CHAPTER I

INTRODUCTION

This chapter provides a brief overview of the research. Consist of six sections; the explanation starts with background, problem identification and objective, scope of work, research methodology, and structure of this thesis. More detailed explanation will be later in the next chapter.

1.1 Background

Robotics has emerged as one of the most rapidly advancing research fields in recent years. With the fast-paced technological progress, autonomous robots are now capable of performing increasingly complex tasks, such as environmental exploration, goods transportation, and even social interaction. One of the main challenges in developing autonomous robots is the ability to navigate and operate in dynamic and unstructured environments, where the role of efficient sensors and computing systems becomes critical [1].

Disaster response is a complex and multifaceted endeavor that involves coordinated efforts to save lives, protect property, and restore essential services in the aftermath of a catastrophic event. It encompasses a wide range of activities, including search and rescue, medical care, shelter provision, and infrastructure repair [30]. Effective disaster response requires rapid mobilization of resources, efficient coordination among various agencies, and accurate assessment of the situation [31].

However, disaster response is fraught with challenges. These challenges often include limited visibility into the affected area, difficulty in accessing and sharing information, and the rapid deterioration of critical infrastructure. The dynamic and unpredictable nature of disasters further compounds these problems, making it difficult to develop and implement effective response strategies. Additionally, the sheer scale of many disasters can overwhelm available resources and personnel, leading to delays in critical response activities [31].

LiDAR (Light Detection and Ranging) technology has long been recognized as one of the best sensory solutions for autonomous robots, particularly in terms of environmental mapping and obstacle avoidance. Lidar utilizes laser light to measure the distance to surrounding objects, producing data that can be used to create two-dimensional (2D) or three-dimensional (3D) maps of the robot's environment [2] [3]. The LiDAR A1, as one of the widely-used Lidar products in robotics, offers highly accurate and detailed data, enabling robots to map environments with high precision [4].

In addition to its mapping capabilities, LiDAR also plays a key role in the implementation of SLAM Algorithms (Simultaneous Localization and Mapping). SLAM enables robots to determine their position within the map being built, which serves as the foundation for autonomous navigation [5]. In this project, the Lidar A1 is utilized to support SLAM, which is executed on a Raspberry Pi 4B as the computational hub. The Raspberry Pi 4B is selected due to its capability to run complex algorithms in real-time and its wide ecosystem of software support, such as ROS (Robot Operating System), which facilitates integration with various sensors and actuators [6].

The Raspberry Pi 4B, equipped with a quad-core processor and sufficient RAM, is an ideal computational platform for robotics applications. In the context of this project, the Raspberry Pi 4B is responsible not only for executing SLAM algorithms but also for managing communication between sensors and actuators through various protocols such as UART, I2C, or SPI [7]. Its combination of strong computational capabilities and flexibility in communication makes the Raspberry Pi 4B an excellent choice for integrating the entire robotic system [8].

The Arduino Mega serves as the microcontroller in this project, specifically for controlling the MG513 motors via the L298N motor driver. The Arduino Mega is chosen for its numerous input/output pins, allowing detailed control over various actuators on the robot [9]. The MG513 motors, equipped with encoders, enable precise measurement of speed and position, which is crucial for ensuring the robot's movement aligns with the navigation commands issued by the Raspberry Pi [10].

The L298N Motor Driver plays a vital role in controlling the DC motors of the robot. Acting as an H-bridge, this driver allows the motors to rotate in both directions and adjust their speed through Pulse Width Modulation (PWM) signals sent by the Arduino Mega [11]. Using an appropriate motor driver is essential to ensure that the robot's movement can be efficiently controlled and is responsive to changes in environmental conditions [12].

The robot employs a tank chassis, which provides stability and the capability to traverse challenging terrains. The tank chassis enables a more even weight distribution and improves grip on various surfaces, making it ideal for both outdoor and indoor applications with varying terrain conditions [13]. This design also supports high maneuverability, which is necessary for navigating environments filled with obstacles [14].

The integration of sensors, actuators, and computational systems in this robot requires efficient communication and synchronization [15]. The Raspberry Pi 4B and Arduino Mega communicate via reliable protocols to ensure that data from the LiDAR sensor is processed in a timely manner and translated into accurate movements by the motors [16]. This synchronization is crucial to avoid delays or errors in navigation, which could result in the robot failing to accomplish its tasks [17].

By leveraging existing technologies, this project aims to develop a robotic system capable of autonomous navigation in complex environments. The application of SLAM algorithms supported by the LiDAR A1 and precise motor control through the Arduino Mega is expected to result in a robot that not only recognizes its surroundings but also dynamically responds to them [18]. This project strives to provide innovative solutions for the development of autonomous robots that can operate effectively under diverse environmental conditions [19].

