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Automated Mobility and Orientation System for Blind or Partially Sighted People

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Abstract- Currently, blind people use a traditional cane as a tool for directing them when they move from one place to another. Although, the traditional cane is the most widespread means that is used today by the visually impaired people, it could not help them to detect dangers from all levels of obstacles. In this context, we propose a new intelligent system for guiding individuals who are blind or partially sighted. The system is used to enable blind people to move with the same ease and confidence as a sighted people. The system is linked with a GSM-GPS module to pin-point the location of the blind person and to establish a two way communication path in a wireless fashion. Moreover, it provides the direction information as well as information to avoid obstacles based on ultrasonic sensors. A beeper, an accelerometer sensor and vibrator are also added to the system. The whole system is designed to be small, light and is used in conjunction with the white cane. The results have shown that the blinds that used this system could move independently and safely.

Index terms: Assistive Technology, Global System for Mobile communication (GSM), Microcontroller, Short Message Service (SMS), AT Commands.

I. INTRODUCTION

Blind mobility is one of the main challenges that scientists are still facing around different parts of the world. According to the World Health Organization, approximately 0.4% of the population is blind in industrialized countries while the percentage is rising to 1% in developing countries [1, 2]. The simplest and most widely used travelling aid used by all blinds is the white cane. It has provided those people with a better way to reach destination and detect obstacles on ground, but it cannot give them a high guarantee to protect themselves and being away from all level of obstacles. With the recent advances in assistive technology, it is possible to extend the support provided to blind people taking into consideration the concept of the white cane.

Historically, there are various types of assistive technologies that are currently available to blind or visually impaired people [3]. One example is the smart phone, which addresses some of the concerns that the blind and partially sighted people needed in their daily life. The smart phones allow those people to listen to voice mails and even write and send emails. Another example refers to the electronic oriented aids, is the laser or ultrasonic. In this technology, energy waves are emitted ahead, then it is reflected from obstacles in the path of the user and detected by a matching sensor. Thus, the distance to the obstacle is calculated according to the time variance between the two signals.

Wearable and portable assistive technologies are also used for assisting people with disabilities such as the blind. Wearable devices are allowing hands-free interaction, or at least minimizing the use of hands when using the device, while portable assistive devices required a constant hand interaction. Wearable technology is achieved by devices that are actually worn on the body such as: assistive devices worn on fingers and hands [4-7], assistive devices worn on the wrist and forearm, assistive devices worn on the tongue [8-10], head-mounted assistive devices [11], vests and belts [12], and assistive devices worn on the feet [13]. Despite efforts and the great variety of wearable assistive devices available, user acceptance is quite low and the white cane will continue to be the most assistive devices for the blind.

On the other hand, to enhance the means that assist blind persons to navigate quickly and safely in an unfamiliar environment, various projects were introduced using different technologies like GPS, RFID, Ultrasonic, Laser and GSM [14, 15, 16]. Laser cane transmits invisible laser beams to detect obstacles then producing a specific audio signal. The laser cane has distinct audio signals; each one indicates a specific distance. Ultrasonic technology is used in the same principle as laser technique; it used different tones to indicate the distance of the object. Each tone signifies a particular distance from the obstruction. GPS system is used by blind persons to determine and verify the correct route. The system was connected to a Braille display so the user can read the information displayed in Braille. RFID was also used but it requires RFID flags along the path to navigate.

The scope of this paper is to develop a low-cost intelligent system capable of assisting the blind and visually impaired without the help of sighted person. The system is a GSM-GPS based so that it takes the advantages of the GSM network such as the popularity and cost-effectiveness. Additionally, GSM-GPS module have been used in different areas of human activity, such as the navigation of vehicles and navigation aids to guide visually impaired pedestrian and let them to avoid obstacles and reach their destination. The remainder of this paper is organized as follows. The next section will explain the related work. In section III, we explain the system architecture, hardware and software design. In section IV, experiments were performed and the results are explained. Finally, we conclude and discuss future work in section V.

