CHAPTER 1
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. A more detailed explanation will be later in the next chapter.

1.1 Background

The use of Light Detection and Ranging (LiDAR) in the robotics industry has become an important point in the development of automation technology. LiDAR, as an advanced sensor that uses the Time of Flight (TOF) principle, gives robots the ability to detect and respond to their surrounding environment with high precision. LiDAR opens up opportunities to improve robot navigation[4], perception[5] and safety[6]. LiDAR's ability to generate three-dimensional(3D) data quickly and accurately enables robots to map their working environment[7], avoid obstacles[8], and interact with surrounding objects[9]. The advantage of LiDAR is not only in its ability to operate in various light conditions, but also in supporting complex data processing systems such as Simultaneous Localisation and Mapping (SLAM)[10]. The integration of LiDAR in robots paves the way for improved efficiency, precision and safety in a wide range of industrial applications, from manufacturing to logistics.

The use of LiDAR technology in research and industry generally involves the use of devices capable of rotating 360 degrees or as the manufacturer specifies. Unfortunately, in its implementation, the existing LiDAR rotation is continuous and cannot be stopped at a certain position. Most commercial LiDAR drive motors are factory defaulted without change such as SICK SLAMTEC RPLIDAR, YDLIDARX4, 2D LiDAR, and several others. This limitation becomes significant when the LiDAR application only requires mapping of a specific part, resulting in inefficient use of time. Therefore, this research aims to develop a LiDAR with non-continuous rotation capability, enabling mapping of specific objects without the need to perform a full rotation. This research was initiated by the need to improve the efficiency of LiDAR data capture, especially in the context of using it on a specific area. To overcome this issue, this research will design a 3D LiDAR by adapting a scanning method called ”electromechanical scanning”. Several studies [11–13] adopted the electromechanical scanning method on 2D commercial lidars to acquire 3D environment maps. Therefore, the electromechanical scanning method in this study will be used on single point LiDAR to obtain a 3D environment map. The use of a single LiDAR is intended so that the motor used as the LiDAR rotating axis can be controlled as needed.

LiDAR acquires data from all angles of view (according to its specifications), including the surroundings of the object that it is not desirable to measure. This issue can be resolved by filtering out unnecessary points, as done in existing research studies. For instance, Point Cloud data (PCD) filtration, as applied in the research by Shuwu Wang et al.[14]. They effectively eliminated points that were either too distant or too near to the target. By utilizing the PCD approach on the LiDAR scan results, data points from the environment around the object that do not need to be measured can be removed. Another research conducted by Jaroslav et al. utilised a readily accessible filtering technique that relied on geometric principles. This involved eliminating data points that were deemed to be too distant from the surface, as determined by a predetermined threshold[15]. Mustafa and Ismail employed four distinct filters, specifically CSF (Cloth Simulation Filtering), LasGround, MCC (Multiscale Curvature Classification), and fusion, to isolate ground on various types of terrain, including densely vegetated landscapes, level surfaces, and rugged and intricate landscapes. The study obtained a 93% accurate classification rate by employing the CSF technique. In addition, there are other research works that employ a Convolutional Neural Network (CNN) based methodology to comprehensively analyse and filter out the impact of adverse weather conditions in point cloud data[16]. Regrettably, the utilization of various filtering methods requires further processing of the LiDAR scan data, which requires additional computation beyond the existing algorithm. As a solution, in this research, an algorithm called edge tracking algorithm is developed. The purpose of this algorithm is to map objects with a certain distance limit. Thus, the installed LiDAR will only acquire data of objects limiting the region of interest (ROI). This approach aims to improve the measurement accuracy and efficiency of LiDAR data collection, especially in the context of particular object.

1.2 Problem Identification

Commercial LiDARs, both 2D and 3D, generally have rotations that are controlled by manufacturer specifications and cannot be changed by the user. It becomes a problem when LiDAR is only required to measure a certain part of the area. This problem has been addressed through various methods, including point cloud filtration (PCD) and Cloth Simulation Filtering (CSF), which serve to remove unnecessary point clouds. However, these methods require additional computation, which can increase the processing load and time required to complete the analysis. Therefore, in this research we propose to build a 3D LiDAR and apply a new algorithm i.e. Edge tracking algorithm to solve the problem.

1.3 Objectives

To simplify the explanation, this thesis assumes the following points

1. This thesis presents the design of a prototype 3D LiDAR sensor with a defined angle coverage. The sensor is capable of scanning an area and creating a three-dimensional map. Additionally, it has the ability to rotate in a controlled rotation.

2. This thesis introduces a new algorithm called the Edge Tracking Algorithm, which is specifically developed to adjust the motion of LiDAR to track the contours of objects.

3. This thesis presents the visualization of scan data obtained from a 3D LiDAR prototype, using MATLAB for the visualization process.

4. This thesis analyses the accuracy, ata processing speed and data processing efficiency of the proposed algorithm.

1.4 Scope of Work

In this research, the defined limitations are presented as follows:

1. The TF-Luna sensor is used to detect objects at a distance of 0.2 meters to 8 meters.

2. Data is only collected in an indoor environment.

3. The 3D LiDAR prototype operate in a three-dimensional environment to create detailed maps.

4. The movement of the sensor uses a stepper motor on the azimuth axis and a servo on the altitude axis.

5. The rotating angle of the designed sensor is 300 degrees in the azimuth axis and 180 degrees in the altitude axis.

6. Objects that are mapped are objects that do not have holes.

1.5 Research Methodology

This thesis is divided into work packages (WP).

- WP 1: System Design and Planning

  Define the scope and objectives of the project, design the overall architecture of the 3D LiDAR system, and plan the hardware and software requirements. This phase involves designing the overall system architecture, including both mechanical and electrical components, the flow chart of the 3D LiDAR prototype movement, and the materials list for the hardware components will be created so that it becomes a well-integrated system.

- WP 2: Mechanical and Electrical System Development

  Develop and assemble the mechanical and electrical components of the 3D LiDAR system. The objective is to procure the necessary hardware, construct the mechanical structure, integrate the LiDAR sensor, and develop the electrical circuits to control the system. This phase ensures that the system's hardware is functional and meets design specifications through careful assembly, calibration, and initial testing.

- WP3: Experimental Setup and Testing

  Prepare experiments to test the performance of the 3D LiDAR system and collect and analyse data. In this phase, documentation of the design and experiment setup, test data and analysis reports, and a list of identified issues and proposed improvements will be produced.

- WP 4: Edge Tracking Algorithm Development

  Developing the Edge Tracking algorithm to be used in the 3D LiDAR system, as well as conducting experiments and improvements on the completed LiDAR prototype system. This stage includes the process of algorithm development, testing and optimisation through trial and error, and integration of the algorithm with existing hardware and software. The results include the optimised Edge Tracking algorithm, documentation of experiments and test results, and a report on the performance evaluation of the algorithm on the prototype system.

- WP5: Result Analysis

  Analyse the results of the developed 3D LiDAR system. The analysis process includes testing accuracy, data processing speed, and data processing efficiency. The analysis was conducted by comparing the performance of the Edge Tracking algorithm with the full scanning method. The aim is to evaluate the effectiveness and efficiency of the developed algorithm in detecting and tracking object edges compared to the full scanning method.