meters. However, transmitting a higher power signal could increase preview distance provided by the aid. This would certainly provide the visually impaired with an increased ability to judge the distance to objects.

In darkness, azimuth and elevation of an obstacle is considered less important compared to range from the object. As long as the preview angle is wide enough for a walking path, it is sufficient for an ETA. In *INSTICK*, the sensor unit is mounted on the middle of the cane. The main shortcoming of this design is that it cannot detect hazards above chest height unless the hazards continue down to the ground. Thus, it is recommended to add another supplementary sensor to protect the user from hazards above chest height. It can be head mounted, lightweight and small in size.

iii. ULTRASONIC

The transmitter emits ultrasound pulses when it gets a signal from the microcontroller. The pulse travels to the object, reflects off the object and then returns to the transducer. The echo that has been received is not an exact replica of the transmitted signal. A sinusoidal signal is reproduced whose magnitude depends on the strength of the echo and the excitation of the piezo material. Due to attenuation and diffraction the received echo is usually weak. As a result, amplification is necessary. A control unit is included to act as an automated switch, allowing transmitter to send ultrasonic signals in interval permitting the pulses to travel to the object and return the echo to the receiver. Next transmission is activated whenever a delay equivalent to maximum detectable

$$\text{Distance} = \frac{\text{speed of sound} \times \text{time of echo}}{2}$$

distance is expired. The delay time T_d is, T_d = (2 x max. distance)/speed of sound = (2/2.5)/330=15ms. Then the distance of obstacle can be measured by

IV. HARDWARE

The system is comprised of three major hardware sections as shown in the block diagram in Fig. 2. These three modules are a sensor (transmitter and receiver), micro-controller and the output module. PIC micro-controller is the CPU of the system. It generates 40 kHz pulses, calculates the distance from the time for echo reception and excites the vibrator and speech synthesizer.

After considering different aspects PIC 16F84 micro-controller has been used. It is a high performance, low-cost, CMOS, fully static 8 bit microcontroller with 1K x 14 EEPROM program memory and 64 bytes of EEPROM data memory. The EEPROM data memory is readable and writeable during normal execution at full V_{DD} range.

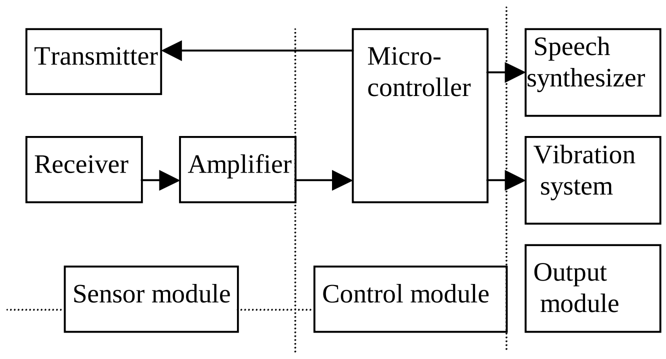
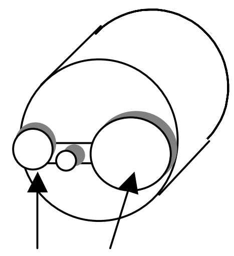


Fig. 2. Hardware block diagram

Most often, ETAs convey range information by sounds that increases/decreases in frequency and/or intensity, as the detected object gets closer. However, one problem with all ETAs based on acoustic feedback is their interference (called masking) with the blind person’s ability to pick up environmental clues through hearing. Thus, tactual indication is alternatively implemented here. In terms of tactual perception, the skin has some similarity to the ear, and can sense tactual stimuli (changing pressures) with attributes including intensity and frequency. Therefore, this is used as a function of position and orientation sensing. In addition, *INSTICK* managed to inform location of the user via synthesized speech. Audible silent warnings are given when an obstacle is first detected at a specified range. This voice indication of distance is not conveyed continuously so as not to mask the environmental sound. It is presented through a $16\,\Omega$ earphone speaker. In addition, *INSTICK* sends the signal through a vibrator, which does not mask environmental sound. Vibration is produced by applying unequal load to the dc motor. The magnitude of vibration depends on the rotation speed and can be changed by varying the average voltage sent to the motor using pulse width modulation. A roller is also introduced in this *INSTICK* that could actually bring comfort to the blind user as well as help the blind to feel the ditches.



Dc motor with unequal load

Fig.3 Vibrator motor as an output device used in ETA

A. Software:

Source code has been developed to control the operation of PIC. The Microchip's assembly language MPLAB is used to write and debug the program. The finished source code is then downloaded into the memory of PIC.

IV. **TESTING AND EVALUATION**

Testing and evaluation for the developed system was done in two different approaches,

1) Testing in the lab to monitor the performance and reliability of the system,
2) Evaluation by blindfolded and visually impaired in real life.