II. RELATED WORK

A number of guide systems to aid the mobility of the visually impaired people have already been developed. The author in [17] proposed RFID based system to aid the blind in the task of grocery shopping. The system relies on the RFID tags that are placed at various locations in the store and provides the aids just inside the store. Other system found in [18] uses GPS location information with building maps and relevant spatial information to provide directions to locations within a campus environment.

A smart wheel-chair system that is equipped with sensors for similar purposes was proposed in [19]. The system uses differential GPS location information to allow the user to navigate to a general area. The usage of GPS technologies is becoming more widespread with blind individuals. One such system that is built around GPS is the Sendero system. The system is software that works with any Braille note product. This technology looks like a miniature computer and be worn easily on the individual. Like the previous technologies, a Street Talk GPS Solution was also introduced. The Street Talk GPS Solution allows the user to create a route in order to get from one location to another. A smart cane has aimed at something similar to the previous systems through the use of onboard sensors for obstacle avoidance [15]. The system is based on an ultrasonic sensor in which it detects obstacles and commands the two-wheeled steering axle. The blind feels the steering command through the handle and follow the stick easily without any conscious effort. Other system that uses the ultrasonic sensor aimed to inform the user of the distance to the detected objects by means of vibrations. The frequency of the vibrator is inversely proportional to the distance between the ultrasonic sensor and the obstacle. The author in [20] proposed an intelligent guide stick that consists of an ultrasound displacement sensor, two DC motors, and a microcontroller.

Since the above invention is aimed to detect and avoid obstacles or objects located in front of the user, a fuzzy controller is required to determine the instructions that will be executed, for example to turn right, left or stop. Another requirement is the RFID tag that should be placed in several areas to navigate the users in case that the RFID attached to the blind body. Normally, RFID is placed inside a bag that worn by the user. The bag supplies electricity power to the system and informs the user through a speaker. In case that the users do not have the ability to hear, there are special gloves that will vibrate at every finger, in which different vibrations in each finger have different meanings.

III. SYSTEM DESCRIPTION

In the following subsections, we will describe the system architecture, hardware components , and software architecture.

3.1 SYSTEM ARCHITECTURE

As shown in figure 1, the architecture of the system mainly consists of eight parts: audio amplifier, microphone amplifier, GSM_GPS modem, PIC-P40 development board, two buzz clicks, ultrasonic sensor and vibration module. The PIC-P40 development board consists mainly from three components: PIC16F877 microcontroller, MAX232 Level converter, and a regulator circuit. PIC16F877 microcontroller is used to send AT commands to GSM_GPS modem and checks all information coming from other modules. In case of any change in the stability of the blind, the PIC16F876A will send SMS message indicating the location of the blind to a preconfigured telephone number. Meanwhile, the blind can call a preconfigured telephone number and activate the microphone and audio amplifiers. Telit GM862-GPS modem that accepts a SIM card, and operates just like a mobile phone was used in this system; the modem is a Quad-band engine that works on frequencies 850MHz, 900MHz, 1800MHz, and 1900MHz. The modem sends SMS messages, makes a call and receives the information from the GPS satellite in NMEA format.

