UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AUTOMATED GUIDED VEHICLE (AGV) SYSTEM BASED ON SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka(UTeM) for the Bachelor Degree of Electronics Engineering Technology (Industrial Electronics) (Hons.)

By

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This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor Degree of Electronics Engineering Technology (Industrial Electronics) (Hons.). The member of the supervisory is as follow:

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EN. SHAHRIZAL BIN SAAT

ABSTRACT

There are many reasons related to the creation of Automated Guided Vehicles (AGVs) around the world. Most of the reason is by overcoming the logistical and problematic issues that occur frequently in the workplace and to improve the facilities provided at the workplace. In the industry, AGV can facilitate physical tension in human workers by performing tiresome tasks to be more effective without any indication of fatigue coming in. Their movements can be expected to encourage or send items to work cells at factories.The main focus of this project is to present a case study of a Simultaneous Localization and Mapping (SLAM) on vehicle that will operate in real-world environments. The SLAM was implemented to provide localization estimates in environments, where there are static landmarks that are only rarely recognized by the vehicle or robot. Thus, SLAM can make up the robot system such as obstacle avoidance, navigation and other function on the future. The project is tested and verified in a curtain room with Robot Operating System (ROS) using sensor RPlidar laser scanner A2. The project includes also a general discussion on how SLAM can be used in room with vehicle. The software development is using Linux OS in Ubuntu to run the ROS and SLAM. As a conclusion, this project is design to consider features that move in the environment using SLAM visual mapping.

ABSTRAK

Terdapat banyak sebab yang berkaitan dengan penciptaan Kenderaan Berpandu Automatik (AGVs) di seluruh dunia. Kebanyakan sebabnya adalah dengan mengatasi masalah logistik dan masalah yang sering berlaku di tempat kerja dan untuk memperbaiki kemudahan yang disediakan di tempat kerja. Dalam industri ini, AGV dapat memfasilitasi ketegangan fizikal dalam pekerja manusia dengan melakukan tugas yang melelahkan untuk menjadi lebih berkesan tanpa menunjukkan keletihan yang masuk. Pergerakan mereka boleh diharapkan untuk menggalakkan atau menghantar barang ke sel kerja di kilang-kilang. Tumpuan utama projek ini adalah untuk membentangkan kajian kes Penyetempatan dan Pemetaan Serentak (SLAM) pada kenderaan yang akan beroperasi di persekitaran dunia nyata. SLAM telah dilaksanakan untuk menyediakan anggaran penyetempatan di persekitaran, di mana terdapat mercu tanda statik yang hanya jarang diiktiraf oleh kenderaan atau robot. Oleh itu, SLAM boleh melengkapkan sistem robot seperti penghalang, navigasi dan fungsi lain pada masa akan datang. Projek ini diuji dan disahkan di dalam bilik dengan Sistem Operasi Robot (ROS) dengan mengunakan laser pengimbas RPlidar A2. Projek ini juga termasuk perbincangan umum mengenai bagaimana SLAM boleh digunakan di bilik dengan kenderaan. Pembangunan perisian yang digunakan ialah OS Linux di Ubuntu untuk menjalankan ROS dan SLAM. Sebagai kesimpulan, projek ini adalah reka bentuk untuk mempertimbangkan ciri-ciri yang bergerak di alam sekitar menggunakan pemetaan visual SLAM.

DEDICATION

Special dedication to my beloved parents,

To my siblings,

To the lecturers,

To all my course mates,

4BETE 2017/2018

Thank you for always supporting and helping me during the journey of completing this project.

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In the name of Allah S.W.T, the most Gracious and Merciful, praise to Allah the Lord of the universe. May blessing and peace of Allah be upon His messenger, Muhammad S.A.W.

I would like to take this opportunity to extend my deepest gratitude to the following persons who helped me a lot in this project, which enabled me to complete my research project in time as a partial of the requirement for the Bachelor's Degree in Electronics Engineering Technology (Industrial Electronics) with Honours. First and foremost, a special thanks to my supervisor Mr. Shahrizal bin Saat, who helped me a lot for the project research, for all the support, continuous patience, and supervision given throughout the project.

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CHAPTER 1
INTRODUCTION

1.0 Introduction

This chapter will briefly discuss the background of the project, the problem statement, the objectives and scope of the project. Besides, it will discuss important projects that outline the benefits that can obtain from this project.

