Development of guide stick navigation for blind person using digital compass and global positioning system

Agusutrisno*, R Wiryadinata and M N R Novianto
Department of Electrical Engineering, Faculty of Engineering, Sultan Ageng Tirtayasa University, Jenderal Sudirman.St Km 3, Kotabumi, Purwakarta, Cilegon City, Banten 42435, Indonesia.

*E-mail: agusutrisno.untirta@ac.id

Abstract. The limited use of navigation technology poses a risk to blind person becoming lost, while in a foreign place and causing them to rarely travel. The purpose of this study is to design guiding sticks for blind person by tracking and homing. The position of coordinates and wind direction is processed into information on sound signals and vibrations. The method used in this research is GPS bearing and inverse angle, using compass and ultrasonic sensors. Afterwards, the data output in this system is directional information in the form of sound, besides in the form of an obstacle when in front of the sensor. The test results prove that the GPS bearing method can produce a more stable direction. However, GPS accuracy can decrease when it is blocked by trees and buildings. While the inverse angle method, GPS data is stored on the data logger, which does not require GPS accuracy when determining direction. The angle of the direction is more accurate if the average angle when tracking is not too wide.

1. Introduction
The guiding stick is enough to answer the problem of blind person in terms of being a guide, but has not been able to answer the right technological problems to overcome the blindness of blind person when traveling. Guide system technology has started to be developed in many ways. One example of a navigation system is the use of a Global Positioning System (GPS) tracking unit. Devices that use GPS allow the location of a person to be displayed either on a map or in real-time during the tracking process [1]. Using GPS starts to be combined with SMS (Short Message Service) by sending latitude and longitude coordinates using an SMS reply to the same cell phone number [2]. Application of GPS technology and SMS on guide sticks by comparing the distance of the position of the blind person to their original state with the coordinates sent to the hand phone [3]. Addition of an IR (Infra-Red) sensor to make it easier for blind person to detect various objects [4]. The use of other sensors such as ultrasonic proximity sensors to detect various obstacles and perforated roads around them continues to be developed [5]. Another navigation system that can be used for blind person is to use the Pedestrian Dead Reckoning (PDR) technique. PDR technique is one alternative in indoor positioning that detects steps and estimated steps by using the help of an accelerometer sensor. The accelerometer sensor is used to recognize the user's step pattern [6]. The use of Indonesian Text-to-Speech (TTS) technology that allows computers to interact with humans not only through writing, but verbally with language that is used daily [7]. This research focuses on the navigation system on blind persons guiding sticks who can record the route and return to their original location. This study also adopted the application of a homing reverse tracking system that had previously been used in robotic navigation systems and drones.
2. Methodology
This research designed and made navigation guiding sticks for blind person. The stick design in figure 1 uses a walking stick with a blind person with adjustable height aluminium material and several modules and buttons.

![Figure 1. Guide stick design for blind person navigation.](image1)

The design of guide stick navigation for blind person consist of several blocks including the GY-273 compass sensor (IC HMC5883L), DFP layer mini, GPS Ublox Neo-7M, SD Card Module, motor driver, vibrator and headphones, as shown in figure 2.

![Figure 2. Guide stick navigation block diagram.](image2)

The navigation system can be done only when the GPS has locked at least 3 satellites or after GPS lock. After GPS locks at least 3 satellites, then the system opens a log data file on the data logger module. The number of rows in the log data file is used as a reference in determining the total number of coordinates (total N). After the number of coordinates is known and when the number of coordinates not zero, the navigation system is continued with two methods, namely the GPS bearing method or the inverse angle method.

The coordinates stored in the data logger module are stored in rows, which are then separated (parsed) into coordinate and angular data. The parsing data is used to navigate through each method. Difference in GPS bearing method and inverse angle method is the determination of angles to direct blind person to the track log point. The number of coordinate points continues to decrease 1 if the blind person has reached the track log point. Persons with visual impairments are considered to have arrived at the starting point if the number of coordinates is zero.

The GPS bearing method is the angle produced from the calculation of two known GPS coordinates with ‘Equation (1)’ to ‘Equation (3)’ which is then compared to the angle of the compass sensor in real-time as in figure 3 [14].

\[
X = \cos\theta b \times \sin(\phi b - \phi a) \\
Y = \cos\theta a \times \sin\theta b - \sin\theta a \times \cos\theta b \times \cos(\phi b - \phi a)
\]
\[
\beta = \tan^{-1}\left(\frac{Y}{X}\right)
\]  

(3)

\(\theta_a\) is the current latitude, \(\theta_b\) is the destination latitude, \(\phi_a\) is longitude now, \(\phi_b\) is the Longitude destination, \(\beta\) is the Bearing Angle.

