Development of multi-terrain automatic guided vehicle (AGV) using vision assistive system

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Bachelor of Mechatronics Engineering with Honours
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

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A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "Development of multi-terrain automatic guided vehicle (AGV) using vision assistive system" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MUHSIN KAMIL BIN ABDUL NAZAR

Date : 4/7/2021

APPROVAL

I hereby declare that I have checked this report entitled "Development of multi-terrain automatic guided vehicle (AGV) using vision assistive system" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature :

Supervisor Name : ASSOC. PROF. DR MARIAM MD GHAZALY

Date : 4/7/2024

DEDICATIONS

To my darling parents

ACKNOWLEDGEMENTS

To start with, I want to thank and appreciation to God for his direction and favors to finish this Final Year Project.

I wish to express my sincere appreciation to my main project supervisor, ASSOC. PROF. DR MARIAM MD GHAZALY, for encouragement, guidance, and critics. Without her continued support and interest, this project would not have been same as presented here.

My kindred postgraduate understudies ought to likewise be perceived for their help. My true appreciation likewise stretches out to every one of my associates and other people who have helped at different events. Their perspectives and tips are valuable undoubtedly. Lamentably, it is unimaginable to expect to list every one of them in this restricted space. I am grateful to all my family members.

ABSTRACT

The multi-terrain automatic guided vehicle (AGV) can be implemented in various categories, such as in production line for automatic delivery and for moving heavy objects from one point to another point. In this project the AGV will implement vision assistive system for detecting object and obstacle. Currently, AGV available on the market have some limitations where it was not designed for obstacle detection, obstacle avoidance, moving on different terrains and slope climbing. In this project, the automatic guided vehicle (AGV) prototype has already been fabricated (continuing from previous FYP project). The first objective is to develop algorithm for object detection and avoidance using pretrained YOLO object recognition model. The second objective is to study the effects when using the algorithm developed to menuever an AGV. YOLO pretrained model will be used in the vision system of this project. For this project, python programming language is selected because it is appropriate for novices and it is not difficult to learn. Python programming language is also widely used in vision system because it contains the OpenCV library used for computer vision. Xiaovv 1080P USB Webcam is used to capture the images of object and laptop is used to carry out recognition. Arduino is used to control the motor on the AGV for meneuvering and obstacle avoidance. There will be 4 experiments done in this project. First experiment would be to compare the performance of YOLOV3 model and YOLOV3-TINY model in terms of frame rate. YOLOV3 have frame rate of 18.3 FPS while YOLOV3-TINY have a frame rate of 49.1 FPS. For the second experiment, the objective would be to compare the performance of YOLOV3 model and YOLOV3-TINY model in terms of accuracy. YOLOV3 have accuracy of 66.66% while YOLOV3-TINY have 65.31% accuracy. In the third experiment, performance of the vision system with different confidence threshold values would be tested. 60% confidence threshold was choosen because it has the highest accuracy of 70.36%. Lastly, for the fourth experiment, the effect of delay in the system would be analysed. All the experiment will be repeated 6 times and the result would be observed. In this project, the AGV is expected to manoeuvre without any control by humans.

