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Blind People Stick Tracking using Android Smartphone and GPS Technology

Rian Adi Chandra [1*], Umi Fadlilah [1], Prasetyo Wibowo [1], Faizal Tegar Nanda Saputra [1], Reyhan Radditya Sulasyono [2]

[1]Dept of Electrical Engineering
Universitas Muhammadiyah Surakarta
Surakarta

[2] Dept. of Architecture
Universitas Muhammadiyah Surakarta
Surakarta

*riantava19@gmail.com

Abstract - Blindness is a term to describe conditions of people who have visual impairments. When a visually impaired do an activity outside, he usually needs a stick to help them move. This study aims to develop a stick tracking that enable a family member to find the location of the blind when they are outside their home and can help the blind to travel. GPS (Global Positioning System) technology allows the stick to get a signal for its location coordinates. When a family member wants to get the location of the blind, he can send a text message with the keyword TRACKER to the mobile phone number of the stick. A GSM (Global System for Mobile Communication) module will send a reply containing the global coordinate, which Google Maps can visualize. In addition, the blind can actively send an emergency help signal to families if they have difficulty finding their way home. An emergency push button is available on the stick, which, if pressed, will send the coordinates to the family's phone number in the form of a short text message. During travelling, blind people can identify obstacles in front of them thanks to an ultrasonic sensor system on the stick. The sensor can detect an object in the range of 100 cm. If the sensor detects an object less than 100 cm, a buzzer will emit an edible sound for the blind. Observations show that the developed stick works well with an average error on the GPS module at a level of 11.89 meters. It also shows a fluctuating percentage of ultrasonic sensor errors depending on the distance of objects.

Keywords: android, GPS, smartphone, tracking stick, blind

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1. Introduction

Blindness in general is a term used for the condition of people who have visual impairments. For the classification, blindness are divided into two categories: total blindness and low vision [1]. Many factors affects the occurrence of visual disturbances, namely accidents, congenital, and bad habits that can cause a reduction in sight sensory capability. The mobility of blind people to carry out activities is reduced because they have a limited ability of sight. Blind people only depend on the hearing and touch sensory organs [2].

Blind people in carrying out daily activities are usually assisted with several kinds of tools. One tool that is often used is a stick. There are obstacles that blind people get when doing activities outside the house. Often blind people get lost or have difficulty finding their way home because they are new to the place they are visiting. This incident can cause concern from the family of the parties [3].

The current research gets inspiration from previous researches, which aims at helping families in monitoring the position of the blinds using *GPS Tracker*. An intelligent guide stick has been developed consisting of ultrasound displacement sensors, two DC motors, and a micro-controller [4]. Another paper presents the design and application of an ultrasonic sensor module to detect obstacles, a buzzer to make the blind alert, and a microcontroller 16F877A to provide safe navigation [5]. A group of researchers implement infrared sensors as a range detector and devise a lightweight low power consumption smart stick that can detect obstacle presence within a range of two meters [6]. Still, another group devises a smart stick that helps guide the user to identify obstacles using various sensors and notify the user as vibrations [7]. Compared to the aforementioned research, the one we propose has a feature to track the user position using a GPS tracker and a GSM module to communicate with someone. A family member, for example, may track the position of the blind by sending a special text message. The blind in an emergency may push a panic button that will send a help alert to the family member which sends the position of the user.

At this time GPS is a tracking system that is used in general. With GPS we can find out the global coordinates of a place [8]. GPS Tracker works by utilizing satellite signals and GSM signals [9]. The tool uses Arduino as an open-source microcontroller. Arduino cannot work alone, so it is necessary to add other supporting components to make it an application that can be used [10]. In the developed tool, Arduino is connected to a GPS module to process Latitude and Longitude data into web addresses that can be connected directly by the Google Maps application. The GSM module sends GPS coordinates that have been converted into a Google Maps link to the mobile number of a blind family via SMS (Short Message Service). In addition, there is a feature so that families can find out the whereabouts of the visually impaired. This tool is equipped with a push-button that is useful for blind people to send a location signal to the family's smartphone when an emergency occurs in the middle of the trip. In addition to the GPS component, the blind person's walking stick is equipped with an ultrasonic sensor that functions to detect obstacles that are in front of the blind person. If there is an obstacle in front of the blind person, the buzzer will make a sound that can be heard by the blind person.