The bearing is compared to the angle obtained from the compass sensor in real-time. The angle value can be obtained by knowing the value of two coordinates (coordinates of the destination and current coordinates). The inverse angle method is the angle obtained from the opposite direction of the stored compass compared to the current compass angle. Opposite the direction of the compass sensor angle that is stored when creating a path, then compared to a compass sensor in real-time. Angles lead in the right direction to determine where blind person walk. The process of determining the intended direction can be done when the comparison of the two angles is known, after which it can be solved by ‘Equation (4)’ through ‘Equation (7)’. The direction illustration for the blind is shown in figure 3.

\begin{align*}
Y &= \cos\theta_a \times \sin\theta_b - P1 = \theta_T - \theta_R \\
P2 &= 360 - \theta_T + \theta_R
\end{align*}

(4)

(5)

When the real-time compass reading angle (\(\theta_R\)) is more than the destination angle (\(\theta_T\)) (\(\theta_R > \theta_T\)) as shown in figure 3 (B) then:

\begin{align*}
P1 &= 360 - \theta_R + \theta_T \\
P2 &= \theta_R - \theta_T
\end{align*}

(6)

(7)

Position angle 1 (P1) compared to position 2 angle (P2), the selected angle is the nearest angle between \(\theta_R\) and \(\theta_T\) so that the smallest angle selected. If P1 < P2 then the direction shown is right, otherwise the direction shown is left. If the angle of reading of the real-time compass (\(\theta_R\)) is still in the tolerance of the destination angle of view (\(\theta_T\)) of 10 degrees as shown in figure 3 (C) the direction shown is straight, which means the blind person does not have to walk diagonally to the right or left. Comparison of GPS coordinates stored with real-time GPS coordinates guide from track log point to reach the end point (homing point).

3. Results and Discussion

3.1. Overall System Testing

Overall system testing aims to determine whether the entire navigation system can work according to the design that has been made from beginning to end. The initial test was carried out when cloudy weather with 80% cloud cover in the UNTIRTA Faculty of Engineering area, that is, with the starting point of the letter U building trip and the end point of the path that is the gate of campus.
Figure 8 is the result of visualization between GPS coordinates when tracking and when homing. The green line is the coordinates of the position when tracking the path. The yellow line shows the results of the coordinates of the position of the GPS bearing method. Retrieval of GPS coordinate data when tracking and homing is carried out every 5 seconds without pause. GPS tolerance to meet track log conditions is a radius of approximately 3 meters and compass tolerance is considered straight is approximately 10 degrees.

The results of GPS coordinates when the GPS bearing method is carried out, there are 2 points of system error. The error is caused by the radius of the track log point that is not reached or exceeded, so the command issued by the system is only left and right. Track log points can be missed because of the inaccuracy of the GPS receiver in receiving coordinates when passing through a tree area. Additional commands are also given to indicate that the track log point is almost over, which is in accordance with figure 8. The right or left attack command is made more specific only if the value of the angle difference in the position of the blind person with the objective angle ranges from 16 to 60 degrees. The ordering system turns left or turns right if the angle difference is more than 60 degrees and less than 160 degrees. The system gives an order to reverse the direction position from blind person to the direction of the destination or if the angle difference is 160 degrees to 180 degrees. The addition of orders is also given if the condition of the blind person has passed the track log that is supposed to be with two choices, the first choice is to make a reverse or second choice by pressing and holding the green button for 5 seconds to pass the current track log point to the next point.

3.2 First Scenario Testing
The first scenario testing is carried out in the Campus environment with a trip point symbolized by the start line and the end of the trip point symbolized by the finish flag. Tests are carried out when cloudy weather with cloud cover 89%, ambient temperature 26 degrees Celsius. Testing includes the three test areas, namely the area around the building, the tree area, and the open area and 4 objects for detecting objects such as (parking signs, sidewalks, cones, and motorbikes). GPS tolerance to meet track log conditions is a radius of approximately 5 meters and compass tolerance is considered straight is approximately 15 °.
Figure 5. Visualization of First Scenario Testing Coordinates.

The test took 29 minutes with details of 8 minutes tracking, 11 minutes testing GPS bearing method and 10 minutes testing Method inverse angle. The coordinates of the tracking and homing testing of the navigation system are then projected on the map as in figure 9. The green line is the coordinates of the position when tracking the path. The yellow line shows the results of the position coordinates of the GPS bearing method against the compass and the blue line is the result of the coordinate position of the method inverse angle. The total distance travelled when tracking the track is 266 meters, the GPS bearing method is 268 meters, and the inverse angle method is 260 meters with a total track log of 52 points. The total distance error in the GPS bearing method is 0.91% and the inverse angle method is 2.03%. Based on figure 9, the coordinates of GPS generated when entering a tree area produce unstable positions compared to when in an open area.

