# *LiDAR-based Technology for Mapping and Object Detection of a Raspberry Pi-based Intelligent Walking Stick*


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***Abstract*– The mobility of visually impaired individuals has always been a concern of society as it is a challenge for them to go from one place to another especially if they are not yet familiar with the area they move around. The LiDAR-based Technology for Mapping and Object Detection, integrated into a Raspberry Pi-based Intelligent Walking Stick, significantly enhances the mobility and independence of visually impaired individuals. By utilizing the Simultaneous Localization and Mapping (SLAM) algorithm, the device is capable of mapping its surroundings and accurately localizing itself within these maps. This is particularly beneficial for users at the Philippine National School for the Blind (PNSB). The walking stick's system allows visually impaired users to interact with it through voice input, enabling them to provide their destination and receive navigation information for effective guidance. Additionally, the integration of obstacle detection and avoidance feature ensures the user's safety while navigating. This innovative device is lightweight, portable, and highly accurate, making it an accessible and practical solution for enhancing the independence of visually impaired individuals.**



***Keywords----- LiDAR-based technology, simultaneous localization and mapping (SLAM), visually impaired, object detection, mobility aid (keywords)***


## I. INTRODUCTION

Mobility poses significant challenges for visually impaired individuals, as they encounter numerous difficulties in their daily activities. According to the World Health Organization (WHO), at least 2.2 billion people globally have near or distance vision impairments [1]. Visually impaired individuals often rely on walking sticks as guides to assist them in navigating their surroundings. As autonomous driving, robot navigation, object detection, and intelligent hardware continue to progress, a novel solution has arisen to address the mobility challenges faced by the visually impaired. The stick is interfaced with a technology, consisting of a camera, voice recorder, speaker, and Raspberry Pi, for making it intelligent [2].

The traditional white cane consists of a basic cane body and handle, offering a singular function and limited detection range [3]. However, in recent years, advancements in autonomous driving, robot navigation, object detection, and intelligent hardware have paved the way for innovative solutions to the mobility challenges faced by the visually impaired [3]. More recently, LiDAR sensors are being used to perform indoor and outdoor navigation [3]. Light Detection and Ranging (LiDAR) is a remote sensing technology that uses lasers to figure out distances and make detailed maps of places. By projecting laser light onto a target and examining the light that reflects, the LiDAR system can generate detailed three-dimensional maps of the targeted area [4]. By utilizing LiDAR-based technology for mapping and object detection in Raspberry Pi-based intelligent walking sticks, they serve as invaluable aids in guiding visually impaired individuals, enhancing their mobility, and helping to prevent accidents. With the assistance of these devices, users can navigate unfamiliar environments independently, without relying on others for support.

## BACKGROUND OF THE STUDY

LiDAR (Light Detection and Ranging) technology has emerged as a pivotal tool in various fields, ranging from autonomous vehicles to environmental monitoring [5]. Its ability to precisely measure distances by emitting laser pulses and analyzing the reflected light has made it indispensable in mapping terrains and detecting objects with high accuracy [5]. In recent years, there has been a growing interest in leveraging LiDAR to enhance the capabilities of assistive devices, particularly for the visually impaired [6]. The integration of LiDAR with Raspberry Pi-based intelligent walking sticks presents a promising avenue for empowering individuals with visual impairments to navigate their surroundings more effectively [7].

Raspberry Pi, a credit-card-sized single-board computer, has gained popularity for its versatility and affordability, making it an ideal platform for developing assistive technologies [8]. By integrating LiDAR technology with a Raspberry Pi-based walking stick, researchers aim to create a comprehensive solution that not only aids in mapping the environment but also detects obstacles in real-time [7]. Such a system could provide users with auditory or haptic feedback, enabling them to safely maneuver through crowded or unfamiliar spaces [6]. Additionally, the compact and portable nature of Raspberry Pi devices ensures that the intelligent walking stick remains lightweight and easily manageable for users [7]. By exploring the integration of LiDAR with Raspberry Pi, this study endeavors to contribute to the advancement of assistive technologies for the visually impaired, promoting greater independence and accessibility in everyday life [8].

## OBJECTIVES

The objective of this journal is to utilize a LiDAR sensor in a Raspberry Pi-based Intelligent Walking Stick to:

- Develop a program that will utilize the device to generate precise and accurate mapping capabilities of a target area.
- Develop real-time object detection to enhance the efficiency of mobility and avoid collisions.