ABSTRAK

Kenderaan berpandu automatik pelbagai medan (AGV) dapat dilaksanakan dalam pelbagai kategori, seperti dalam barisan pengeluaran untuk penghantaran automatik dan untuk memindahkan objek berat dari satu titik ke titik yang lain. Dalam projek ini AGV akan melaksanakan sistem bantuan penglihatan untuk mengesan objek dan halangan. Saat ini, AGV yang tersedia di pasar memiliki beberapa batasan di mana ia tidak dirancang untuk pengesanan rintangan, penghindaran halangan, bergerak di berbagai medan dan pendakian lereng. Dalam projek ini, prototaip kenderaan berpandu automatik (AGV) telah dibuat (bersambung dari projek FYP sebelumnya). Objektif pertama adalah untuk mengembangkan algoritma untuk pengesanan dan penghindaran objek menggunakan model pengenalan objek YOLO yang telah dilatih. Objektif kedua adalah mengkaji kesan ketika menggunakan algoritma yang dikembangkan untuk menunaikan AGV. Model pra-latihan YOLO akan digunakan dalam sistem penglihatan projek ini. Untuk projek ini, bahasa pengaturcaraan python dipilih kerana sesuai untuk pemula dan tidak sukar untuk dipelajari. Bahasa pengaturcaraan Python juga banyak digunakan dalam sistem penglihatan kerana mengandungi perpustakaan OpenCV yang digunakan untuk penglihatan komputer. Xiaovv 1080P USB Webcam digunakan untuk menangkap gambar objek dan komputer riba digunakan untuk melakukan pengecaman. Arduino digunakan untuk mengawal motor pada AGV untuk melakukan manuver dan penghindaran halangan. Akan ada 4 eksperimen yang dilakukan dalam projek ini. Percubaan pertama ialah membandingkan prestasi model YOLOV3 dan model YOLOV3-TINY dari segi kadar bingkai. YOLOV3 mempunyai kadar bingkai 18.3 FPS sementara YOLOV3-TINY mempunyai kadar bingkai 49.1 FPS. Untuk eksperimen kedua, objektifnya adalah membandingkan prestasi model YOLOV3 dan model YOLOV3-TINY dari segi ketepatan. YOLOV3 mempunyai ketepatan 66.66% sementara YOLOV3-TINY mempunyai ketepatan 65.31%. Dalam eksperimen ketiga, prestasi sistem penglihatan dengan nilai ambang keyakinan yang berbeza akan diuji. Ambang keyakinan 60% dipilih kerana mempunyai ketepatan tertinggi 70.36%. Terakhir, untuk eksperimen keempat, kesan kelewatan sistem akan dianalisis. Semua eksperimen akan diulang 6 kali dan hasilnya akan diperhatikan. Dalam projek ini, AGV diharapkan dapat melakukan manuver tanpa kawalan oleh manusia. Semua keputusan harus dilakukan oleh sistem itu sendiri.

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LIST OF SYMBOLS

$ii(x,y)$	-	Integral image
$i(x',y')$	-	Orginal image
$s(x,y)$	-	cumulative row sum
w_{ki}	-	weight refers with the connection between the k^{th} input element and the i^{th}
w'_{ij}	-	Wight between i^{th} hidden layer and j^{th} output layer
Σ	-	Sigma

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Automated Guided Vehicle (AGV) have been evolving for around 60 years. AGVs have been utilized for assignments like movement of items in warehouse, dispersions and storage functions or transport of subparts between various assembly stations in a creation line [1]. AGV that is available in the market today uses many different types of sensors as the path guider and localization method. Every sensor has their advantages and disadvantages. There are a few types of AGVs that is widely used in the manufacturing factory such as the line guided AGV, rail guided AGV, AGV that is guided by magnetic tape or magnetic line that is buried in the floor, laser guided AGV and many more. As the IR 4.0 rises, applying computer vision to mobile robot navigation has been concentrated for over twenty years [2]. This is made possible with the IoT and big data since the vision system needs to use Artificial Intelligence (AI) and Cloud to store the data that were acquired. Considering the development cost, AGV should be worked without line or rail. AGV ought to explore, dodge obstructions, and plan the most short and upgraded approach to work in the open space. A low-cost camera is needed for AGV to capture pictures progressively to sort out the conditions of the environment and choose the following move accordingly [3]. To use the computer vision, AI and deep learning would be used to train the system to recognize the objects around it.

1.2 Problem Statement

Before technologies were invented, human labor was used to do all the work in a warehouse. As time goes, researchers have been doing many studies to find ways to make the production line in a warehouse more efficient. This is because using human strength to do all the work is time consuming and humans gets tired. Therefore, using machines in a manufacturing factory is a way to increase the daily production. As technologies grow, researchers found that using AGV in a manufacturing factory would reduce the labor cost while increasing production rate since machine does not get tired like humans. With the localization technology in AGV that uses many types of sensors for navigation to achieve its objectives, there is no constant human supervision needed.

Using camera as the sensor for navigation on an AGV is a popular choice of research these days. This is because of all the advantages that a camera could provide. However, the problem that almost all researchers face is the disadvantage of the camera itself, which is cameras are sensitive to high laminations and shadows [2,3,4,5,6]. It is important to overcome this problem as they may interfere with the accuracy of the results that would be produced.

