

# Embedded voice synthesiser and Sensors in Navigation Aid system for Blind People

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**Abstract:** World Health Organization estimates that there are 38 millions blind and 285 million visually impaired people worldwide, mainly in developing countries. People who are visually impaired often encounter physical and information barriers that limit their accessibility and mobility.

In this research work, we describe the design of a navigation aid system for Visually-Impaired and Blind Persons. It is based on a new type of microcontroller with synthesiser speech module VR-Stamp. The system is a portable, self-contained that will allow blind and visually impaired individuals to travel through familiar and unfamiliar routes without the assistance of guides. The proposed and designed system provides information to the user about urban walking routes using spoken words to indicate what decisions to make and during travel it detects obstacles. It was tested inside the university by students and obtained results are encouraging.

**Keywords:** Blind navigation aid system, embedded system design, Microcontroller, Speech synthesizer, Distance measurement, Ultrasonic sensors.

## 1. Introduction

According to statistics from the Federal Highway Administration (FHWA) in USA, each year approximately 17% of all work zone fatalities are pedestrians. People who are visually impaired often encounter physical and information barriers that limit their accessibility and mobility.

The Americans with Disability (ADA) requires that pedestrians with disabilities be accommodated in completed facilities as well as during times of construction.

Pedestrian movements around work zone areas require proper planning and consideration in order to avoid conflicts with work site equipment, vehicles and operations [1]. A variety of high-tech devices, using different types of range finders are available in the market and have been widely used too, but they are discarded on the basis of cost and other factors. Some of the old devices are Nottingham Obstacle Detector, (NOD) [2], Binaural Sonic Aid (Sonic guide) [3], Guide Cane [4], Mowat Sensor [4], C-5 Laser cane [5]. Advancement in technology has resulted in developing the old devices into new ones with additional features.

Blind individuals have begun to benefit from high-tech systems [6] designed to aid them in orientation and navigation. We have already tackled this problem in [7] and [8]. Hence during the last several decades, some blind mobility aids have been developed. Sonic-Guide [9], Sonic Pathfinder [10], Mowat-Sensor [11], and Guide-Cane [12] are called clear path indicators or

obstacle detectors since the blind can only know whether there is an obstacle in the path ahead [13]. These devices are used to search for obstacles in front of the blind person, and they operate in a manner similar to a flashlight, which has very narrow directivity. Sonic-Guide and NavBelt [14], however, are called an environment sensor since it has wide directivity enabling it to search for several obstacles at the same time.

The proposed visually impaired pedestrian navigation system involves then a microcontroller with speech synthesis processor and embedded sensors. It is relatively small and lightweight. It is a self contained portable electronic unit. Moreover, it also can supply the blind person with assistance about walking routes by using spoken words to point out what direction to take on his way. In addition, to help blind or visually impaired travellers to navigate safely and quickly around fixed obstacles [15] and other hazards faced by blind users, an obstacle detection system using four pair of ultrasonic sensors [16] has been considered in this aid. The first one is mounted on glasses combined with wireless transmission circuit Bluetooth module [17] in order to function as an environment sensor. The remaining three US (Ultra-Sonic) sensors modules are mounted on a belt around the chest of user, the position of the modules allow the system to detect approximate obstacle in front and overhanging, left and right position.

To guide the person on his way, the system should compute the travelled distance. In this case and in

order to overcome the imperfections of existing electronic travel aids, the proposed method of measuring distance travelled, is to use the acceleration of a moving body which in this case is the blind person [18]. An accelerometer, followed by two software integrators is used to measure a distance travelled by the blind. This technique is considered in inertial navigation systems (called acceleration based navigation systems) [19]. It suffers from drift problems caused by the double integration and offset due to the accelerometer which are overcome by the footswitch placed inside the shoes [80] and [20]. When this footswitch is closed, the acceleration and the velocity are equal to zero and this can be used to apply a correction on acceleration computation.