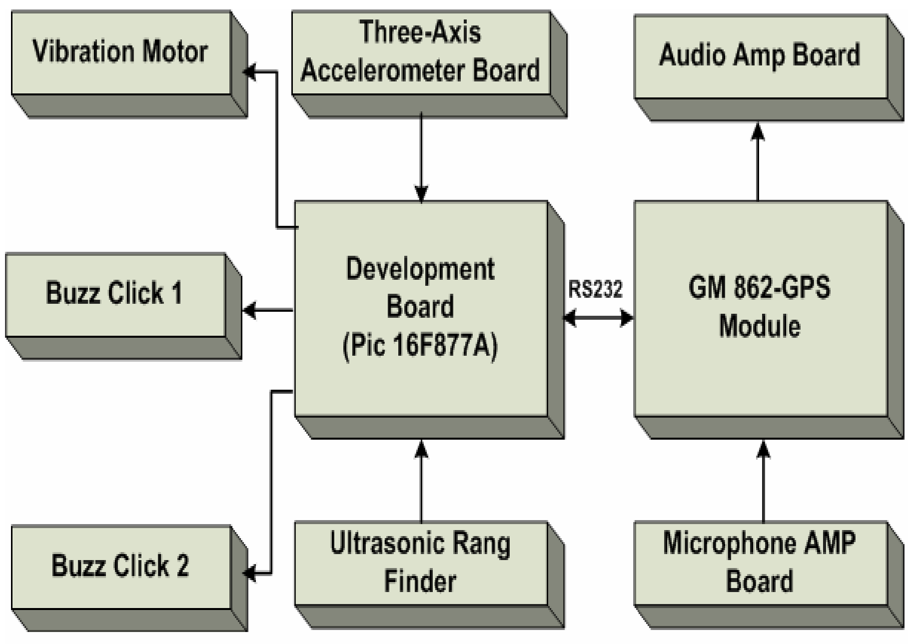


Figure 1. Block Diagram of the System

3.2 HARDWARE COMPONENTS

As shown in figure 2, the entire system is completely implemented using cost-effective assistive technologies to provide blind people with a greater degree of independence in their daily life. It includes PIC-P40 development board, ultrasonic sensor, MAX232, MAX2323 level convertor, PIC16F877 microcontroller, keypad unit, power supply, 3-axis acceleration sensor board, audio module, buzz click module, vibration module, and finally a GSM_GPS module that has been used in different areas of human activity, such as navigation systems. Each unit in the system undertakes a specific job and can be explained as follows:

PIC-P40 is a development board that has RS232 connector and driver for interfacing PIC microcontroller with 40 pins to other embedded systems or PC with RS232. PIC16F877 microcontroller was used and integrated with the GSM_GPS modem through the MAX232 and MAX2323 chips. Both chips convert the signal from RS232 voltage levels to TTL voltage levels and vice versa.

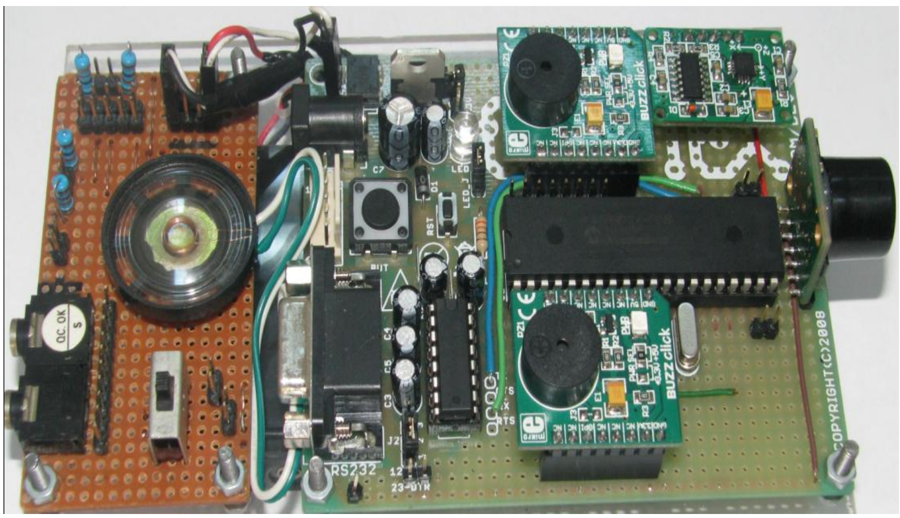
The ultrasonic sensor determines the distance between obstacle in front of the stick and the system. To accomplish this, the sensor sends out ultrasonic bursts of acoustic energy through an ultrasonic transducer and detects the echo that results from an obstacle in the beam path. The elapsed time between the initial transmission and the detection of an echo can be measured; hence the distance of an obstacle can be calculated. The interface output formats of the ultrasonic sensor used in this project include pulse width output, analog voltage output, and serial output. Analog voltage output is used her and it is inversely proportional to the distance from an obstacle. The information from 6-inches out to 254-inches with 1-inch resolution is obtained. This information is integrated with a speaker to alert the user when an obstacle is detected in his way.