2. Method

a. System design

The stages of designing a tracking stick based on an android smartphone and GPS technology are described in Figure 1. The design of this tool requires several components such as Arduino Nano, ublox Neo 6mV2 GPS module, GSM Sim800l module, ultrasonic sensor HC-SR04, Buzzer, DC-DC step-down LM2596, and push-buttons. Each component has its function. Arduino Nano is the microcontroller that is the brain for this device. The ublox Neo 6mV2 GPS module functions to determine the coordination point in the form of latitude and longitude data. On SIM 800l there is a receiver leg that functions as a sender and a transceiver leg as a receiver [11]. However, for SIM 800l to work properly, the voltage from the Arduino needs to be lowered to 4.4 V using the LM 2596 DC-DC Step-down component [12]. The ultrasonic sensor HC-SR04 serves to detect obstacles that are in front. The sensor works by utilizing ultrasonic waves reflected by obstacles in front and converted into distance [13].

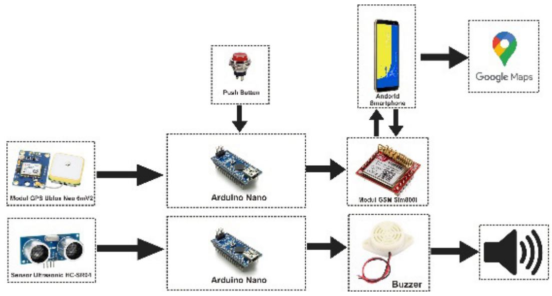
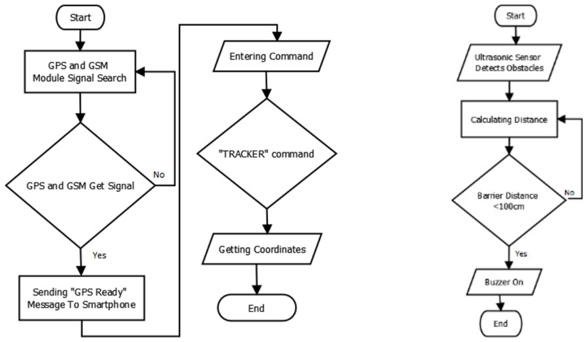


Figure 1. System Block Diagram



(a) (b)

Figure 2. (a) Flowchart on tracking system; (b) Flowchart on ultrasonic system

Figure 2 shows the system workflow on the tracking stick. The tracking stick works with two systems, namely a GPS tracking system to determine the coordinates of the stick and an ultrasonic system to detect obstacles in front of blind people. The way the GPS tracking system works is to look for signals on the GPS module and GSM module. After the GPS module and GSM module get a signal, the stick has got the coordinates through the GPS module which can be sent to the smartphone via the GSM module. The next system is the ultrasonic system. The way the ultrasonic system works is to detect obstacles in front of blind people with a predetermined distance of 100 cm. If the ultrasonic sensor detects an obstacle in front with a distance of less than 100 cm, the buzzer will sound.

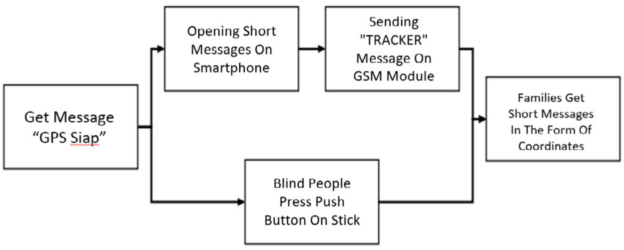
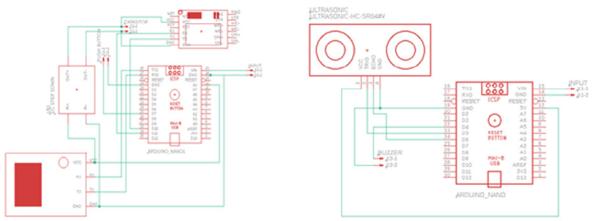


