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Smart belt for the visually impaired to detect obstacles and track position

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ABSTRACT

Mobility remains a significant challenge for individuals with visual impairments due to the difficulty in detecting obstacles around them. This study aims to design and develop a Smart Belt to assist visually impaired users by detecting obstacles and tracking their location in real time. The Smart Belt is equipped with a VL53L0X LiDAR sensor to detect frontal obstacles and a NEO-6MV2 GPS module for location tracking. Data collected from the sensors is processed by an ESP32 microcontroller and delivered to the user via a Telegram bot as notifications. Testing results indicate that the device is capable of accurately detecting obstacles and providing vibration alerts, while also successfully transmitting location coordinates to Telegram with satisfactory accuracy. This innovation is expected to enhance the independence and safety of visually impaired individuals in their daily activities.

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1. INTRODUCTION

Visual impairment affects millions of people worldwide and is a serious barrier to their mobility and independence in carrying out daily activities. According to the World Health Organization (WHO), approximately 285 million people suffer from visual impairment, with approximately 39 million people experiencing total blindness [1]. Conventional mobility aids such as white canes have limitations, especially in detecting overhead obstacles such as tree branches or signs [2].

Technological advances have opened up new opportunities to improve the mobility of blind individuals in carrying out activities. LiDAR (Light Detection and Ranging) and GPS (Global Positioning System) technologies offer real-time obstacle detection and user location tracking [3]. These technologies not only increase environmental awareness but also provide peace of mind for users and their families [4]. Many studies have explored sensor-based navigation aids for the blind. Devices such as smart canes and electronic glasses often use ultrasonic, infrared, or computer vision technologies [5]. However, many of these devices still struggle with real-time processing, accuracy, and ease of use. In addition, high costs are a barrier to adoption.

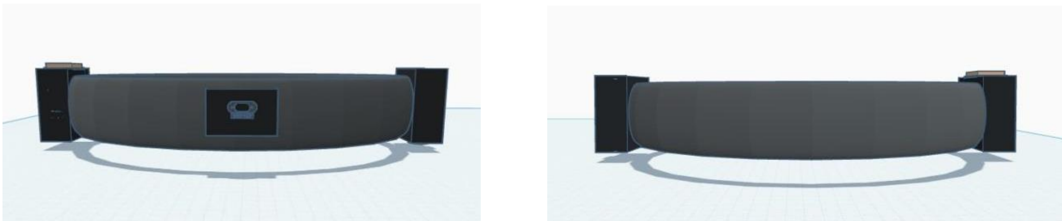
This research proposes a Smart Belt that integrates LiDAR and GPS technologies as a navigation solution for visually impaired users [6]. The device detects surrounding obstacles and transmits real-time location data to caregivers via the Telegram platform [7]. It is also equipped with vibration motors to provide tactile feedback when obstacles are detected [8]. The objective of this study is to design and develop a Smart Belt capable of accurately detecting obstacles and tracking user location [9]. Furthermore, the study evaluates the system’s accuracy, usability, and overall performance, aiming to present a practical and affordable assistive solution to enhance user autonomy and safety [10].

2. METHOD

This research involved hardware and software development for the Smart Belt. The hardware includes a VL53L0X LiDAR sensor for obstacle detection, a NEO-6MV2 GPS module for location tracking, an ESP32 microcontroller as the system's core, and vibration motors for alerts [11]-[12]. The software was built using the Arduino IDE, with data communication handled through the Telegram Bot API for real-time notifications [13]. Two main test phases were conducted: 1) LiDAR sensor testing for measuring detection accuracy of various obstacles under different lighting conditions, 2) GPS module testing for evaluating location accuracy in different environments to verify real-time position tracking. Figure 1 shows the diagram block of the proposed system.

Figure 1. Diagram block of proposed system

This block diagram illustrates an assistive system for the visually impaired based on the ESP32, which integrates a LiDAR sensor for obstacle detection and a NEO-6MV2 GPS module for location tracking [14]. Data from the LiDAR sensor is processed by the ESP32 to activate a vibration motor as a warning when an obstacle is detected in front of the user [15]. Additionally, the ESP32 transmits GPS location information to Telegram, allowing family members or caregivers to monitor the user's position in real time. This system is designed to enhance the mobility and safety of visually impaired individuals by providing haptic feedback along with location tracking features [16]. Figure 2 shows the device design.