The keypad is organized as a matrix of 4 rows and 4 columns. In this paper, 4 rows are just interfaced to PORTB of the PIC16F877 microcontroller. Pins RB4-RB7 of Port B is connected to the keypad and it is the task of the PIC microcontroller to scan the 4 rows continuously to detect and identify the key pressed. The keyboard unit is used to type in a number that point to a predefined mobile number.

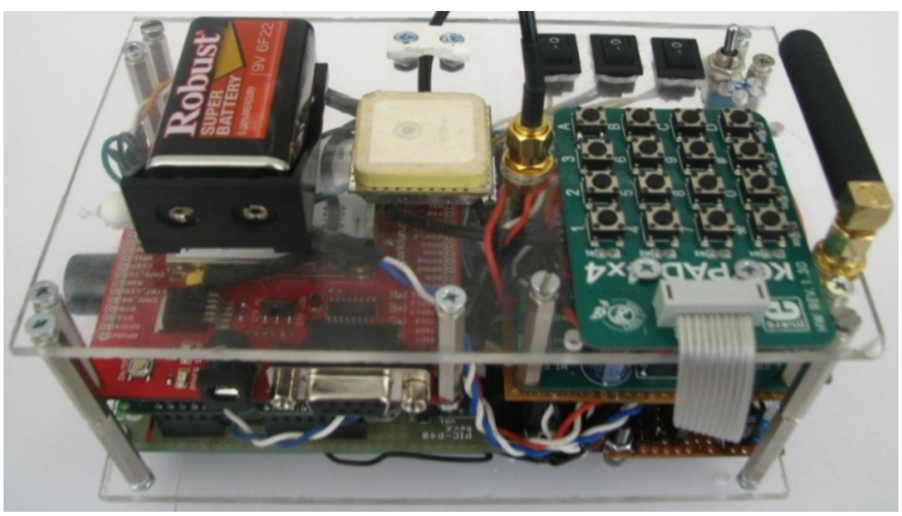
The audio module works by converting the voltage received from the ultrasonic sensor into PWM (Pulse Width Modulation) for output to a buzz click module. A headphone jack is added so that the user himself can listen to the signal instead of listening to the external speaker. Another module that includes an audio amplifier and a microphone was also used in this project and integrated with the GSM_GPS module. In addition to audio amplifier, the vibration of the handle is produced by a small DC motor that is controlled through PORTD.

The 3-axis acceleration sensor board is an additional board used to measure the force of gravity and acceleration. The board is based on the ADXL330 chip; it is a complete 3-axis acceleration measurement system on a single monolithic IC. The output signals from the ADXL330 are analog voltages that are proportional to acceleration. ADXL330 used in this project for sensing the tilt in the X, Y, and Z axes. A vibration of the handle is produced if the reading of X, Y axes exceeded a certain threshold, while a text message is sent through the GSM_GPS module if the blind fell down on the ground. In summary, The GSM_GPS module receives the information from the GPS satellite in NMEA format and transfers the latitude and longitude information as SMS message to a predefined mobile number.

Finally, the power supply circuit has a diode bridge which allows the user to power this system with both AC and DC power supply. The input voltage for the system could be anything within the range of 6 – 15V DC. Voltage regulation is made with LM317 adjustable voltage regulator and 7805 voltage regulator. To supply enough power for all of the various components, a 12-Volt battery is used to power the GSM_ GPS module while the nine volt battery is used to power other circuits.