Figure 3. Block diagrams get coordinates using a smartphone and a push-button

Figure 3 describes how the coordinate point delivery system is via a smartphone and a push button. The sending of coordinates of the GPS module on the stick is sent by the GSM module to a smartphone that can be accessed by families with visual impairments. Requests for the coordinates of the GPS module using a smartphone can be done by sending an SMS with the keyword "TRACKER" through a short message application on the smartphone and sent to the GSM module. Short messages with these keywords will get a reply in the form of coordinates that have been converted into links so that they can be displayed via the Google Maps application. Sending coordinates can also be done using a push button. How to send coordinates, by pressing the push button on the blind stick. After that, the coordinates will be sent by the GSM module via a short message on the smartphone.

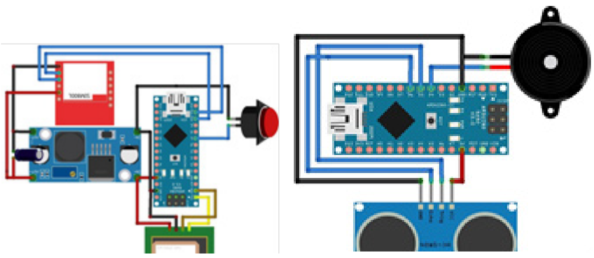
b. Electronic Design

The electronic circuit schematic in this tool is designed using Eagle as software for making PCB layouts and Fritzing as software for making wiring diagrams. Figure 4 is a diagram used to create a PCB layout using Eagle.



(a) (b)

Figure 4. (a) Schematic of the GPS module; (b) ultrasonic module schematic



(a) (b)

Figure 5. (a) GPS module wiring diagram; (b) Ultrasonic module wiring diagram

The wiring diagram created using the Fritzing software will be shown in Figure 5. The wiring diagram for the GPS is shown in Figure 5a and the wiring diagram for the ultrasonic system is shown in Figure 5b. The GPS module requires a voltage of 5 volts and the RX TX pin is connected to the Arduino Nano's RX TX pin. The GSM module requires a voltage of 4 volts so it requires a DC stepdown to lower the 5-volt voltage from the Arduino. The TX pin of the GSM module is connected to pin 10 of the Arduino Nano and the RX pin is connected to pin 11. The push-button is connected to pin 7 of the Arduino Nano. The wiring diagram in Figure 5b is for the ultrasonic circuit. The ultrasonic circuit requires a voltage of 5 volts on the Arduino Nano. The trigger leg on the ultrasonic sensor is connected to pin 5 of the Arduino Nano and the Echo leg is connected to pin 6. The buzzer is connected to pin 4 of the Arduino Nano.

c. Hardware Design

Figure 6 shows the hardware design of a tracking stick for blind people based on Android smartphones and GPS technology. The design for this tracking stick is kept as minimal as possible which aims for the comfort of the visually impaired when using it. The voltage source in the stick tracking system is obtained from two 9 volt batteries. Each system on this tracking stick is supplied by each 9-volt battery which aims so that when the tool is used, the power in the battery does not run out quickly and lasts a long time. In Figure 6, component 1 is a push button, component 2 is an electronic component box, component 3 is a 9-volt battery, component 4 is a stick, and component 5 is an ultrasonic sensor.

