Navigation assistant for vision impaired people using ultrasonic (sonar vision) and global positioning system (GPS)

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Abstract. People with low vision usually use stick to find their way or to face an obstacle in front of them. However, this detection only can be felt as long as the length of the stick from its handle is as far as the reach of the hand. Seeing this limitation, a set of sonar vision was made using sonar sensor, which equipped as a wristwatch and a buckle of a belt. The sonar vision was designed to detect an obstacle for up to 3 meters away. A hundred low vision people already got the benefit of this system, which 84% of them felt that the sonar vision helped them in the navigation. The new design based on the feedback is presented in this paper, which is equipped with GPS for positioning information.

Keywords: sonar, low vision, blind, obstacle detection, GPS.

1. Introduction
Helping person with disability is one of the noble things that people like to do. Therefore some researchers are trying to invent technologies for person with disability [1] and the elderly [2]. Some technologies for the disabled was invented such as application for hearing disability people based on Android platform [3], Paralympics technology for disability athletes [4], virtual reality to help brain damage rehabilitation [5], assistive technology for cognitive disability [6], technology based on online therapy for mental health [7] and electronic tool for vision impairment people [8]. These innovations do not stop researchers to develop better technology in the future.

The main purpose of this research is to develop an obstacle detection and navigation assistant for people with vision impairment. The idea of this system was to compete the commercialize product of electronic walking stick in the market [9] by making it affordable. The electronic devices that equipped with ultrasonic (sonar vision) was developed in order to complete the present walking stick owned by users.

The first design of the sonar vision was in the form of the buckle of a belt and a bulky wristwatch equipped with ultrasonic sensor and a motor that could vibrate accordingly. The vibration was varied depended on the obstacle distance. The vibration was fast and intense as the obstacle is getting closer to the user. The farthest recorded distance was 3 meters away. The first design was successfully shared to 100 low vision people [10] from Aceh, DKI Jakarta, and Bali as shown in figure 1.a. and figure 1.b. for the first design. From this activity, some feedbacks were collected regarding to the design of the
sonar vision and the result is 84% of the responded felt satisfied with the sonar vision buckle in the belt and 64% of the correspondences responded that the sonar vision wristwatch were too bulky and needed to be minimized. They also suggested that the sonar vision should be waterproof, had a navigation system, had a dim light for others to see, could detect holes in the street, and had a sound feedback instead of vibration feedback to the user. From this feedback, the second design was made and presented in this paper where the details can be seen in the design and implementation section of this paper.

![Figure 1](image1.jpg)

**Figure 1.** (a) The first sonar vision was shared among 100 vision impairment people and (b) its first design.

2. **Design and Implementation**

Figure 2 shows the diagram block of the whole system where the module was consisted of microcontroller (Arduino Nano), ultrasonic sensor, Global Navigation Satellite System (GNSS) module, Global System for Mobile communication (GSM) module, battery charging module, vibrate motor, buzzer, and button. The main feature of the system was to detect obstacles/objects which triggered the vibration according to the distance between user and the objects.
Figure 2. The main block diagram of the system and its flowchart

Figure 3 shows both the flowchart diagram of (a) the whole system and (b) the object detection. In the flowchart diagram of the whole system, there are three sub processes and three interrupt routines that support the system in the flowchart. The first process is initializing the variables, functions, and module which is going to be used. Later, the system will check the battery whether it is fully charged or not. Charging monitoring sub process will be started whenever the battery is empty and will stop the continuity to the next process. Object detection sub process will run when the switch power is ON, and it will also run the GNSS data transfer sub process as long as the other selection in the process is running well.
Figure 3. The flowchart diagram of (a) the whole system and (b) the object detection algorithm.

There are four conditions/patterns that will be felt by user, which defines the distance of the objects. If the distance is less than 50cm the instrument will produce a fast vibration and buzzer at the same time, which can be felt in both the belly and the arm of the user. The other pattern is for a distance between 50cm to 100cm where user will feel a slower vibration than the previous one. The further the distance, the slower the vibration will be felt by the user until no vibration at all if the distance is 300 cm or 3 m from the user. This tool can be used as a walking stick replacement if it is used in indoor area, but it will become the additional tool if it is used in the outdoor area.
Beside the object detection, the new system was completed with GNSS module, which can be seen in figure 4. The GPS system was used in this system in order to help the family to allocate their vision impair relatives who is getting lost in an area. The family can track by using web application and Google Maps as shown in figure 5.

![Flowchart diagram of the GNSS data transfer sub process.](image-url)

**Figure 4.** Flowchart diagram of the GNSS data transfer sub process.
3. Results and Discussion

The mockup of the system can be seen in figure 6 where the new design made it as the handheld tool on top of the walking stick. It is powered by a Li-ion 18650 3.7 Volt battery connected to TP4056 charging module. During testing, the device can run for 8.5 hours for each charging. The charging time is also improved from previous version which only take 100 minutes to fully charge the battery. The tracking system can be seen in figure 7 and there are several parameters tested in order to make

![Flowchart Diagram](image-url)
sure that the new design suitable and comfortably for low vision people. Parameters such as successful rate of obstacles detection, and accuracy of the position detection will be discussed as follows.