(a)



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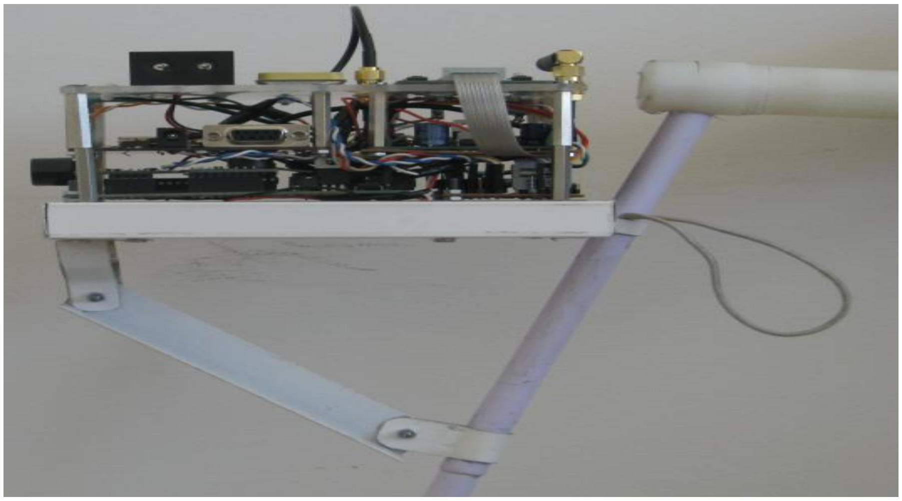

(c)

Figure 2. Hardware Components of the System: (a) Lower Part , (b) Upper Part, (c) Entire System Installed on the CANE.

3.3 SOFTWARE ARCHITECTURE

The software for the system has been developed in C language. The flowcharts of the system are shown in figure 3, figure 4, figure 5, figure 6, and figure 7. Figure 3 shows module startup. PIC16F877 microcontroller is initialized to configure ports A and B as an input, port C and port D as an output. UART is initialized for 9600 kbps, 8-bit, no parity and 1 stop bit. For enabling the system using GSM_GPS modem, microcontroller sends AT command until the modem responds with OK, then it will issue another command to check the SIM presence and to test whether module is connected to network or not. If the microcontroller does not receive the correct response, GSM_GPS module keeps on checking for network status until it connects to network. Once it makes sure that module is connected to network, the system will start a subroutine for checking obstacles ahead of the stick, and location of the blind.

As shown in figure 4, ultrasonic range finder is used to measure distance by generating an ultrasonic pulse which propagates through the media and is echoed by a reflection surface. The software for the ultrasonic sensor starts by initializing the variables and PWM, then measuring the distance. If an obstacle is detected, vibration and buzzer signals are switched on. In case there is no obstacle the program enters the cycle again.