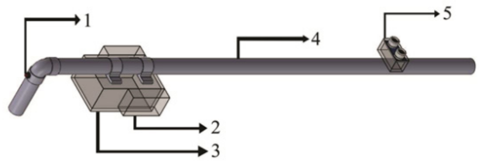


Figure 6. Tracking stick hardware design; see the text for the meaning of the numbers in the pictures

3. Result

a. Results of the Design of the Tracking Stick

The making of this tracking stick hardware uses a 2.5 cm diameter pipe with a stick length of 80 cm and a handle length of 7 cm. While the component box on this stick is made of acrylic material with dimensions of 11.8 cm long, 7.5 cm wide, and 5 cm high. The box for components is made as minimal as possible so as not to affect the weight of the cane too much which affects the comfort of the visually impaired when using a cane. The weight of this stick is 0.73 kg.

Figure 7. Blind stick hardware

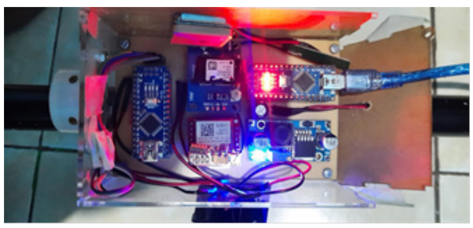


Figure 8. The electronic circuit inbox

This design that has been made still requires refinement because blind sticks have special characteristics. The blind cane should be light enough and adjustable in height. The light stick aims to prevent blind people from getting tired of using a stick. The lower end of the stick serves to provide the user with ground tactile information to improve balance while walking.

b. Testing and Discussion

1) GPS Module Coordinate Test

This GPS module test aims to determine the accuracy of the module. Testing of the GPS module is carried out with the equipment not moving and carried out when it is sunny in an open room so that the GPS module can easily get a signal because it is not blocked by buildings and trees [14]. This test uses a comparison of the coordinates on Google Maps according to the position of the tool. The coordinates that have been determined are the latitude position at -7.568394° and longitude at 110.759641°. The coordination points obtained by the GPS module can also be seen by opening the serial monitor in the Arduino IDE application. The error or difference in distance between the GPS module and the actual coordinates can be calculated using Equations 1 and 2 [15].

$$Z = \sqrt{(B-A)^2 + (D-C)^2} \quad (1)$$

$$\text{Error Distance} = Z \times 111322 \quad (2)$$

In equations 1 and 2,
Z = Degree value
A = Actual latitude value
B = Latitude value of GPS module
C = Actual longitude value
D = Longitude value of GPS module

1° in *maps* = 111.322 kilometers

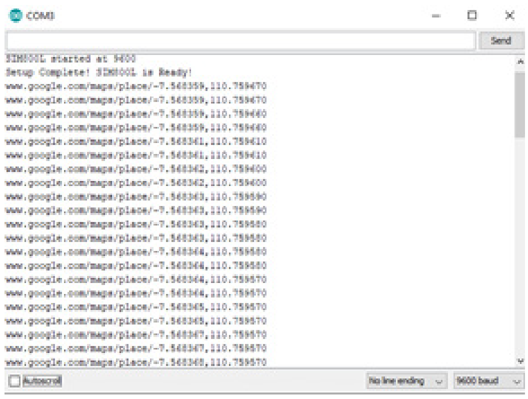


Figure 9. Arduino IDE monitor serial display

Figure 9 shows the results of testing the GPS module as seen from the serial monitor on the Arduino IDE application. The data that appears on the serial monitor repeats every 1 second. The data shown in the serial monitor has been converted to a Google Maps address which is ready to be sent to smartphone users via the GSM module. Table 1 shows 10 data collections where each data collection is carried out in one minute. Furthermore, the value of Z and the difference in distance is calculated using equations 1 and 2.

Table 1 shows the results of coordinate measurements and the results of calculating the difference in distance from 10 data taken in 10 minutes. The table shows the average distance error of 11.89 meters with the difference between the closest distance being 11.2 meters and the farthest 13.4 meters.