(a) (b)

Figure 2. Device design, a)Front view, b)Rear view

The working principle of the Smart Belt automation system for the visually impaired, based on the ESP32 microcontroller, is to serve as the main processing unit that manages and controls the obstacle detection and position tracking processes [17]. The VL53L0X LiDAR sensor is used to measure and detect obstacles around the user, while the NEO-6MV2 GPS module functions to determine the user's location in real time [18]. The ESP32 controls the vibration motor, which provides haptic feedback when an obstacle is detected in front of the user [19]. Location data and notifications are sent to the user or caregiver via a Telegram bot to enhance safety. Overall, the system integrates both hardware and software to automate navigation for visually impaired individuals, with the ESP32 serving as the central controller [20]. Figure 3 shows the control circuit of the proposed system

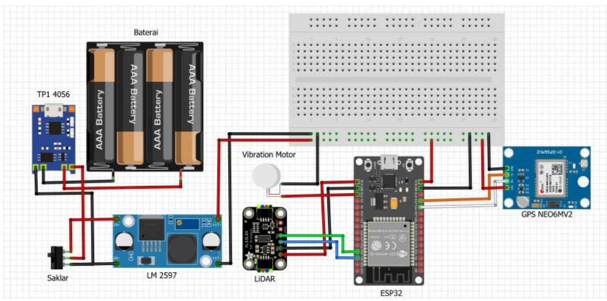


Figure 3. Control circuit of the proposed system

3. RESULTS AND DISCUSSION

Figure 4 shows the devices. Tests on the VL53L0X LiDAR sensor involved placing obstacles at varying distances and conditions to assess its accuracy. Results showed that the sensor could detect objects between 100 cm and 200 cm with high precision. When an object was within a defined threshold, the ESP32 activated the vibration motor to alert the user in real time. Figure 5 shows the LiDaR test results.

(a)

(b)

Figure 4. The results of the device, a) From the front, b) From the back

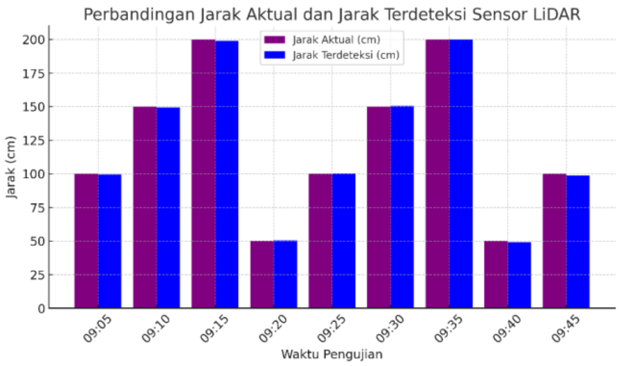


Figure 5. The LiDAR test results

The NEO-6M GPS is a satellite signal receiver module used to determine geographic location with a high degree of accuracy. It operates by receiving signals from GPS satellites to identify positions in the form of latitude and longitude coordinates [21]. The NEO-6M GPS features an external antenna to enhance signal reception and is equipped with EEPROM for storing configurations permanently. This module operates at a voltage range of 3.3V to 5V and uses UART serial communication with an adjustable baud rate [22]-[23]. In this study, the NEO-6M GPS is used to determine the user's location in real time, which can then be transmitted via communication platforms such as a Telegram bot [24]. The accuracy of the GPS data is tested by comparing the received coordinates under various environmental conditions, such as indoors, outdoors, and during clear or cloudy weather [25]. Figure 6 shows the NEO-6M GPS test results.