Our purpose is to develop a multifunction device taking into consideration the requirements of the blind.

## 2. Considerations

Simplicity of controls, low cost, portability, and above all efficiency are most important factors which govern the practicality and user acceptance of such devices.

The embedded system travel aid (ETA) is a kind of portable device. Hence it should be a small-sized and

lightweight device to be proper for portability; it should consume less energy or enclose an energy harvesting circuit.

The blind is not able to see the display panel, control buttons, or labels. Hence the device should be easy to control: No complex control buttons, switches and display panel should be present. Moreover, the ETA device should be low-price to be used by more blind persons.

Our system is developed for portable (small size and lightweight), inexpensive and easy to use, and low-power consumption (supplied by battery).

## 3. System Presentation

This assistance system is based on the new type of microcontroller based on Atmega1280 as a main processor, an accelerometer, a footswitch, a speech synthesizer based on speech processor VR-Stamp, a bray hexadecimal keypad, a mode switch, four ultrasonic sensors, a pair of transmitter-receiver, a power switch and a glasses. The block diagram of the system is represented in figure 1.

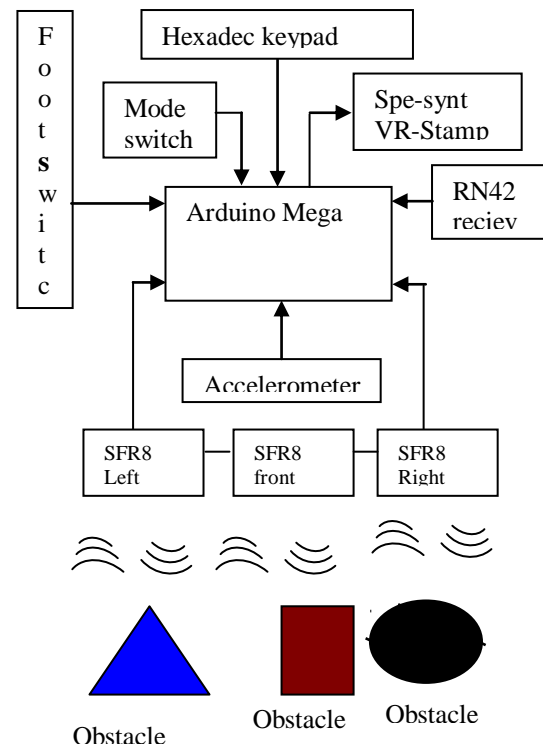


Figure 1

The obstacle detection part of the system contains four ultrasonic's transmitter-receiver. One pair of these ultrasonic sensors is mounted on glasses and connected to a Bluetooth module for wireless transmission of the distance measured by the smart ultrasonic sensor as shown in figure 2.a and 2.b

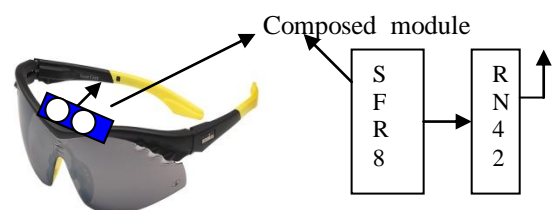


Figure 2.a Ultrasonic sensors mounted on glasses. 2.b. Composed module FSR08 and Bluetooth transmitter

The three other ultrasonic sensors are mounted on a belt (figure 3) the FSR08 modules mounted on the belt will detect approximate obstacles in left front and right of the user. These glasses and belt use a 40 KHz ultrasonic signal to acquire information. They can detect the presence of any obstacle within the specified measurement range of approximately 0.5 to 10 meters. They operate by sending out a pulse of ultrasound. Eventually the pulse is reflected from a solid object in the path of the pulse. The time between the outgoing pulse being transmitted and its echo being received corresponds to the distance between the transmitter and the object or the obstacle the FSR08 module

compute the distance then transmit it in I2C protocol. This information is then relayed to the blind in some speech way via headphones.