Table 1. GPS module testing

Data acquisition from GPS Module		Data acquisition from Google Maps		Z(°)	Difference Distance (m)
Latitude (°)	*Longitude* (°)	*Latitude* (°)	*Longitude* (°)		
-7.568406	110.75953	-7.568394	110.759641	0.000111647	12.4
-7.568407	110.75954	-7.568394	110.759641	0.000101833	11.3
-7.568406	110.75953	-7.568394	110.759641	0.000111647	12.4
-7.568400	110.75952	-7.568394	110.759641	0.000121149	13.4
-7.568398	110.75953	-7.568394	110.759641	0.000111072	12.3
-7.568400	110.75954	-7.568394	110.759641	0.000101178	11.2
-7.568400	110.75954	-7.568394	110.759641	0.000101178	11.2
-7.568394	110.75954	-7.568394	110.759641	0.000101	11.2
-7.568397	110.75953	-7.568394	110.759641	0.000111041	12.3
-7.568401	110.75954	-7.568394	110.759641	0.000101242	11.2
Average distance difference = 11.89 Meters					

2) GSM Module Testing

GSM module testing aims to determine the effectiveness of the GSM module. The GSM module has an LED as an indicator. If the LED flashes every 1 second, then the module is looking for a signal. If the LED flashes every 3 seconds, then the GSM module has received a signal [16]. The GSM module test uses two types of hardware, namely the Samsung A50s smartphone that is connected to the Telkomsel provider and the second uses a push button that can be accessed by the visually impaired. To determine the location of the stick using a smartphone, the user needs to send an SMS with the keyword "TRACKER". SMS is sent to the SIM800l module which will reply with the location of the stick. To test the work of the push button, the user only needs to press the push button on the stick. This action will cause the GSM module to send the coordinates of the stick to the smartphone.

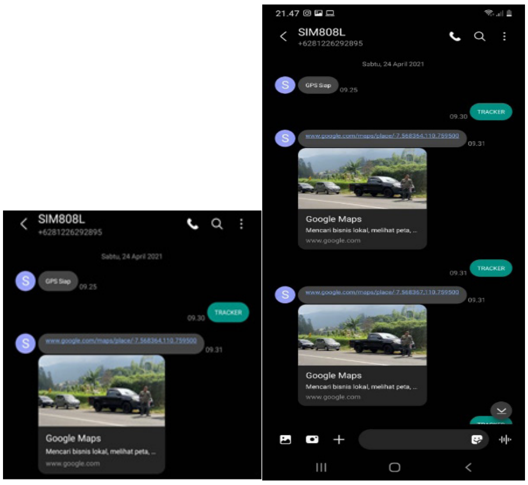


Figure 10. (a) The GPS is on; (b) send keywords to get location

Table 2. GSM module testing with smartphones and push buttons

Trial to-	Response Time(s)	
	Device Smartphone	***Device Push Button***
1	11.12	7.8
2	11.22	8.2
3	14.23	7.6
4	10.5	7.7
5	10.66	11.8
6	11.21	8.9
7	12.17	6.6
8	10.77	8,9
9	10.9	7.4
10	9.97	7.2
Average	**11.27**	**8.21**

Table 2 shows the GSM module test data that gives different response times to two different actions. Tests using smartphone devices show the longest response time is 14.23 seconds and the fastest response time is 9.97 seconds with an average overall response time of 11.27 seconds. Testing the GSM module using pushbuttons produces the longest response of 11.8 and the fastest response of 6.6 seconds with an average response time of 8.21 seconds. Tests show that the smartphone device takes longer to get the stick location data if the data is retrieved using SMS from the smartphone.

3) Ultrasonic Sensor Test

Testing of the ultrasonic sensor HC-SR04 was carried out to find out the accuracy of the ultrasonic sensor HC-SR04 in determining the distance [17]. The distance that can be read by the ultrasonic sensor is 2–500 cm [18]. Determining the accuracy of the sensor requires a comparison measuring instrument, namely a ruler. The object used in determining the distance is a solid object with a flat surface to obtain consistent measurement results [19].