1.1 Project Background

A vehicle is moving freely on the floor while the laser scanner scan the environment. They are often used as part of modern applications to transfer materials around manufacturing facilities or warehouses freely. As for this project, the Simultaneous Localization and Mapping (SLAM) will be created to visualize the environment with mapping and able to define their location.

SLAM can create an automated guided vehicle as a trackless robot to expand effectiveness and decrease costs by serving to mechanize a manufacturing facility or warehouse. Robots can use laser scanners by scanning room with lasers to perform required tasks such as automated guards.

1.2 Problem Statement

There are many reasons related to the creation of Automated Guided Vehicles (AGVs) around the world. Most of the reason is by overcoming the logistical and problematic issues that occur frequently in the workplace and to improve the facilities provided at the workplace. Usually AGV is actualized on the production line, hospital, workplace, home, and can also be found everywhere without being recognized individually. In the industry, AGV can facilitate physical tension in human workers by performing tiresome tasks, for example, lifting and delivering extraordinary materials to be more effective without any indication of fatigue coming in. AGV can carry more tasks than human workers, and their movement can be tracked electronically over time. Their movements can be expected to encourage or send items to work cells at factories.

This project is aiming to develop a vehicle based on SLAM that has the free-wheel movement that will successfully localize and mapping to the environment by the user.

1.3 Project Objectives

i) To develop a system that will be sturdy enough to cover mostly flat terrain using Simultaneous localization and mapping (SLAM).

ii) To develop a system that will be able to establish its own location on the map and use information from the RPlidar Laser Scanner.

1.4 Scope

The scope of this project is to create a vehicle model that capability to move freely by user and create a 2D environment mapping. This outcome is to be done using an RPlidar laser scanner to allow visualize a map to become aware of its position in a room. The Robot Operating System (ROS) will be acting just like the brain for the model that controls all operations of the system from a laptop or PC.

The model is a four-wheeled vehicle that has the potential to move freely by the user using a RPlidar laser scanner that being set. There are four wheels which are free-turning rollers positioned at 90 degrees to the axle around the periphery. Combining of this movement with the rotation of the wheel makes the vehicle can move the vehicle in any direction freely.

To begin the whole project, it consists of three steps which are the concept of simultaneous localization and mapping, the Robot Operating System (ROS), and the software programming use in Ubuntu. The thing to consider is how the robot can visualize a mapping using laser scanner. It is also significant to choose the most suitable algorithm, ROS package, and sensors to achieve the project objectives.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction of project

In this chapter, opinions of researches which can be associated with this project could be mentioned. This chapter will describe information about the literature review of the components and structures used on this project. This chapter will provide the concept of the key components, RPLidar laser scanner and Simultaneous Localization and Mapping (SLAM). Furthermore, it will consist of the explanations and information of the components chosen of the project. This information is very beneficial to assist the author to understand how this element functioning and their overall performance.

2.1 Automated Guided Vehicles (AGV)

Automated guided automobiles (AGVs) are mobile robots that follow markers or wires in the ground. Parts of AGV use imaginative and prescient, magnet, or laser for navigation. The automatic guided vehicle system is a fully automated transport structure using unmanned vehicles. AGVs efficiently transport all forms of products without human intervention in production, logistics, warehouses and distribution environments. Therefore, this system is a clean way to reduce costs and improve performance and profitability. T. Ganesharajah, N. G. Hall and C. Sriskandarajah also stated the benefits of AGV consisting of better route flexibility and field use, and reduced standard operating costs. The adoption of automatic guided vehicles has been extended over the late twentieth century.

Ganesharajah, T., Hall, N. G. and Sriskandarajah, D. (1998). *"Design and operation issues in AGV-served manufacturing systems",* Ann. Oper. Res., vol. 76, pp. 109-154.

2.1.1 Shortest Routing of Bidirectional Automated Guided Vehicles Avoiding Deadlock and Blocking

N. Wu and M.C. Zhou stated that the extraordinary task of successfully managing automated manufacturing systems where automated guided vehicles (AGVs) were followed to handle materials, due to the capabilities such as AGV's earlier demand and change AGV's initial position. Goods and supplies AGV supplies most workstations and storage in AMS through manual, physical or virtual manual passages and controlled by computer-based controllers, but, when more than one AGV is used, management issues, including transitions, blocking, conflicts, deadlocks, and avoiding the shortest clashes, especially when bidirectional routes are followed for performance and flexibility at the manufacturing unit level.