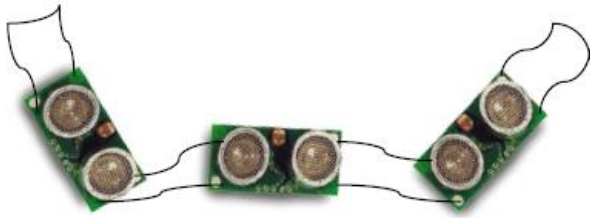


Figure 3. The ultrasonic Belt with FSR08 modules

On the other hand and as for the 'Micromap'[21], the system has two modes of operation, train and playback. In addition, the playback mode has two directions, forward and reverses. The user selects then, one of these three possibilities by bray keypads.

In the training mode, the blind walks the route of interest from start point to arrival point, and the aid measures the distance travelled by the user. When the blind reaches a decision point, for instance a point at which the route takes a left turn, the user presses a key on the aid to initiate recording of decision word within the speech synthesizer.

This has two effects:

- The distance travelled is stored in memory of the microcontroller, and the counter reset to zero.
- The left turn instruction is memorised as a code i.e table 1.

Afterwards, the blind walks to the next decision point and the above procedure is repeated.

In the playback mode, the aid measures again the distance travelled by the user. When this is equal to that stored in the memory for that section of the route, a corresponding decision word generated by the speech synthesizer is given to the blind. The spoken word indicates what action the user should take at this point, for instance turn left. In the reverse direction, the procedure is exactly the same except that the route information stored in the memory is used in reverse order, and that left and right is interchanged.

At decisions points, the blind can make any of the following decisions:

- Turn right.
- Turn left.
- Cross road.
- Cross road junction.
- Pedestrian crossing.
- Steps.
- Pause (Routing is halted temporarily).
- Stop (End of route).

Each of these decisions has separate bray-key. There are also extra bray-keys available, which are undefined in the present software, but which the blind could have available for their specific use.

The system can store a number of routes, each of which are numbered, and be selected using the same set of keys as for the decisions. In practice the number is likely to be set by the size of the available memory.

## 4.Main Components and Hardware Details

The main components used in our design are:

### 4.1 . Microcontroller System (Arduino-Mega)

The choice of processor is the major factor affecting the design of the unit, since it is central to system operation and it should consume less energy. The microcontroller used in this design is Arduino Mega[22] from 'Arduino'.

The Arduino Mega is a microcontroller board based on the ATmega1280 [23]. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Its main features are:

- ATmega2560 microcontroller [23]
- Input voltage - 7-12V
- 54 Digital I/O Pins (14 PWM outputs)
- 16 Analog Inputs
- 256k Flash Memory
- 16Mhz Clock Speed

This module has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega1280 provides four hardware UARTs for TTL (5V) serial communication. An FTDI FT232RL on the board channels one of these over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Mega's digital pins. The ATmega1280 also supports I2C and SPI communication. The software includes a Wire library to simplify use of the I2C bus.

The circuit can be programmed with the Arduino software that can be downloaded from the site in [24]. The open-source software makes it easy to write code and upload it to the board. It runs on windows and Linux. The environment is written in Java and based on processing and other open-source software. It can be used with any arduino board. We can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header, see in [24].

#### 4.2. Accelerometer

The accelerometer used is the ADXL312 where we can find the datasheet in [25] from 'Analog devices'. It was specifically designed to work with low cost microcontrollers. This accelerometer is low cost, low power and a complete three axis acceleration measurement systems on a single monolithic IC. The ADXL312 is a small, thin, low power, 3-axis accelerometer with high resolution (13-bit) measurement up to  $\pm 12$  g. Digital output data is formatted as 16-bit two's complement and is accessible through either a SPI (3- or 4-wire) or I2C digital interface.