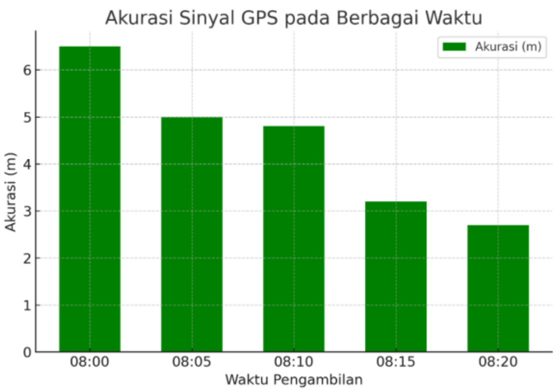


Figure 6. NEO-6M GPS test results

The results of the Telegram bot test show that the system can send real-time location data to the user. The test was conducted by sending the /location command through the Telegram bot connected to the device. In some of the initial trials, the system displayed the message "GPS location not available," indicating that the GPS module was still in the process of acquiring a signal or had not yet obtained valid coordinates. After a while, the system successfully sent the current location with accurate latitude and longitude in the format, along with a Google Maps link to facilitate navigation. These results indicate that the Telegram bot functions well in providing user location information, although there is a slight delay in obtaining the GPS data. Figure 7 shows the telegram display.

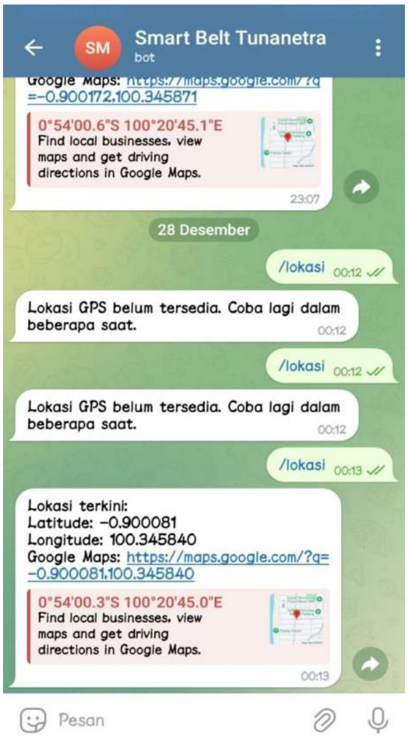


Figure 7. Telegram display.

The results of the test for the assistive device for the visually impaired show that the system functions well in detecting distance using the LiDAR sensor, providing feedback through a vibrating motor, and determining the user's location with the NEO-6M GPS module. When the detected distance is between 100 cm and 200 cm, the vibrating motor is activated as a warning. However, if the distance is less than 100 cm or greater than 200 cm, the vibrating motor remains inactive. The GPS module successfully provided location coordinates with good accuracy, with the signal status remaining stable throughout the testing. Additionally, the notifications through the Telegram bot worked well, ensuring that any obtained data could be sent and monitored in real-time. With these results, the developed device can assist the visually impaired in navigating more safely and efficiently. Tabel 1 ilustrate the overall test results of the device.

Tabel 1. The overall test results of the device.

No	Time	LiDAR Distance (cm)	Vibrating motor	Latitude	Longitude	GPS (m)	State	Telegram	Information
1	01-02-2025 09:05	100	Active	-0.892636	100.345673	6.5	Accurate	Accepted	Succeed
2	01-02-2025 09:10	150	Active	-0.892584	100.345643	5.0	Accurate	Accepted	Succeed
3	01-02-2025 09:15	200	No Active	-0.892623	100.345641	4.8	Accurate	Accepted	Succeed
4	01-02-2025 09:20	50	No Active	-0.892637	100.345650	3.2	Accurate	Accepted	Succeed
5	01-02-2025 09:25	100	Active	-0.892623	100.345649	2.7	Accurate	Accepted	Succeed

4. CONCLUSION

This research successfully developed a Smart Belt that can assist the visually impaired in detecting obstacles and tracking their position in real-time. The developed system utilizes the VL53L0X LiDAR sensor and the NEO-6MV2 GPS module, controlled by an ESP32, with testing results showing good detection accuracy. With the notification feature via Telegram, this device can enhance the safety and independence of users in their activities. In the future, this research can be further developed by improving battery life and integrating artificial intelligence systems to enhance obstacle detection accuracy.

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