An effective way to handle the deadlock with the AGV system is to avoid deadlock. Seeing all deadlock avoidance guidelines is closed-loop controls and used in real-time, they may be strong. The path for each AGV is known, and the effort to avoid the deadlock is to ensure the task of each AGV can be resolved, or AGVs can reach their location from their source nodes. Wu and Zhou set up high-level planning for low-level logic controls. Delivery and routing problems can be solved at a higher level, known as planning. At the planning stage, one can focus on system performance and provide a viable starting state for a lower level, and at a lower level, it is a supervisory control that ensures a system-free deadlock operation. Figure 2.1.1.1 shows the control structure of the AGV system. (Wu & Zhou, 2007)

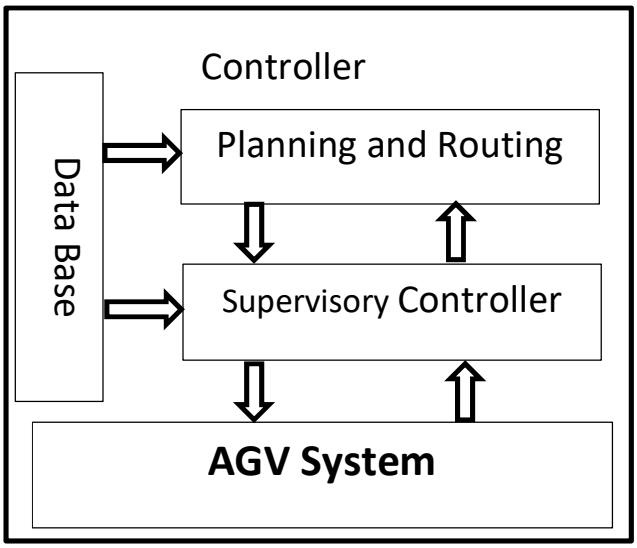

Figure 2.1: Control architecture for an AGV system.

Wu, N. Q. and Zhou, M. C. (2007). ” Shortest Routing of Bidirectional Automated Guided Vehicles Avoiding Deadlock and Blocking.” *IEEE/ASME Transactions on Mechatronics*, Vol. 12, no.1, pp. 63-72.

2.1.2 Control Program Design for Automated Guided Vehicle Systems via Petri Nets

AGV control techniques have been studied extensively. Programmable logic controllers (PLCs) are types of industrial control devices used to control AGVs. The overall design of the PLC program is based on experience, and its validation is usually done through experiments and simulations. Such methods cannot ensure the safety and reliability of the program. Additionally, the PLC program usually needs to be changed substantially when the specs design and exchange of command systems, or hardware damage occur. Unfortunately, the original program changes, reuse and debugging is difficult, boring and extremely valuable. The reconstruction of the PLC program is desirable to reduce losses when some hardware equipment is suddenly broken. To achieve that, Luo, Ni and Zhou designs based on official techniques are very important for most researchers working to find ways to bridge the gap between% design and formal techniques. Typical Petri-net (PN) based techniques for designing a programmable logic controller (PLC) that prevent

collisions between vehicles in an automated vehicle (AGV) system. There are 3 methods has been proposed. As a result, closed loop PN is obtained as a supervisor to prevent collisions between vehicles in the AGV system. Finally, the technique is brought to automatically translate the enclosed closed loop PN into the ladder diagram using the Boolean expression. Therefore, closed loop PN can be done using PLC. An example is used to demonstrate this technique. (Luo, Ni, & Zhou, 2015)

Luo, J. L., Ni, H. J. and Zhou, M. C. (2015). ”Control Program Design for Automated Guided Vehicle Systems via Petri Nets.” *IEEE Transactions on Systems Man Cybernetics-Systems*, Vol. 45, no.1, pp. 44-55.