A. **Laboratory Testing**:

To verify the sensor sensitivity and overall reliability of the complete hardware, lab experiments were conducted using three objects; a flat glass about 30 cm in length and 20 cm in width, a cardboard rod with a diameter of 10 cm and a 60 cm x 45 cm wood board. These objects were put above the ground, within a distance of about 3-m from the stick. The responses of the sensors were recorded from the oscilloscope moving the objects gradually closer to the stick. The process was repeated with the surface at different tilted positions. The cardboard rod was detected at a distance of 1.2-m. Glass plate was detected at 2.1 m when it is perpendicular to the sensor line of collimination. The detectable range decreased with the increase of titling angle and at a distance of 1 m, the maximum tilting angle is 20°. For perpendicular wood board the maximum detectable range was 2.9 m. During the test the output modules responded reliably and the frequency response of the system was also examined by varying the frequency. It has been found that the device has shown excellent performance at 40 kHz.

A test has also been carried out to determine the maximum coverage angle θ. An obstacle outside this coverage area will not be detected.

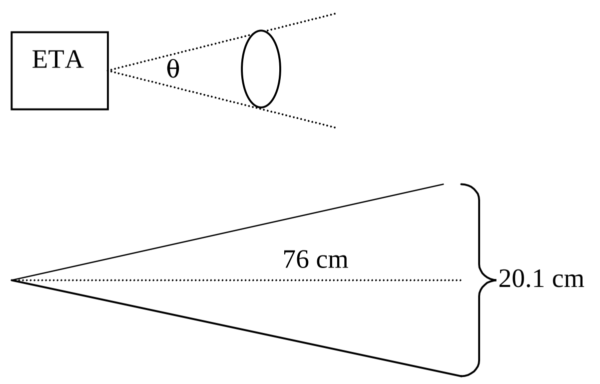


Fig. 4. Coverage area of ETA

This test was conducted by moving a stick with the height of 297 cm slowly around the ETA at a distance of 76 cm. The distance between the boundary points of detection (represented by the dotted lines) was measured. From the obtained result, θ is calculated as,

$$\theta = 2 \times \tan^{-1} \frac{20.1}{2 \times 76} = 15^{\circ}$$

This result shows that convergence angle is suitable for the job.

B. **Real-Time Testing**:

During this evaluation, the complete ETA system was tested and evaluated by blindfolded and visually impaired person. Three different routes have been chosen to test the performance and reliability of the system.

Route 1:

The route was on the fifth floor of Laboratory building where there were more corners of the wall than obstacles. The blind was unfamiliar with the place. A comparative performance with white cane is shown in table 1.

Table 1: Test results for route 1.

Path	Length m	With ETA		With White Cane	
		Time, s	Speed, m/s	Time, s	Speed, m/s
A	28.8	77	0.37	42	0.69
B	13.8	21	0.66	16	0.86
C	27.0	52	0.52	35	0.77
D	3.9	6	0.65	6	0.65
E	6.3	10	0.63	9	0.70
F	12.0	15	0.80	12	0.80

The total length of the route was 91.8m and was covered at an speed of 0.765 m/s with white cane, whereas, with ETA the speed is 0.570m/s. The result might show that white cane has outperformed the ETA, however, familiarity with ETA would certainly improve the situation.

Route 2:

The route 2 consists of a lot of obstacles is thus more realistic. Here also the blind has completed the path twice as before with white cane and ETA respectively. The performance is shown in Table 2.

Table 2. Test performance for route 2

	Distance, m	Time, s	Velocity, m/s	Total obstacle	No. of Collision
White Cane	52	74	0.703	23	9
ETA	47	78	0.603	28	6

From the result it is evident that ETA can be a more efficient device for blinds to avoid obstacles in the route.

Route 3:

Putting several different obstacles randomly on the way of the blind created the route 3. The obstacles include chairs, rod, polystyrene and tables. The test was carried out for five times changing the orientation and number of obstacles for both ETA and walking cane. Results are summarized in table 3.

Table 3. Test performance with different orientation and number of obstacles;

Total	With White Cane	With ETA

Obstacles	No. of Collisions	%	No. of collisions	%
15	6	40	3	20.0
8	3	37.5	1	12.5
9	3	33.3	2	22.2
12	5	41.7	3	25.0
14	4	28.6	4	28.6

From the testing results above it can be inferred that the ETA can be effectively used as a travelling aid for the visually impaired.

V. COMFORT AND PORTABILITY

One of the important parameter that determines the utility of an ETA is its portability. However, the *INSTICK* designed did not fulfil this criterion completely. According to one participant, during the evaluation test, the travel aid is heavy, and clumsy to deal with compared to the white cane. Furthermore, it cannot be folded as the white cane could

Nevertheless, all the problems mentioned above could be solved easily. Regarding the weight of *INSTICK*, it is recommended that the normal 9V and four 1.5V batteries be

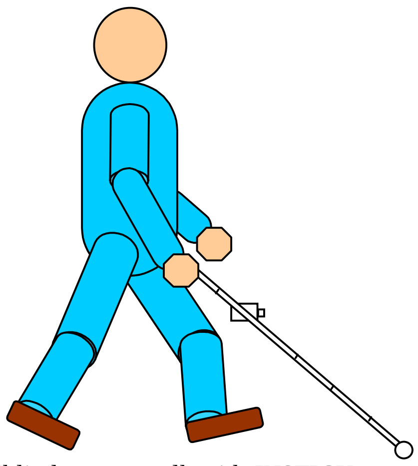


Figure 5: A blind person walk with *INSTICK*

replaced by lithium battery. This type of battery is often called a "coin cell" because it is shaped like a coin. It is small in size and this is sure to reduce the weight of the ETA. Speaker can be changed to the earphone type to reduce the weight and offer an audible signal that is less influenced by the noise in the environment. The handle used could actually be made adjustable so that could be folded into small size.