1.3 Objectives

1. To develop algorithm for object detection and avoidance using pretrained YOLO object recognition model.

2. To study the effects when using the algorithm developed to menuever an AGV

1.4 Scope

The scope of this project is limited to developing a vision assistive system for the multi terrain AGV that was developed by a previous student. This system would be developed to be used in a controlled environment such as the lightings and paths are constant. In this project, the AGV would be using the vision system together with two IR sensors to obtain a more robust localization method since the vision system alone is not stable enough to use as a stand-alone sensor for an AGV.

CHAPTER 2

LITERATURE REVIEW

2.1 Automated Guided Vehicle (AGV)

AGV or also can be known as LGV (laser-guided vehicle), Mobile Robots, SGV (Self-Guided Vehicle), Guided Carts, Autonomous Vehicles, and Driverless Vehicles interacts with robots and monitors that function as navigator to ensure objects move by following system command to the destination that had been appointed. AGV is developed consisting of radio waves and vision camera to produce accurate navigation. AGV functioning as an indicator in different situations, depending on active surrounding based on few factors such as smart city, the shape, size, and operations differ. There were 3 types of AGV such as laser, natural and magnetic which are functioning as a medium to interact with vehicles and RSU (Rode Side Unit) [1].

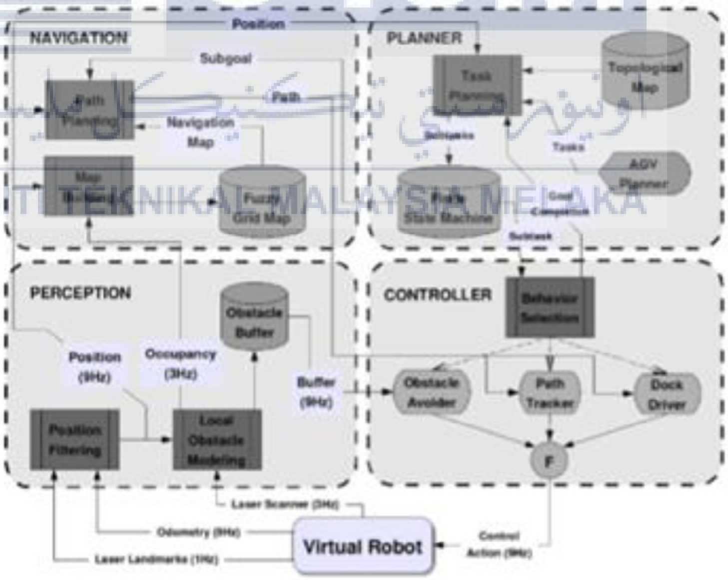

Figure 2. 1: framework used to integrate the different functionalities of a flexible AGV equipped with a laser navigation system, laser scanner and odometry [1]

Nowadays, AGV are widely used in Industry to moved object from one destination to desired destination. Currently, the usage of AGVs in industry is developing quick and dynamic. A market report by Grand View Research predicts that from 2018 to 2025 will focuses on the potential growth of AGVs functions will be influenced by few factors such as the emergence of flexible manufacturing systems, the rising demand for customized AGVs and the adoption of industrial automation by SMEs. The newest version of AGV-systems is conventional and widely used in manufacturing, medicine, and logistics. In these systems, a fleet of AGVs is arranged in a centralized way. Motion planning and allocation of tasks are done by a central entity as shown in Figure 2.2(a) [2].