This research journal's objectives were to integrate the capabilities of LiDAR technology into the development of a Raspberry Pi-based intelligent walking stick to aid the mobility of visually impaired individuals. Using a LiDAR sensor, the researchers developed a program that generated a precise and accurate mapping of a target area. This mapped area served as a database for the mobility of the intelligent walking stick as it wandered through the mapped environment.

Along with the mapping capabilities, the researchers developed a real-time object detection feature that enhanced the efficiency of mobility of visually impaired individuals. Through the sensor, the device was able to observe real-time movements or changes through the mapped environment which helped to avoid and prevent collisions with such objects. Also, using the database of the mapped area, the device was able to compare changes in the structure of the area. With these features, the mobility of the visually impaired individuals was ensured with efficiency and independence.

## II. RELATED LITERATURE

The study's proponent seeks to design and develop a walking stick that empowers visually impaired individuals to move about with greater independence, ultimately boosting their confidence and sense of autonomy. This initiative's main goal is to provide users with the ability to detect obstacles and make informed decisions to navigate around them safely. Such a walking stick has the potential to significantly enhance the mobility and quality of life for individuals with visual impairments.

A solution that integrates LiDAR-based technology for mapping and object detection, aimed at providing improved navigation assistance, particularly for individuals with visual impairments. A study by F. Felix, Development of Navigation System for Blind People based on Light Detection and Ranging Technology (LiDAR). This system utilizes a LiDAR sensor to detect nearby objects in the user's path. When an obstacle is detected, the sensor triggers a buzzer, alerting the user with sound signals to indicate that something is in front of them. [9]

The device's effectiveness came from various research studies, including the study of M. Anandan, M. Manikandan, and T. Karthick. It is an Advanced Indoor and Outdoor Navigation System for Blind People Using Raspberry Pi, where the system consists of two main modules: static object detection and dynamic obstacle handling the visual information is then converted into audio information using a Raspberry Pi setup. [10] The Raspberry Pi has GPIO pins which allow it to link up with various sensors and hardware components, which is crucial for a navigation system that needs to interact with sensors or other devices to detect objects and navigate effectively.

A study by M. Ferreira served as an inspiration for this study. The study focuses on developing a navigation system for an inexpensive mobile robot. The robot utilizes Beckhoff motors controlled by Twin CAT 3 software on an industrial PC for movement, while a Raspberry Pi manages environmental sensing, localization, and movement planning using ROS, with the support of an Okdo Lidar LD06 module designed for Raspberry Pi and ROS integration, enabling tasks such as data analysis from the Lidar and camera, receiving movement feedback, executing navigation plans, and adjusting speed. [11] In addition, the study of Liu et al, introduced a user-friendly assistive system that utilizes a solid-state LiDAR sensor for comprehensive indoor detection through 3D point cloud instance segmentation, followed by post-processing to eliminate outliers and project points onto a 2D map representation, ultimately facilitating intuitive interaction with users through acoustic feedback. [12] This system should enable the robot to autonomously navigate its surroundings and evade obstacles which is also incorporated into the study with the use of Raspberry Pi and Okdo Lidar.

As technology advances, innovations emerge, particularly in the realm of intelligent walking sticks, which are increasingly essential for individuals with visual impairments. For Bala et al., no single feature can fully support visually impaired individuals, but having access to all features can be inconvenient due to the need to carry multiple devices and the necessity of understanding how to use the technology. [13]

## III. METHODOLOGY

As the LiDAR-based device is intended for real-time navigation, throughout the navigation process, the device utilizes sensors to detect and identify any obstacles or obstructions in the surroundings. Also, through the sensor, the device was able to guide the user to the desired destination using the mapping of the area of the device. To improve user interaction, the device included haptic feedback to notify users when it's turned on or off. It utilizes speech-to-text inputs to process user commands based on spoken input, enhancing accessibility. Additionally, the device offers audio feedback that will guide them through wearable devices like earphones, delivering spoken directions to assist users in navigating to their desired destination.

### A. Design of the Device

The fabrication of the device underwent a few conceptualizations and prototypes before the final design of the device was developed as shown in the figures below.