Figure 6. The mock-up of new sonar vision which in the form of handheld.

Figure 7. The tracking system view with table of coordinate history dan Google Maps in order to allocate the vision impaired person who uses the sonar vision.

Figure 8 shows the successful rate of objects detection by using HC-SR04 sensor [11] which is used in the sonar vision. The accuracy of detection is 96.25% which vary from one object to the other. Object like jeans given lesser accuracy compared to other objects since cloth does not easily reflect the ultrasound compared to other materials. Therefore, the ultrasonic sensor was changed to LV-MaxSonar-EZ1 [12] which gave more accuracy for any kind of materials as seen in figure 9. This is due to the higher frequency that is used in LV-MaxSonar-EZ1 which is around 42kHz.

For the position accuracy of the person who used sonar vision had a displacement around 10 meters from the actual position. The data were taken by reading the position via Google Map and table compared with the current position in the field. This displacement was mainly from the Google Maps reading and somehow can be tolerate. By this design, a reliable obstacle detection with more compact design and positioning detection can be produced with affordable price ($55) compared to the one sold in the market which is above $250 range [13] [14].
4. Conclusion
An affordable and yet compact sonar vision has been successfully designed and produced with high accuracy for objects detection and position determination. By using LV-MaxSonar-EZ1 sensor, it improves the obstacle detection as far as 3 meters compared to the previous design. A bigger and compact battery system also improves the working hour of the sonar vision up to 8.5 hours without charging. The charging time is also faster than the previous design as fast as 100 minutes to make it fully charged. The displacement between Google Maps and the real position is about 10 meters and this displacement is tolerable. Hopefully, this product can be manufactured and available in the market to help the vision impaired people.
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References

[1] S. Alper, & S. Raharinirina, "Assistive technology and mild disabilities," vol. 21, no. 2, pp. 47-64, 1 March 2006.

[2] D.H. Stefanov, Z. Bien, & W.C. Bang, "The smart house for older persons and persons with physical disabilities: structure, technology arrangements, and perspectives," IEEE transactions on neural systems and rehabilitation engineering, vol. 12, no. 2, pp. 228-250, 2004.

[3] E.E. Abdallah, & E. Fayyoumi, "Assistive Technology for Deaf People Based on Android Platform," Procedia Computer Science, vol. 94, pp. 295-301, 2016.

[4] P. Howe, "Cyborg and Supercrip: The Paralympics Technology and the (Dis)empowerment of Disabled Athletes," Sociology, vol. 45, no. 5, pp. 868-882, 2011.

[5] F.D. Rose, B.M. Brooks, & A.A. Rizzo, "Virtual reality in brain damage rehabilitation," Cyberpsychology & behavior, vol. 8, no. 3, pp. 241-262, 22 June 2005.

[6] E.F. Lopresti, A. Mihailidis, & N. Kirsch, "Assistive technology for cognitive rehabilitation: State of the art," Neuropsychological rehabilitation, vol. 14, no. 1-2, pp. 5-39, 2004.

[7] R Lederman, G Wadley, J Gleeson, S Bendall, & M. Álvarez-Jiménez, "Moderated online social therapy: Designing and evaluating technology for mental health," ACM Transactions on Computer-Human Interaction (TOCHI), vol. 21, no. 1, p. 5, February 2014.

[8] J. Faria, S. Lopes, H. Fernandes, P. Martins, & J. Barroso, "Electronic white cane for blind people navigation assistance," in 2010 World Automation Congress, Kobe, Japan, 2010.

[9] UltraCane, "Ultracane - the safer way to travel," Ultracane, 25 May 2018. [Online]. Available: https://www.ultracane.com/. [Accessed 29 July 2019].

[10] B. University, "Mahasiswa BINUS Ciptakan Sonar Vision Untuk Bantu Tuna Netra," Bina Nusantara, 18 October 2018. [Online]. Available: https://binus.ac.id/2018/10/mahasiswa-binus-ciptakan-sonar-vision-untuk-bantu-tuna-netra/. [Accessed 29 July 2019].

[11] U. Papa, & G. Del Core, "Design of sonar sensor model for safe landing of an UAV," in 2015 IEEE Metrology for Aerospace (MetroAeroSpace), Benevento, Italy, 2015.

[12] R. Abdubrani, & S.S.N. Alhady, "Performance improvement of contactless distance sensors using neural network," in 11th WSEAS international conference on Instrumentation, Measurement, Circuits and Systems, & 12th WSEAS international conference on Robotics, Control and Manufacturing Technology, & 12th WSEAS international conference on Multimedia Systems & Signal Proces, Rovaniem, Finland, 2012.

[13] Maxiaids, "Ray Electronic Mobility Aid for the Blind," MaxiAIDS, [Online]. Available: https://www.maxiaids.com/ray-electronic-mobility-aid-for-the-blind. [Accessed 30 September 2019].

[14] UltraCane, "UltraCane," UltraCane, [Online]. Available: https://www.ultracane.com/ultracanecat/ultracane. [Accessed 30 September 2019].