VI. APPLICATION

The blind users find most ETAs unreliable. For example, Mowat Sensor does not provide protection from floor level obstacles, staircase, curb, floor irregularities, etc. Therefore a long handle with wheel is implemented in this INSTICK. The ETA cane introduced can actually detect objects on the ground, ditch and stairs mechanically. Furthermore, the user is able to know what is the object detected by simply knock the cane on the obstacle.

Besides that, the cane is also made visible at night by introducing LEDs light on it. On the other hand, how does a blind person knows whether the device used is on? When the ETA is on, user may hear the aid "beeping" for several seconds. This sound indicates that the aid is ready to be used. All these applications would sure make the device a useable one.

VII. SPECIAL FEATURES

Among the special features of the *INSTICK* are the “minimal noise speech synthesizing unit” (MNSU), tactual warning through vibration which does not mask the environmental sound, and the sensing of drains and staircase by using the long handle with a rolling wheel.

One particularly difficult problem for blind pedestrians is that facing of stairs. The *INSTICK* offers solutions for both down-steps and up-steps by utilizing the failsafe manner. When a visually impaired is going to hit the staircase or is going to drop down from a down-step, the rolling wheel will either face a strong resistance or a sudden drop off which is an obvious signal that the user cannot miss.

Finally from the point of cost, *INSTICK* is much cheaper compared to other currently available electronic travel aid (ETA). A List of the prices of ETAs that are available in the market are shown in table 4.

Table 4. Price comparison list

ETA	(US$)
Laser Cane	2500
Mowat Sensor	775
Polaron	870
Sensory 6	950
KASPA:SonicGuide	3300
Sonic Pathfinder	1695
Wheelchair Pathfinder	2500 - 4500

For *INSTICK*, the production cost is only approximately US $60. With its cheap production cost, *INSTICK* can benefit much to visually impaired.

CONCLUSION

The current prototype version of *INSTICK* has been tested in laboratory conditions and is successful at its major purpose of identifying potential hazards at ranges of one to three meters. Further trials with real users are planned to further evaluate the device. In particular to experiment with gearing the device to user's walking speed. Efforts are also continued to improve the device to make it lighter and foldable.

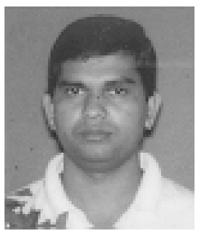
REFERENCES

[1] Johann Borenstein and Yoram Koren, “The Guide Cane – A computerized Travel Aid for the Active Guidance for the Blind Pedestrians”, Proceedings of the IEEE International Conference on Robotics and Automation, Albuquerque, page 1283-1288, April 21-27, 1997.

[2] Anthony Heyes, “The Sonic Pathfinder: A New Electronic Travel Aid”, Journal of Visual Impairment and Blindness, Vol. 78, No. 5, pp. 200-202, May 1984.

[3] Johanna Borenstein and Yoram Koren, “Error Eliminating Ultrasonic Firing for Mobile Robot Obstacle Avoidance”, IEEE Transactions on Robotics and Automation February 1995, Vol. 11, No. 1, pp. 132-138.
[4] Shane MacNamara, G. Lacey, " A smart waker for the frail visually impaired", Proceedings of the 2000 IEEE on Robotic & Automation, San Francisco, CA, pp. 1354-1359, April 2000

Mahmoud MOGHAVVEMI was born in Tehran, Iran on May 23, 1959. He obtained his B.Sc. in Civil and Electrical Engineering from the State University of New York at Buffalo, M.Sc. from the University of Bridgeport and Ph.D. from the University of Malaya, Malaysia. Dr. Moghavvemi served with CTI Electronics as a research scientist in 1987. In 1988 he joined Informatics Group of Colleges as Director for the School of Engineering. He joined the University of Malaya’s Department of Electrical Engineering in 1991 where he is currently serving as an Associate Professor and leading the Power and Control Systems Research Group. His research interests includes applied electronics in biomedical, power systems stability and security assessment, and applications of ANN to power and control systems.



Md. Omar Faruque was born in Noakhali, Bangladesh, on October 15, 1967. He graduated in Electrical & Electronic Engineering from Bangladesh Institute of Technology, Chittagong in 1992. He has also received his Masters of Engineering Science degree at the University of Malaya, Malaysia in 1999. He is now pursuing a Ph.D. in the University of Malaya, Malaysia where he has been employed as a lecturer also.