Draft Design

***Fig. 1.*** *Concept and Actual 3D Design of the Device.*

Prototypes

***Fig. 2.*** *1st Prototype made of Cardboard Box.*

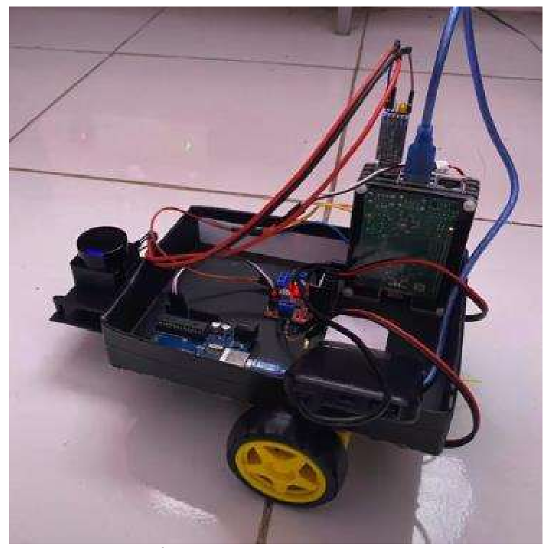

***Fig. 3.*** *2nd Prototype made of Cardboard.*

***Fig. 4*** *3D Printed Chassis of the Device.*

*Fig. 5 Final Design of the Device.*

Previous iterations and existing prototypes faced several challenges, primarily regarding the weight of the components inside the chassis. Efforts were made to address this issue by making a robust design of the device that will support the weight of components and is not too hard for the motors to carry, as evident in the provided images. The proponents continued to refine the design until reaching an optimal size that maximizes efficiency for users. The final design device, shown in Figure 5, represents the best version developed by the proponents to address the previous problems in past prototypes.

B. Functionality

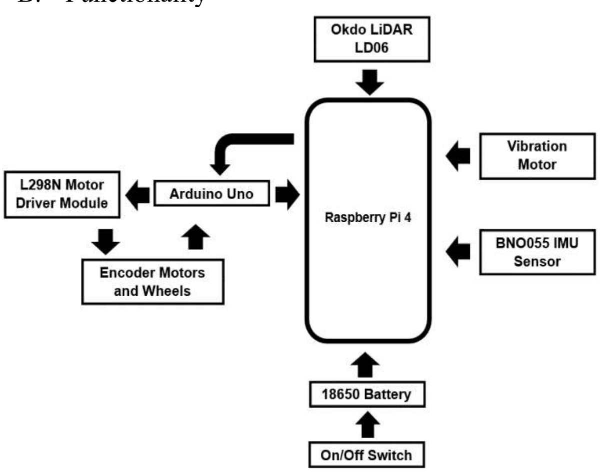


***Fig. 6.** Block Diagram of the System.*

Figure 6 illustrates the system block diagram of the system. The central controller for the device is the Raspberry Pi 4, which serves as the primary control unit that will execute the overall process of the system. Connected to the Raspberry Pi 4 are various essential components, including the Okdo LiDAR sensor which is necessary for real-time object detection for obstacle avoidance and for mapping the environment.

Also, components such as Arduino Uno, IMU sensor, and Vibration Motor are connected for the additional features of the device. The L298N Motor Driver, Encoder Motor, and Arduino Uno are also linked together, creating a system where these parts can work together smoothly.

## IV. TESTING AND RESULTS

Upon arriving at the deployment site, the initialization of the device was started. There were two trials that were made for mapping using Hector SLAM to ensure the accuracy of the static mapping.