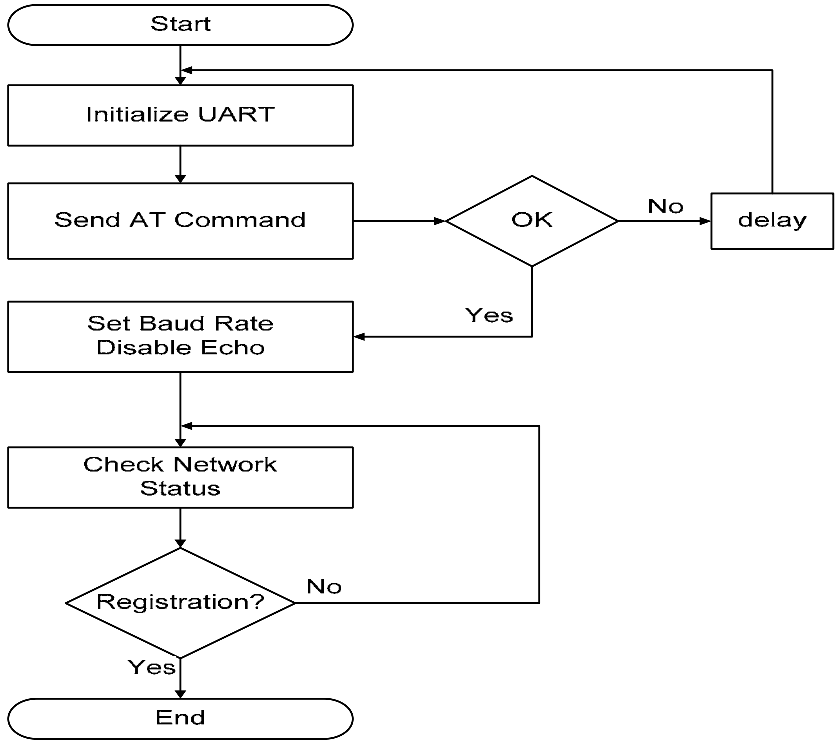

Figure 3. Flow Chart for Module Startup

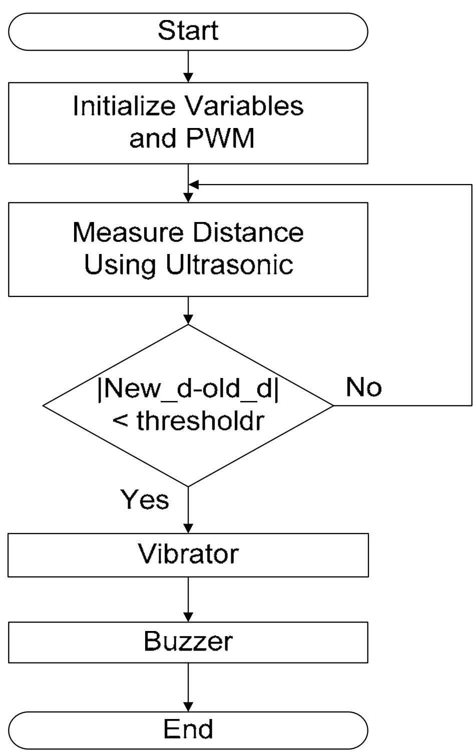

Figure 4. Flow Chart for Ultrasonic Range Finder

Flow chart in figure 5 describes the GSM response process. If the module received (RING), it will answer the call immediately; else the program enters the cycle again. To dial a number, the flow chart in figure 6 describes the process of four buttons. Buttons one, two and three are used to dial three numbers and the last button is used to end the call.

Finally, flow chart in figure 7 describes the process for reading the accelerometer sensor. By sensing the amount of dynamic acceleration, the accelerometer can find out how fast and in what direction the blind is moving. If it rotates around X or Y axis, a vibration signal will switched on, then a buzzer signal is switched on and SMS message will be sent including the location of the blind.