2.1.3 Ensemble Coordination Approach in Multi-AGV Systems Applied to Industrial Warehouses

Automated warehouse systems are gaining a reputation, research on the coordination of automatic guided vehicles (AGVs) fleet, as a solution to addressing the problem of manufacturing performance and flexibility, is becoming increasingly important. Such coordination should keep in mind the entire system to improve global performance and not just interested in a multi-robot system. In fact, optimizing local price features is not enough to maximize overall performance across the globe. A broad example of this declaration can be determined in the frequent truth, nowadays industrial utilities, manual site traffic guidelines are used to address local issues as a failed match between a roadmap order and a set of guided guidelines. Actually, although many techniques can be found in the literature for street map definitions, no one considers the following coordination to do with the road map itself, fully through daily business operations. Therefore, the main concept behind this paper is to remember this problem as a whole, with a desire to find a good solution for some of it.

This paper provides a holistic approach to align automated vehicle fleet (AGVs) in an industrial environment. Objective Digani, Sabattini, Secchi, & Fantuzzi are aiming to solve coordination problems in a holistic way. They propose an ensemble method where the layers manipulate the architecture and a set of automated guidelines for the definition of the road plan is combined. The structure consists of layers. Lower level represents the road itself. Excessive titles illustrate topology relationships between specific areas around. The objective of the proposed approach in managing the overall design setup and managing techniques automatically, reducing time for setup and installation. Strength also improved by considering the alignment technique for the AGV fleet no longer based on manual ad-hoc guidelines. Simulations are achieved by comparing the proposed methods for the contemporary industry. In the future, industrial factors, such as warehouses that manage the system, may be included as a way of achieving actual and overall industry capabilities. (Digani, Sabattini, Secchi, & Fantuzzi, 2015)

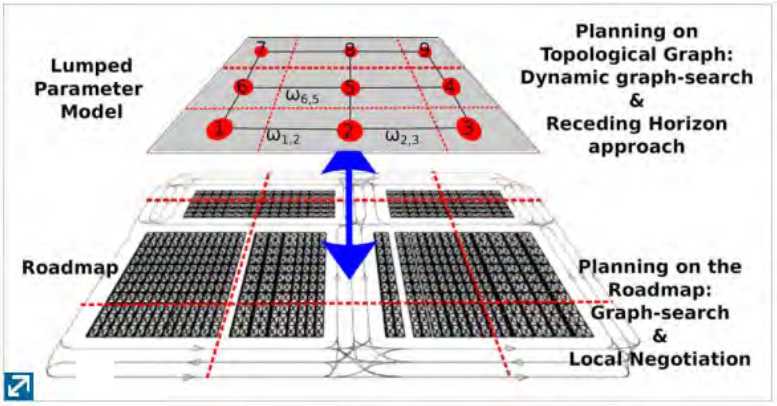

Figure 2.2: System architecture overview

V. Digani., L. Sabattini, C. Secchi and C. Fantuzzi (2015). ” Ensemble Coordination Approach in Multi-AGV Systems Applied to Industrial Warehouses.” *IEEE Transactions on Automation Science and Engineering*,” Vol. 12, no.3, pp. 922-934.

2.2 Simultaneous Localization and Mapping (SLAM)

SLAM refer the issue to try to localize the same time to find the location or orientation of the various sensors with respect to the environment and at the same environment mapping structure. Depending on this situation can be achieved in many ways. The SLAM system means a set of algorithms that work to solve simulation and simultaneous mapping problems.

The overview provides the three main paradigms of SLAM algorithm in which various types of published methods are currently available. First come traditional techniques, which depend on the Extended Kalman Filter (EKF) to represent the best approximation robots. The second paradigm draws on the fact that the SLAM problem can be seen as a rare barrier graph, and it uses nonlinear optimization to improve the map and place the robot. Finally, measure the paradigm dust filter, which uses nonparametric density estimates and effective techniques for SLAM factoring problems. This chapter discusses major advanced techniques. It explains the variation of the SLAM problem and proposes taxonomies for this sector. Relevant research refers extensively and discusses research issues. (Thrun & Leonard, 2008)

S. Thrun and J.J. Leonard (2008). "Simultaneous Localization and Mapping." *Springer Handbook of Robotics*, pp 871-889.

Lately, various effective approaches to simultaneous localization and mapping (SLAM) based on ground robots have been presented. However, problem can occur when using their algorithms for systems with higher real-time requirements, such as micro aerial vehicles (MAVs). This paper provides a quick and useful way to SLAM problem, which enables autonomous quadruple to find an unknown indoor environment. They insist that a probabilistic approach to estimation is based on an algorithm that is almost