The ADXL312 is well suited for car alarm or black box applications. It measures the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock. Its high resolution (2.9 mg/LSB) enables resolution of inclination changes of as little as  $0.25^\circ$ . A built-in FIFO facilitates using oversampling techniques to improve resolution to as little as  $0.05^\circ$  of inclination. Several special sensing functions are provided. Activity and inactivity sensing detects the presence or absence of motion and whether the acceleration on any axis exceeds a user-set level. These functions can be mapped to interrupt output pins. An integrated 32 level FIFO can be used to store data to minimize host processor intervention.

For each axis, an output circuit converts the analogue signal to a duty cycle modulated (DCM) digital signal that can be decoded with a counter/timer port on the microcontroller Arduino-Mega. With this accelerometer, no A/D converter is then required.

Its specifications are as follows:

- Acceleration: Any Axis, Unpowered 10,000 g  
Any Axis, Powered 10,000 g
- VS  $-0.3$  V to  $3.9$  V
- Sensitivity:  $4.0$  %/g.
- Temperature Range Powered  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$

In this assistance system, the accelerometer needs to be attached to the shoe or to a rigid part of the leg where the condition of both acceleration and velocity equal zero is applied.

#### 4.3. Footswitch

The footswitch is used to allow the microcontroller Arduino Mega to provide frequent corrections of drift effects. This footswitch 'FS' needs to be attached to the heel of the shoe. When the blind starts to walk, 'S' is equal to zero. The microcontroller estimates then the acceleration and calculates the distance.

When the footswitch is on the ground, 'FS' is equal to one. The microcontroller estimates and calculates the errors. Afterwards, corrections are made. The micro-switch is one example of switch which can be used because it is more flexible.

#### 4.4 Speech synthesizer VR-Stamp

Voice Recognition Stamp [26] is a new component from Sensory inc. It has more capabilities designed for embedded systems. It was designed for consumer telephony products and cost-sensitive consumer electronic applications such as home electronics, personal security, and personal communication because of its performances:

- Noise-robust Speaker Independent (SI) and Speaker Dependent (SD) recognition.
- High quality, 2.4-7.8 kbps speech synthesis &
- Speaker Verification Word Spot (SVWS) -Noise robust voice biometric security.

The module VR-Stamp is based on the following components: a special microcontroller RSC4128, a reference word storage 24C65 of EEPROM type that holds the parameters of referenced word produced during the training phase, a Flash program memory of 4 Mega-byte that holds the main program of word recognition, and a parallel interface of 24 lines (divided into 3 by 8-bit ports) to generate the results of recognition or to introduce commands, and audio communication lines for microphone and speakers.

The module has been used as speech synthesis circuit. In training phase, the module gets features of the 10 spotted words used in the vocabulary for navigation and presented in table 1, among these words, the starting keyword "Lasa" which is the name the laboratory and finishes with the Keyword "Tabek" which means 'execute' the command, so whenever the system wants to submit a voice command the sentence should start with the word "Lasa" and finishes with the word "Tabek". In playback phase the microcontroller should construct a sentence from some spotted word codes and then submit the codes to the VR-Stamp to synthesis the words.

Example if the US sensors detects an obstacle in front, the microcontroller will generate de codes: 9,4,5,0,10. then the synthesis circuit will provide to the user the following sentence: "Lasa hadari hajez ammam tabek", which means "Lasa, Attention there is an obstacle in front", the module will submit the codes: 4 and 5 for indicate "attention obstacle" and the



code 0 to indicate position of obstacle, the codes are presented in table 1 with the corresponding Arabic words and meaning.

TABLE 1. THE SYNTHESISED WORDS AND ASSIGNED CODE.

Code) Word	Meaning
0) ammam	front
1) yasar	left
2) yamine	right
3) kif	stop
4)hadari	attention
5) hajez	obstacle
6) mouftarak	intersection
7) tarik	road
8) icharat	Signals road
9) lasa	Starting keyword
10)Tabek	Fish keyword

The speech synthesizer device chosen is the VR-Stamp [26] from 'sensory' and is used as an audio output. The chip is a low power, single-chip solution offering digital storage capability and up to 16 minutes of high quality, audio record and playback functionality, along with a new integrated voice-band CODEC.