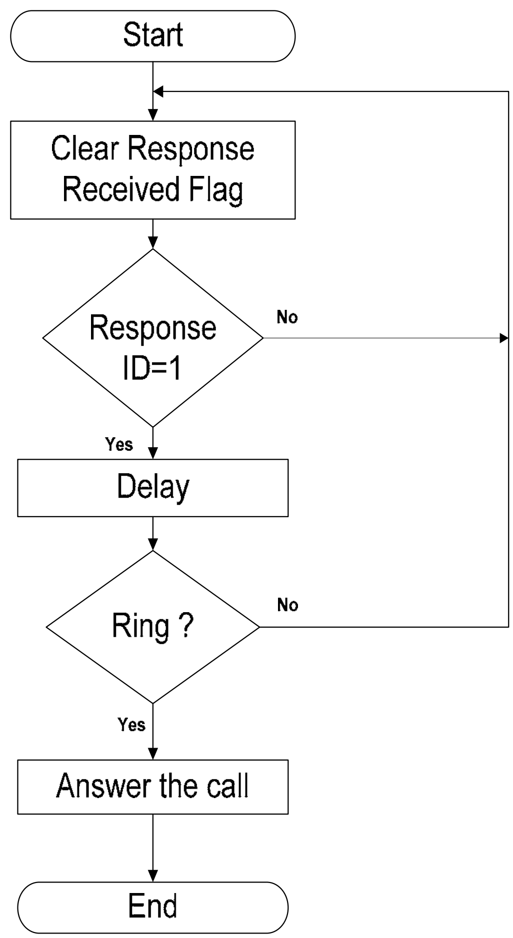

Figure 5. Flow Chart for Answering the Call

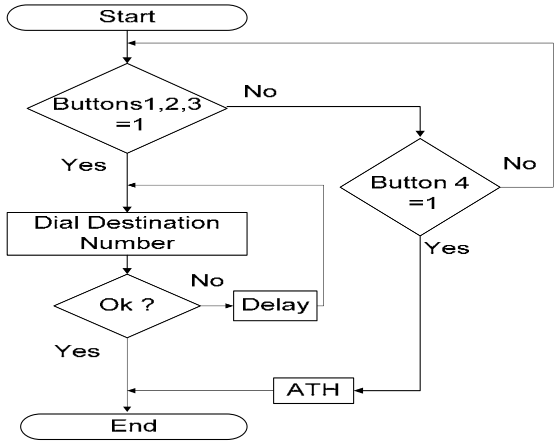

Figure 6. Flow Chart for Dialing a Number

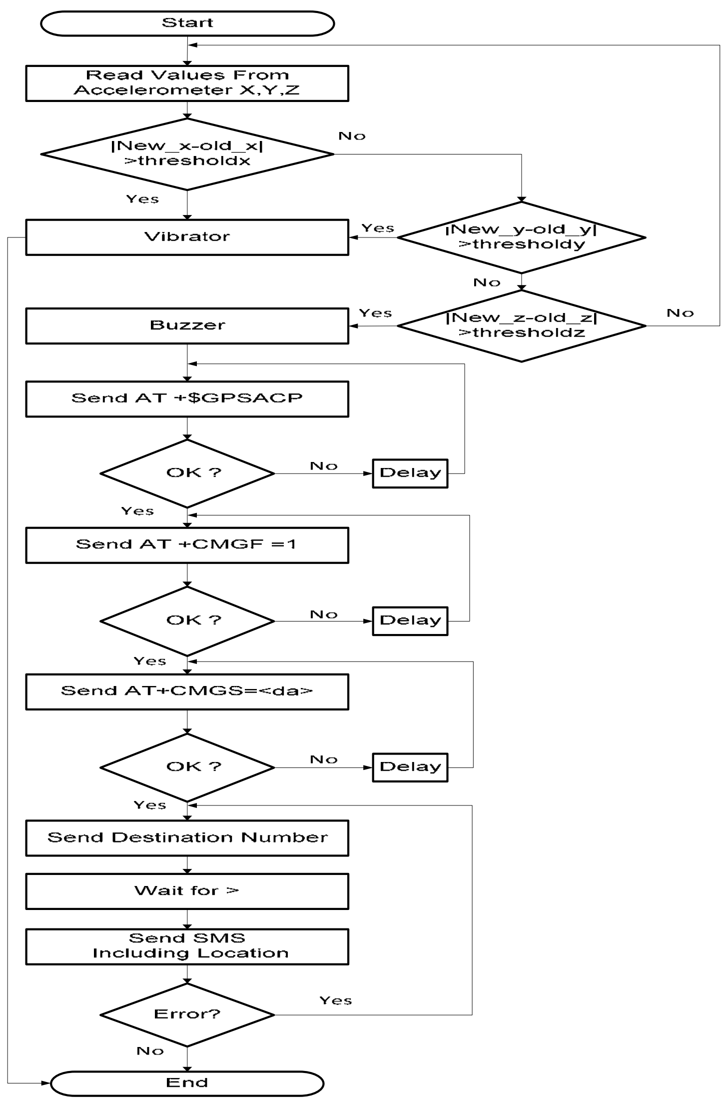

Figure 7. Flow Chart for Reading Accelerometer Sensor.