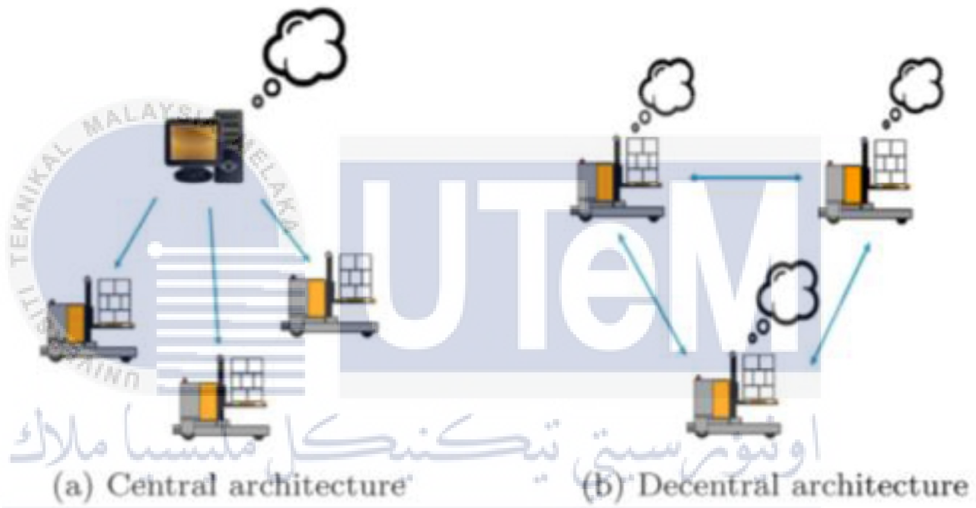

Figure 2. 2: Central and decentral control architectures [2]

Caused by future requirements such as flexibility, robustness, and scalability, make decentralization the current trend in AGVs. The authors clarify decentralization as the distribution of the total intelligence of a system to its components such as in order for the device to have the option to work autonomously, each device will get a part of the total intelligence. Chasing for the same global goals as shown in figure 2.2(b), the Grand View Research market report define decentralization as one of the future technologies that will be used in industry. The main reason of increment of AGV demand will be the improvement of AGV fleet. In the future, more unpredictable framework will be expected to fulfill the need of transportation interest [2].

The main reason AGV was used in industry for production and services purpose is the implication of AGV can increase the improvement of productions effectiveness. AGV can expand the effectiveness and exactness of creation and services activities. AGVs also can be utilized in risky climate as it can diminish the danger of blast in specific conditions. In services application context, the used of AGV is proven in enhancing the availability, safety and security of industrial sites and infrastructure systems [7].

Industry 4.0 were defined as the fourth industrial revolution in manufacturing industry. The change creates value from information obtain and refined from data. It is the change implemented for the future of manufacturing industries which allow mass customization to happen and allow further horizontal and vertical integration. This revolution will probably cause the free data flow between few elements in production or on the logistic ecosystem and if this happens, we can discard the used of central architectures. With the change of 4.0 models from typical automation pyramid ISA 95 to RAMI 4.0 as seen in figure 2.3 and 2.4, members in complex system can communicate easier with their local environment on another different level [2].

Figure 2. 3: ISA 95 model [2]

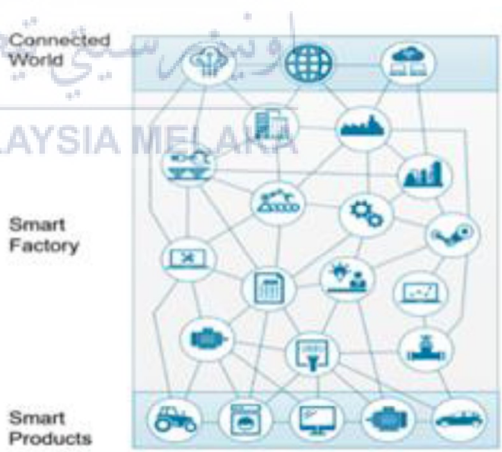

Figure 2. 4: Axis 1 of the RAMI 4.0 model [2]

The fourth industrial revolution is indicated as hyperconnectivity and superintelligance which will create a paradigm to a better, wider and faster society compared to the exsiting industrial revolutions. There are a few context that will be implemented a lot in industry and services along the 4.0 industrial revolutions such as AI (Artificial Intelligence), IoT (Internet of Things), big data and cloud system. In manufacturing factory, all items and administrations will be associated with an network and will be intellectualized. The excecution of the usage of AGV, the result of big data processing and deep learning will lead to a situation where factory will become far more smarter. Figure 2.5 shows the various types of AGVs in the manufacturingfactory [3].

Figure 2. 5 (various type of AGVs): (a) line-guided (excerpted from YES MACHINERY) (b) rail-guided (excerpted from MURATA MACHINERY USA) (c) laser-guided (excerpted from SICK) [3]

AGV is choosen to be operated without line or rail by considering the infranstructure construction cost as factor and AGV should be functioning to navigate, avoid obstacle, and plan the briefest and upgraded way in an open space. Due to these reasons, low cost camera is used in orger for AGV to captue images in real time so that it can figure out the environement surrounding so that AGV can decide the next move. On the other hand, to ensure the accuracy in controlling AGVs without line or rail, it is important to ensure the precise positioning. The factory layout should be recognized by extracting 2D coordinates to ensure the precise positioning of AGV and plan the optimized path from departure and the destination. Combining depth and information from the image and 2D coordinates will be really expected to compute relative distance among AGV, gear and items precisely and with minimum number of position error [3].