The technical specifications of this speech synthesizer are the followings:

- Voice and digital data record and playback system on a single chip.
- Industry leading sound quality.
- Message management.
- Non volatile message storage.
- 8, 10, 12 and 16 minutes duration.
- 100 year message retention (typical).

The speech synthesizer is activated by codes from the microcontroller. The output represents the different actions to be taken (e.g. road right turn, left turn, stop...). The speech synthesizer chip with a small vocabulary tells then the blind person about presence of obstacle, travelled distance, present location and decisions to make. Information about the route is stored in the memory in the form of a digital map of the device to guide the user to his destination via the planned routes.

Some guidelines for synthesized speech include:

- Voice warnings should be presented in a voice that is different from other voices that will be heard in the task situation. The user can train the system using his proper voice.
- If synthesized speech is used for other types of information in addition to warnings, the user needs to be able to distinguish between these messages.
- Maximise the intelligibility of the messages.

- If the message is missed, it is beneficial for people to be able to replay it.

- If the message is familiar, the ability to interrupt the message would be beneficial for experienced users.

- Make the voice as natural as possible so people are more likely to accept it.

- Computer generated speech is appropriate for situations that require different messages to be generated.

- Where the choice of messages is relatively limited, human voices are preferred because synthetic speech is less intelligible and less preferred.

- Use non-speech audio messages only for the purposes of alerting.

- Make a headphone socket available for private speech output.

- A volume control is beneficial.

#### 4.5 . Ultrasonic and Bluetooth mounted on glasses

a) Communication with the SRF08 ultrasonic rangefinder is via the I2C bus [27]. This is available on popular controllers such as the Pic12c508 and Basic-Stamp microcontroller (BS2), as well as a wide variety of microcontrollers. To the programmer the SRF08 behaves in the same way as the ubiquitous 24xx series eeprom's, except that the I2C address is different. The default shipped address of the SRF08 is 0xE0. It can be changed by the user to any of 16 addresses E0, E2, E4, E6, E8, EA, EC, EE, F0, F2, F4, F6, F8, FA, FC or FE, therefore up to 16 sonar's can be used. In addition to the above addresses, all sonar's on the I2C bus will respond to address 0 - the General Broadcast address. This means that writing a ranging command to I2C address 0 (0x00) will start all sonar's ranging at the same time. The results must be read individually from each sonar's real address. We have examples of using the SRF08 module with a wide range of popular controllers.

In our application, the first ultrasonic transmitter-receiver FSR08 is equipped on the rims of glasses and we fixed the address to 'E0'. Since the user can move freely his head, he can confirm the path clearness and recognize obstacles in various directions. The data received from FSR8 sensors is transmitted to the microcontroller Arduino Mega by the RN42 Bluetooth module.

b) The RN42 is a small form factor, low power, highly economic Bluetooth [28] radio for OEM's adding wireless capability to their products. The RN42 supports multiple interface protocols, is simple to design in and fully certified, making it a complete embedded Bluetooth solution. The RN 42 is functionally compatible with RN 41. With its high performance on chip antenna and support for Bluetooth® Enhanced Data Rate (EDR), the RN42 delivers up to 3 Mbps data rate for distances to 20M. T

#### 4.6. Ultrasonic Belt

The electronic belt used for this navigation aid is based on an three ultrasonic transmitter-receiver type FSR08 connected to the main microcontroller via I2C protocol. The addresses of these three modules are chosen as : E2,E4 and E6. With different addresses and alternative request for the four SFR8 modes, there will be no interference of ultra sonic signals.

#### 4.7. Headphones

Since hearing for blind people is very important, the headphones would dull this sense. For this system, it has been decided to consider headphones used for walkman. Spoken words from the speech synthesizer which represent the different action to be taken will therefore be heard by the blind.