IV. EXPERIMENTAL RESULTS

The intelligent cane has been evaluated with three main experiments. In the first experiment, we examines how the ultrasonic sensor functioning. For this test, three types of ultrasonic sensors were examined: LV-MaxSonar EZ0, LV-MaxSonar EZ2, and LV-MaxSonar EZ4. The gathered data are presented in Table 1. The table shows analysis of the ultrasonic sensors based on the beam width. The LV-MaxSonar EZ0 ultrasonic sensor has been chosen because of its usefulness in detection low level obstacles. This sensor has a wider beam width than the others and it is better suited for detecting small objects. The others were excluded because they were unable to detect close and small objects. Distance information is then conveyed to the user though a buzzer and vibrator.

Table 1: Analysis of the Ultrasonic Sensors Based on the Beam Width

	Obstacle Distance					
Sensor Type	Less than 1m	1m	2m	3m	4m	5m
LV-MaxSonar EZ0	X	X	X	X	X	X
LV-MaxSonar EZ2	--	--	X	X	X	X
LV-MaxSonar EZ4	--	--	--	X	X	X

In the second experiment, GSM-GPS module and the accelerometer sensor were tested to pin-point the location of the blind person, establish a two way communication path in a wireless fashion, and examine if there is a change in the stability of the blind. As shown in figure 9, a message is sent automatically from the system to a preconfigured telephone number indicating the location of the blind. This message is sent by the system as a result of stability changing in the z direction.

Figure 9: Testing GSM-GPS Module and Accelerometer Sensor.

Finally, experiment was conducted by a volunteer in order to test the functionality of the smart cane and to make sure it works as intended. As shown in figure 8(a), the user who was given a training course on the usage of this cane was requested to walk towards a wall from a random distance. The user was informed to rise his left hand up as soon as he feels a vibration underneath the right hand and then continue walking forward till he hears a continues sound. The threshold value that is given to the vibration was the maximum rage of the ultrasonic sensor, while half of this value was given to generate a sound to indicate the risk of obstacles. The user in this phase was able to infer the distance of obstacle from the vibratory and sound information. Figure 8(b) shows another test where the user was asked to walk towards the front of the car that lies below the horizontal level of the cane. The user was able to detect the vehicle before coming in contact with it from a distance of 1.0m. At the end of this experiment, the user was asked to turn the smart cane left and right for purpose of detecting the presence of obstacles while ambulating. Figure 7(c) illustrates that the user was able to detect a tree using this technique from a distance of 1.0m. The aim of this test was to train the user to recognize the size of obstacles and decide on a suitable direction.

(a) (b) (c)

Figure 8: Testing the Smart Cane by a Volunteer in Terms of its Functionality. (a) Detection a Wall Using Sound and Vibration. (b) Detection Obstacles Below the Horizontal Level of the Smart Cane (c) Detection Obstacles while Turning the Smart Cane Left and Right.

V. CONCLUSIONS

In this paper, we have presented new intelligent system for guiding individuals who are blind or partially sighted, and we have described how the system can be used to enable those people to move with the same ease and confidence as a sighted people. In order to incorporate the properties of the GSM_GPS module, we have developed another module that comprising different sensing devices and pic16f877 microcontroller. The system has been used to receive the data from the sensing devices and command the GSM module. We have integrated the ultrasonic, accelerometer sensor data in order to detect obstacles, and to obtain more detailed regarding the blind's environment. Evaluations of the system that we have developed have been conducted by attaching the prototype to the handle of the white cane. The experimental results have shown the usefulness of the system in allowing blind people to move independently, safely and quickly among obstacles and hazardous places.

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