Figure 2. 6: Motion control of AGV by image detection

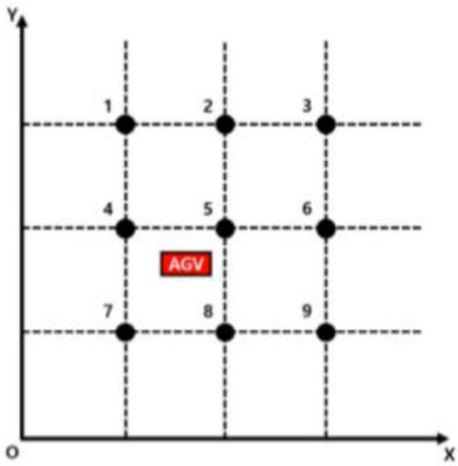

Figure 2. 7: Precise positioning of AGV by extracting 2D coordinate

There are few techniques that AGV has integrated in order to build the adaptability by free-route between waypoints in mostly organized industrial conditions. The techniques are on-board localisation, mapping and path planning which allow workplace changed to be distinguished and directions to be adjusted to new circumstances [8].

The AGV needs a map and a method to distinguished its own area to explore through the courses determined on-board. Laser, inertial and Cartesian guidance are widely used in current systems. In laser guidance, there are few passive reflective beacons that can return the emitted laser beam from a device implant in AGV. The position of AGV can be computed using geometry by knowing this beacons' location on the map. This method has the highest accuracy but quite expensive and this method will be needing some kind of external calibration as the system will degrade by times [8].

Mapping is used becase of its compact representation of the environment. Grid maps are offently used metric maps although it has few disadvantages especailly due to the complexity in both time and space. The method used for map building is based on fuzzy grid maps which consists of two values which are the degree of certainty that the cell is empty (EIJ) and the degree of certainty that the cell is occupied (OIJ). These values will need to be extracted to be used in each cell in the beam of a single sensor. Through this method, the robot uses and maintains three different maps such as the map of cells that are likely to be empty (E(i,j)), the mapof cells that are likely to be occupied (O(i,j)) and the navigation map (M(i,j)). The difference between this method and the traditional method is this method use sonar sensors while the traditional one use laser scanner [8]. Path planning is used to find the minimum length path between AGS's position and the goal to reach. The most direct method in path-planning using grid maps is to consider each cellas a node in a graph and use them to search the algorithm [8].

2.2 Vision Assistive System

Assistive technology (AT) is being widely used these days. Starting from designated to help individual with disabilities, AT is now being used in industry. There were few existing AT nowadays and the one that currently spike the demand in industry is vission assistive system. We have few type of vission assitive system in manufacturing industry such as Network High-speed Vision, Spherical Vision Camera, Ultra-wide FOV LWIR Stereo Vision System, Multi-camera Visual SLAM, Night Vision Camera and Vision Odometer.

Network High-speed Vision system is designated such as the high-speed cameras will be connected to a network that will enable thwm to communicate with each other. These cameras has a features called FOV that can ensure the accuracy of the cameras to observe the entire surrounding desired. As shown in figure 2.8, each camera forms a node with its processing unit. All nodes are synchronized to submilisecond order using defined precision time protocol [9]. There are system that combine Network High-speed Vision system and Evasive Maneuver Assist (EMA) which functioning as assitive device for drivers to perform evasive maneuvers at the exact moment when sudden reaction is required. There are few advance existing (EMA) including the one that used on-board camera but it still have limited field-of-view (FOV) which the system can reach any blind spot. The current EMA is combined with network high-speed vision 12V-based has achieves few results benifiting the users. The benefits are system consist of EMA and network high-speed vision capable of surveiling traffic situations involving vehicles, pedestrian and obstacles on road. It can reach the hidden spot behind other vehicles or buildings [9].