This research is expected to make significant contributions to the advancement of autonomous robotics, particularly in terms of navigation and environmental mapping. By combining various sensing and computational technologies into a single robotic platform, this project aims to address the challenges of creating robots capable of operating independently with high accuracy and efficiency [20]. Moreover, the results of this research are also anticipated to serve as a foundation for further development in robotic applications across various fields, including industry, military, and exploration.

This research is organized into five chapters to discuss this research comprehensively. Chapter 1 is the introduction, explaining the background, problem identification, objective, scope of work, and research methodology. Chapter 2 discusses the theoretical foundation, presenting theories related to the robot mobile, mapping and algorithm. Chapter 3 outlines the methodology, describing the system model, wiring diagram, ROS configuration, LiDAR cofiguration, and algorithm for object detection. Chapter 4 presents the results, presenting the experimental findings and analysis. Finally, Chapter 5 contains conclusions and suggestions for future research.

1.2 Problem Identification

In various previous studies [5] [6] [7] [8] [9], Utilizing Lidar A1 data for real time environmental mapping involves the implementation of (SLAM) Simultaneous Localization and Mapping algorithms, which enable the robot to construct maps of unknown environments while simultaneously determining its position within them. The LiDAR A1 sensor provides precise distance measurements that can be processed to identify obstacles and guide the robot's navigation. This capability is critical for ensuring safe operation in dynamic and unstructured environments, allowing the robot to make informed decisions and avoid collisions in real-time.

The integration of Gmapping, RANSAC, and DBSCAN in LiDAR-based mapping is essential to address key challenges in SLAM, noise filtering, and object classification. Gmapping is used to handle odometry drift, scan matching errors, and loop closure issues, which cause map distortions due to sensor inaccuracies and environmental changes. However, raw LiDAR data contains outliers from reflective surfaces and noise, affecting wall detection and object boundaries, which RANSAC mitigates by filtering these inaccuracies. Even after outlier removal, differentiating between static (debris) and dynamic (human) objects remains difficult due to density variations in point cloud data. DBSCAN is implemented to classify objects based on spatial clustering, improving environmental awareness. Despite its effectiveness, DBSCAN is highly sensitive to parameter tuning, requiring adaptive adjustments for optimal clustering in varying conditions.

1.3 Objectives

This thesis assumes the following objectives:

1. To develop mapping integrated with the SLAM system using the Gmapping algorithm from LiDAR data, focusing on identifying the room layout around the robot.
2. LiDAR data is utilized to differentiate objects surrounding the robot, such as debris or walls.
3. DBSCAN and RANSAC are integrated into the system to enhance mapping accuracy. The DBSCAN algorithm is used to classify between debris and non debris, while the RANSAC algorithm is applied to remove outliers in wall data, reducing noise that could affect mapping precision.
4. This research is conducted in real time in both indoor and outdoor environments. In outdoor settings, testing is limited to a radius of approximately 3–5 meters under adequate lighting conditions (not dark), allowing the robot to navigate the area and explore its surroundings.

1.4 Scope of Work

To maintain focus and prevent the experiment from becoming overly extensive, this thesis limits the scope of work as follows:

1. The robot features a metal tank-shaped body.
2. The LiDAR A1 sensor is used to provide precise and reliable environmental sensing of the surroundings.
3. Raspberry Pi 4B serves as the minicomputer.
4. Arduino Mega 2560 acts as the microcontroller, connecting the Raspberry Pi 4B to two MG513 motors controlled by an L298N motor driver.
5. The Gmapping algorithm is employed for environment mapping.

6. The DBSCAN algorithm is utilized to classify detected objects as debris or walls.
7. The RANSAC algorithm is implemented to reduce noise and outliers in wall data within the environment.
8. The distance between the robot and the user is limited to approximately 3–5 meters to maintain a stable connection for displaying mapping results.
9. The map produced during this experiment is constrained to elevations between 0 and 30 cm from the ground surface.
10. The map displayed in RViz is confined to an area with a radius of approximately up to 5 meters from the LiDAR's position.

1.5 Research Methodology

This thesis is divided into 3 work packages (WP) to produce high quality results.

• Study of Literature

This Literature Study Searches were carried out on local and foreign papers, textbooks related to mobile robot, LiDAR, SLAM, Gmapping algorithm, DBSCAN algorithm, and RANSAC algorithm.

• System design and mapping

Mobile robot design, design of a mobile robot that will be used for search and detection missions by considering the size, mobility and reliability of the robot. Simulations in the software are carried out to obtain prediction values for mapping and localization. Apply the DBSCAN algorithm to cluster LiDAR data and classify objects into walls or debris. The RANSAC algorithm to filter noise and improve the accuracy of wall mapping.

• Testing and Analysis

This final project tests the system and analyzes the data obtained from the testing process to determine the performance results produced by the system. Display mapping and detection results in real time, testing the system under various conditions (indoor and outdoor) to measure mapping accuracy and classification.