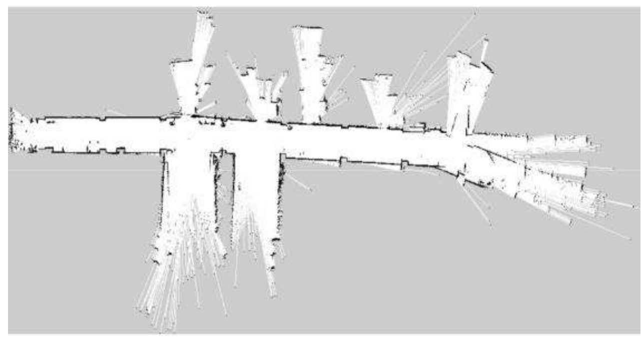

***Fig.** 7 Mapping of the first half of the PNSB Administration Building using Hector SLAM.*

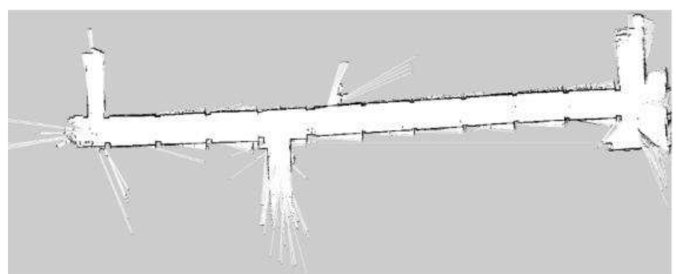

***Fig. 8** Mapping of the second half of the PNSB Administration Building using Hector SLAM.*

The mapping of the first half of the PNSB Administration Building using Hector SLAM. The pixel gray map generated has a dimension of 941 x 442 pixels which covers the left outermost part of the building until the entrance of the first comfort room. The mapped environment is 0.85 meters since the LiDAR is mounted 0.85 meters above the ground. All the obstacles and variables presented above and below 0.85 meters are not registered in the generated map. However, there is an error in the mapping of the as can be seen in the rightmost part of the pixel gray map. This is due to the sudden change in movement of the device in the process of mapping.

The mapping of the second half of the PNSB Administration Building using Hector SLAM. The pixel gray map generated has a dimension of 1173 x 442 pixels which covers the first stair until the exit connecting to the entrance hallway to the PNSB dormitory.

***Fig. 9*** *Actual Testing of Device by a visually impaired individual.*

The actual testing of the device by a visually impaired individual of PNSB started from the rightmost part of the vicinity, the user was prompted to navigate through the clinic room of the PNSB Administration Building.

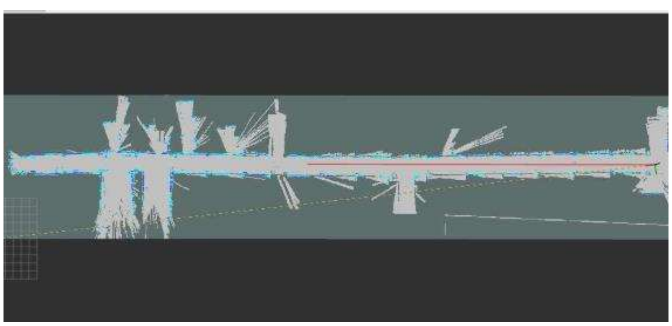

***Fig. 9*** *Localization and Path Planning of Device for Actual Testing.*

The localization and path planned by the device were based on the current situation of the environment and the pre-determined map. The colored dots and lines represent the point cloud data, which is obtained from LiDAR LD06. This shows the environment around the robot and the user. The long red line represents the path planned by the device which is from the rightmost part of the vicinity going to the clinic room.

## V. CONCLUSION

After the testing of the device, evaluations and consultations were made to see if the objectives of this paper were achieved. Based on the evaluation of the device together with the data gathered on the tests that were conducted, the researchers were able to conclude the following:

- The integration of the Okdo LiDAR LD06 sensor into the Raspberry Pi-based walking stick successfully enabled accurate real-time detection of obstacles. The system effectively used point cloud data to prevent potential collisions, significantly enhancing user safety.
- The LiDAR-based SLAM technology was successfully integrated into the device, creating detailed and accurate real-time maps for both indoor and outdoor settings. This capability allowed the device to navigate environments autonomously, maintaining accurate obstacle detection and navigation.

This research journal on LiDAR-based Technology for Mapping and Object Detection of a Raspberry Pi-based Intelligent Walking Stick achieved all its goals, demonstrating the impressive potential of innovating technology in creating helpful devices for visually impaired people. The project successfully combined real-time obstacle detection, speech-to-text navigation, and precise mapping using LiDAR-based SLAM technology. These features made the walking stick reliable, easy to use, and highly effective. As a result, this innovative device greatly improves the mobility and independence of visually impaired individuals, giving them more freedom and ensuring their safety as they navigate their daily environments. This study highlights how advanced technology can make a real difference in people's lives, offering new opportunities for independence and confidence.

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