#### 4.8. Hexadecimal keypad

In order to input information, a bray-hexadecimal 4x4 keypad is used in this design. It is placed on the side of the case, and can be seen in figure 4. The keypad switches enable the user to select routes and to enter decision. It is of course possible to label these keys with Braille symbols if it is thought necessary.

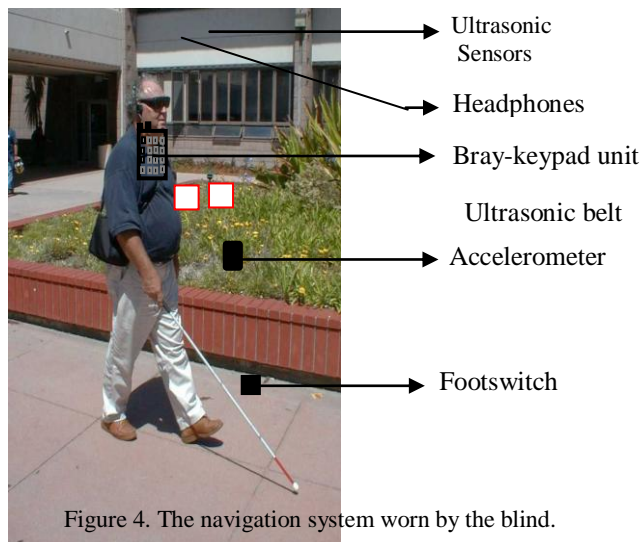


Figure 4. The navigation system worn by the blind.

### 5. USE OF THE SYSTEM

The system is straightforward to use. It is attached to a belt which is fastened around the user's waist. There is provision for a test to ascertain that the blind person's step is detected by the accelerometer, and then a calibration phase for the FSR8 sensors is done.

The user then selects the training or navigation mode:

In training mode: the system records distances between decision points and directions to be taken. Once the arrival point is reached, a route number is affected to this training session.

A repeat key has been considered to enable the blind person to make the aid repeat the word indicating a decision. This is to ensure that the user can be certain of the decision, in case it is obscured the first time by, for example, traffic noise. The system has been used on some preliminary trials. In the near future, it is planned to carry out more extensive tests.