Table 3. Ultrasonic Sensor Testing HC-SR04

No.	Set Distance (cm)	Sensor Reading (cm)	Difference (cm)	Error
1	10	10.44	0.44	4%
2	20	19.5	0.5	3%
3	30	29,15	0.85	3%
4	40	39.95	0.05	0%
5	50	48.11	1.89	4%
6	60	57.41	2.59	4%
7	70	67.44	2.56	4%
8	80	76.82	3.18	4%
9	90	87.45	2.55	3%
10	100	97.29	2.71	3%
Rata-rata			1.732	3%

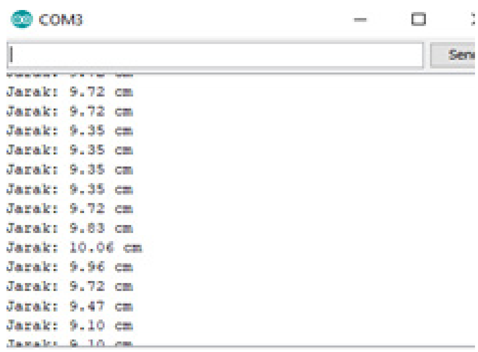


Figure 11. Ultrasonic sensor reading a serial monitor

Table 3 shows the test data for the ultrasonic sensor HC-HS04 with a distance range of 10 – 100 cm. In measurements with a set distance of 10 cm, the sensor readings show an error of 0.44 cm. The error will continue to increase as the test distance increases. The test shows that the farther away the object is, the greater the difference in distance between the comparison measuring instrument and the sensor. Figure 10 shows a serial monitor for ultrasonic sensor readings. The calculation of the percentage error using equation 3, where x is the ultrasonic sensor distance reading (cm) and y is the distance on the comparison measuring instrument (cm).

$$Error = \frac{x - y}{y} \times 100\% \quad (3)$$

Table 4. Ultrasonic sensor testing with three obstacle

Set Distance (cm)	*Obstacle*			*Error*		
	Wall (cm)	Tree (cm)	Human (cm)	Wall	Tree	Human
10	9.96	9.96	10.73	0%	0%	7%
20	18.79	18.56	19.8	6%	7%	1%
30	29.37	29.94	29.63	2%	0%	1%
40	38.77	39.15	38.56	3%	2%	4%
50	48.45	48,28	47,83	3%	3%	4%
60	58.34	57,7	58,65	3%	4%	2%
70	68.63	68.78	68.12	2%	2%	3%
80	78.22	78.98	76.33	2%	1%	5%
90	87.77	82.28	85.94	2%	9%	5%
100	97.11	96.97	97.73	3%	3%	2%

Table 4 shows the results of ultrasonic sensor testing using three different obstacles, namely walls with a thickness of 14.5 cm, trees with a thickness of 36 cm, and humans. The reason for choosing the three obstacles is because when the visually impaired travel, the three obstacles are the most frequent. The ultrasonic sensor test data shows a fluctuating value. This is because, in each set of distances, the sensor readings have a percentage error that results up and down. The error calculation in this test is carried out using equation 3.

4. Discussion

Smart sticks have been designed and tested a lot. Most of the tools designed are focused on obstacle detection that helps blind people when moving. Sensors used can be ultrasonic or infrared sensors. Meanwhile, the indication of an obstacle is manifested in the form of a buzzer or vibration. Not many tools are equipped with GPS and GSM modules that help monitor the position of blind people or help people with disabilities during emergencies. A blind stick with a GPS tracker feature like this provides an additional function to find out the location of the blind person that can be accessed via a smartphone. In addition, blind people can also press the push button on the blind stick to send a signal of help to the family. This is very helpful for blind people and families of blind people.

5. Conclusion

The constructed tracking stick can help blind people detect obstacles in the front, which help them move around during travelling outside. The tool can help family members find locations of the blind by replying to a specified text message with the coordinates. It also assists blind people to send an emergency message containing their position by pressing a push-button if they forget their way home. The average coordinate position error is 11.89 meters. The percentage error of the ultrasonic sensor fluctuates depending on the distance and type of object in front of the stick.

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