Some objects such as parking signs, road dividers, cones, and stopping motors are also used as objects detected in this test. The point of the object is symbolized as an orange flag on the map. Testing objects is used to determine whether when the entire system is turned on, ultrasonic sensors can detect objects (see table 5).

Table 1. The first scenario object detection.

| No | Objects    | Detection Information |
|----|------------|-----------------------|
| 1  | Parking sign | Not Detected         |
| 2  | Sidewalk   | Detected              |
| 3  | Cone       | Detected              |
| 4  | Motorbike  | Detected              |

The four results of object detection in table 5, 3 of which are able to be detected properly. Parking signs are not detected because the reflection of ultrasonic waves does not bounce perfectly because parking signs that are too small in diameter.

3.3 Second Scenario Testing
Tests are carried out when the weather is sunny with 55% cloud cover and ambient temperature 32 degrees Celsius. The second scenario is carried out in a residential area that has 3 testing areas, namely trees, uphill areas, open and circular areas, and residential areas. Testing the second scenario is shown in figure 10.
The second scenario testing location has three object detection objects symbolized by orange flags, the ramp, sidewalks and parked cars. The test in the second scenario took 38 minutes with details of 11 minutes tracking, 14 minutes testing GPS bearing method and 13 minutes testing Method inverse angle.

GPS tolerance to meet track log conditions is a radius of approximately 5 meters and the compass tolerance is considered straight is approximately 15 degrees. Tests in the second scenario are carried out with ascending and descending lines and requiring blind person to cross the road twice. The total distance travelled when tracking the track is 323 meters, the GPS bearing method is 324 meters, and the inverse angle method is 339 meters with a number of track logs of 60 points. The total distance error overall in the GPS bearing method is 0.15% and the inverse angle method is 4.95%.

Ultrasonic sensors always vibrate or are active as long as blind person find contours of the uphill road. The next example when blind person find a sidewalk, the object can be read when the sensor is facing the sidewalk surface, because the sensor does not read the sidewalk as an object when the object is in a straight line with the blind. The third object is a car parked in a residential area, the car is able to detect its presence before the stick touches the vehicle. Three results of object detection in table 6 are all detected properly.

Table 2. Results of the second scenario object detection.

| No | Objects       | Detection Information |
|----|---------------|-----------------------|
| 1  | Ramp          | Detected              |
| 2  | Sidewalks     | Detected              |
| 3  | Car           | Detected              |

3.4 Third Scenario Testing
Tests are carried out when the weather is cloudy with 87% cloud cover and 29 degrees Celsius ambient temperature. The third scenario is carried out in crowded places such as the town square, this place was chosen to conduct testing in an open place and there are several objects for detecting objects such as sidewalks, stairs, and trees. The third scenario test location has 3 object detection objects symbolized by orange flags as shown in figure 11.
Figure 7. Visualization of third scenario testing coordinates.

The test in the third scenario spent 11 minutes with details of 3 minutes tracking, 4 minutes testing GPS bearing method and 4 minutes testing Method inverse angle. GPS tolerance to meet track log conditions is a radius of approximately 5 meters and the compass tolerance is considered straight is approximately 15 degrees. The total distance travelled when tracking the track is 86 meters, the GPS bearing method is 95 meters, and the inverse angle method is 93 meters with the number of track logs of 18 points. The total distance error in the GPS bearing method is 10.88% and the inverse angle method is 8.69%.

Table 3. Results of the third scenario object detection.

| No | Object     | Detection Information |
|----|------------|------------------------|
| 1  | Sidewalks  | Detected              |
| 2  | Stairs     | Detected              |
| 3  | Tree       | Detected              |

The sidewalk is only detected when the ultrasonic sensor faces the sidewalk surface, otherwise the sensor does not detect that the sidewalk is an object. Trees are successfully detected without being touched first by the guide stick, so that blind person can avoid these objects. Detection of ladder objects is not done entirely by proximity sensors, but still relies on the ability of blind person to feel. The test results on the three objects in table 7 show that all three object objects were successfully detected when the test was carried out.

4. Conclusion
Based on the results of research on the system of navigation systems on guide sticks for blind person using GPS (General Positioning System) and digital compass. The navigation system on guide sticks for blind person persons can be carried out in two methods and capable of issuing voice signals through wired headsets and vibrating signals. Based on the results obtained shows that the percentage of the smallest mileage errors is in scenarios 1 and 2 using the GPS bearing method which produces an error percentage of 0.91% and 0.15%. Testing with the GPS bearing method results in a more stable direction but the GPS accuracy decreases if the travel path area is much blocked by trees and buildings. The inverse angle method stores GPS data on the data logger so it does not require high GPS accuracy to
determine direction. The direction of the goal is more accurate if the average angle when tracking is not too large. The proximity sensor successfully detects 7 objects from a total of 8 objects found in all test scenarios.

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