### 6. FLOWCHART OF FUNCTIONING

The flowchart of the system is shown in figure 5.a

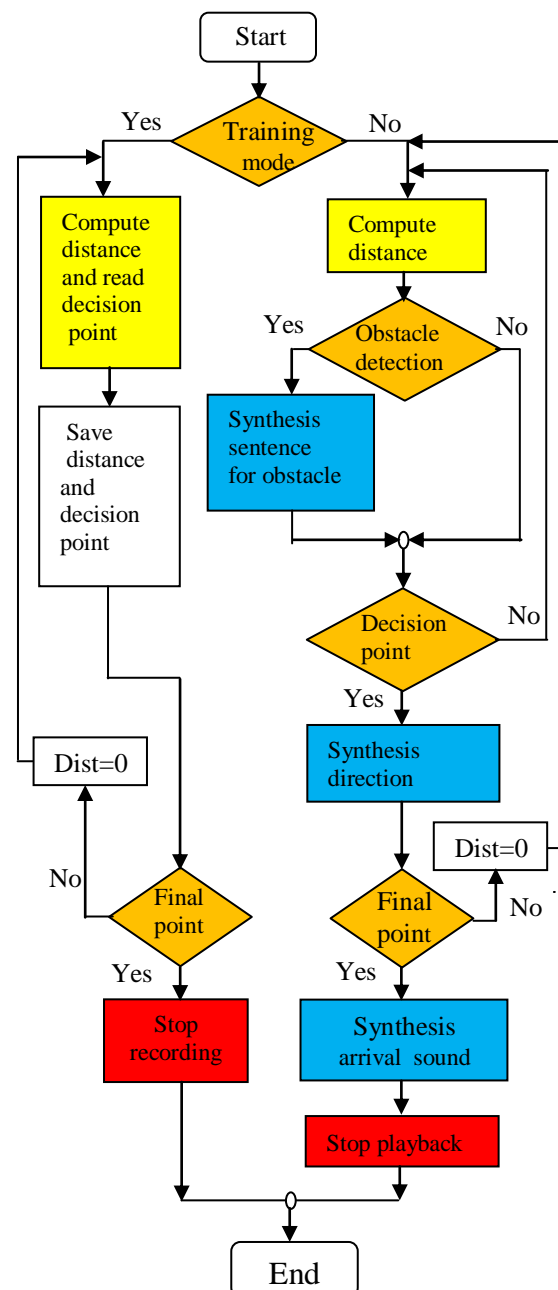


Figure 5.a. The flowchart of the system.

## 7. Experiments and Tests

In the experiment, we selected two students from our department, first subject is a girl of age 22 and the second is a boy of age 23 years. The selected path has a distance of 187 meters and four decision points in the following order: turn left, turn right, turn right and stop.

In order to illustrate the efficiency of the proposed navigation system, Figure 5.b shows the path programmed for two subjects to go from restaurant place to the Electronic Department, the red point ( at exit from restaurant) is the start point and the arrival is the green point which is the 'Electronics Department at Badji Mokhtar Annaba University. Figure 5.b shows the tracks of two subjects made blind by an opaque bandage on their eyes navigated outdoor. Equipped with our blind assistance navigation system , they have been able to walk near the reference path in open space without point of reference, after a training mode registered on the system.



Figure 5.b. Programmed and registered itinerary for test by two student subjects.

While in figure 5.c we illustrate the roads taken by both subject using our designed system, the path of first subjecte drown in red and the other drown in blue. We noticed that the total real distance computed from the way drown in figure 5.a is as follows:

$D_{blk} = 120 + 50 + 15 + 2 = 187$  m and it takes around 280 seconds for normal persons; distance travels by first subject in red was computed  $D_{red} = 199$ m and it took her 280+92 seconds , while the distance travelled by the second subject in blue was computed  $D_{blu} = 196$  m and it took him 280+69 seconds. We can conclude from these results that the girl student takes more time because of hesitation on each decision point and in our case we have four decision points.

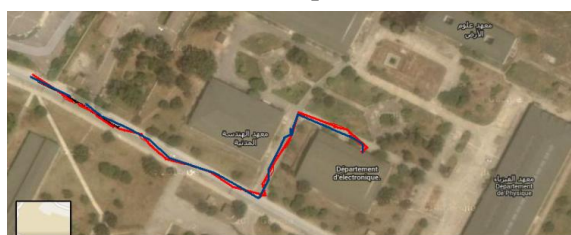


Figure 5.c. illustrates the itinerary of both subjects ( red and blue)

## 8. Conclusions and Future Work

The designed navigation system has been developed in order to enhance the independent mobility of blind individuals, and thus improve the quality of their everyday lives. The use of the footswitch is highly advantageous because without it, drift errors due to the accelerometer and double integration would be considerably greater in magnitude and would reduce the effective range of the electronic travel aid.

It should be noted that blind and visually impaired travellers indicate a reluctance to consider a system involving the use of headphones because it might block environmental sounds. More tests are in progress to improve the system regarding speech synthesis words. More new efficient sensors can be added such as compass or even explore the sensors and applications within smart phones.

However, it is difficult to know where the blind is globally. The global positioning system (GPS) [29] will be employed to get the user position information. Further research is required to determine the utility of this aid. Indoors, where GPS is not effective, the same path programming or lead-through techniques can be used to have the aid automatically guide the user to a desired location, using dead-reckoning based on encoder and compass readings. We intend to use wireless position indicator network based on Xbee transmitter nodes.

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