MOBILE ROBOT NAVIGATION SYSTEM VISION BASED THROUGH INDOOR CORRIDORS

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DECLARATION

I declare that this thesis entitled “MOBILE ROBOT NAVIGATION SYSTEM VISION BASED THROUGH INDOOR CORRIDORS 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.

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APPROVAL

I hereby declare that I have checked this report entitled “title of the project” 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 : .....

Date : .....

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DEDICATIONS

To my beloved mother and father

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ABSTRACT

Nowadays, industry has been moving toward fourth industry revolution, but surveillance industry is still using human in patrol. This will put this industry in risk due to human nature instincts. By using a mobile robot with assist of vision sensor to patrol can bring this industry to a new level. However, the indoor corridor navigation will become a big challenge to this method. The objective of this project is to develop a navigation system using vision sensor and navigate the mobile robot in indoor corridor environment. To perform this operation, a control system though the WLAN communication develop to guide the movement of mobile robot. Besides that, corridor following system with vision sensor that using Sobel edge detection method and Hough transform to getting the vanish point is needed to help the robot to safely travel in the corridor. Both systems can be using MATLAB to be execute and link with the mobile robot through WLAN connection. This system can be analyse the corridor condition base on different feature and can decide to drive the mobile car in the direction that given. The image capture by mobile robot can be stream to MATLAB in real time and receive a feedback in short time.

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ABSTRAK

Pada era globalisasi ini, kebanyakan sektor industi telah melakukan transformasi ke arah revolusi industi 4.0, tetapi industri keselamatan masih menggunakan manusia dalam rodaan. Keadaan ini akan meletakkan industri ini dalam bahaya disebabkan sifat manusia yang tamak. Dengan menggunakan robot dan dibantu oleh "vision sensor" dalam rodaan dapat meningkatkan industi ini ke aras baru. Namun, navigasi dalam bangunan merupakan cabaran dalam pelaksanaan kaedah ini. Objektif projek ini adalah untuk meghasilkan satu sistem navigasi menggunakan "vision sensor" dan menavigasi dalam koridor bangunan. Demi melaksanankan kaedah ini, satu sistem kawalan melalui penghubugan WLAN dicipta untuk mengawal pengerakkan robot. Selain itu, sistem mengikut koridor dengan bantuan "vision sensor" yang menggunakan "Sobel edge detection method" dan "Hough transform" dalam memperolehi titik lenyap adalah diperlukan dalam memastikan robot dapat bergerak dengan selamat dalam koridor. Sistem-sistem diatas dapat dilaksanakan dalam MATLAB melalui penghubungan WLAN. Sistem ini dapat menganalisikan keadaan koridor berdasarkan ciri-ciri berlainan dan membuat keputusan untuk bergerak dalam arah yang diberi. Gambar yang diambil oleh robot akan dihantar ke MATLAB dan menerima maklumbalas dalam masa singkat.

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LIST OF SYMBOLS AND ABBREVIATIONS

CCTV	-	closed-circuit television
DoF	-	Degree of freedom
fps	-	frame per second
GPS	-	Global Positioning System
IMU	-	Inertia Measurement Unit
IoT	-	Internet of things
MATLAB	-	matrix laboratory
WLAN	-	wireless local area networking

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CHAPTER 1

INTRODUCTION

In era of fourth industry revolution, most of the industry is transform into cyber-physical system. This system is control or monitor a mechanism of an industry through a computer-based algorithm. All the operation on that industry is digitalize, so all the output, input or problem can be analyses. From the analysis, a pattern can be obtained by the system, this pattern will be led to the main problem. By recognize and solve the main problem, it will produce a better result in term of the quantity and quality of the product.

In surveillance system, the system mostly used is closed-circuit television (CCTV) which also known as the video surveillance. In this method, the video recorded can be monitor in real time or as a reference in future in order to obtain some information from it. However, this method having some blind spot due to it required a large quantity of CCTVs to cover all place in a building.

To overcome that problem, human patrol is used to secure a place. Human is used to guard an area of place with the assist of the CCTV. Besides that, human also required to patrol the area in a random or fixed time and route frequently. This will give them permission to assess the area and it will be having some risk in it. This is due to the nature of human being that is greedy.

Hence, the human patrol task needs to be digitalized. To making this solution achieve, the advantage of the human patrol which is highly mobility must implant into the CCTV system. A robot with a camera which can move inside the path of patrol can carry out this task, but the storage of the data obtained will be an issue. This issue can be solved through the IoT solution in fourth industry revolution. This method will record the situation on the blind sport of CCTV system.

With a support of the mobile system, the human patrol can be replaced. At the same, the fixed CCTV only installed in importance location and the blind sport of the CCTV can be eliminated using the mobile system. The network of coverage of the surveillance system is expanded into larger area.

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1.1 Motivation

In Malaysia, there is a massive amount of money that had stolen by the security guards who secure the building. This case is occurred on election night 2018 at Prime Minister's Office. Former Prime Minister claimed that a total of RM 3.5 billion is stolen by 17 security guards [1].

From the above incidence, there are a potential hazard in hiring a human with unknow personality to secure our estate. Therefore, it is required to replace the human patrol with machine. This machine can be a robot with vision sensor, which can analyses the area of patrol and record all the data obtained for future reference. This method not only overcome the problem above, but it also increases the quality of the patrol system. This system can provide a powerful evidence in form of image or video rather that a testimony of a security guard.

1.2 Problem Statement

The technology with vision is advance with rise of fourth industrial revolution, many industries used vision to replace human's eye in order to analyses an event. At the same time, the algorithm used for each industry is different from each other due to the field and method of analysis is different.

In this system, the most challenging part is how to make the robot tracking the corridor and moving in indoor corridor without collision. This can be real with some algorithm to process the image get by the robot in real time and return a respond to the robot in a short time. This required a high processing power to make this system effective.

Besides that, the robot also needs to be able recognize the corridors. In order to perform the navigation task, the robot required to identify the corridor condition. For example, the robot must identify the different type of junction and making the correct turning based on the navigation task.

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1.3 Objective

This project has the following objectives:

1. To design and develop a navigation system using vision sensor for mobile robot.
2. To control movement of mobile robot based on the navigation system.
3. To analyze performance of mobile robot in term of accuracy of corridor tracking and recognizing.

1.4 Scope

The main scope of this project is the navigation system is design for mobile robot with camera as vision sensor. The system is use for the navigation at indoor corridors environment only. The information for the corridor condition is detect by a camera placed in front of the mobile robot, so this navigation system only can guide the mobile robot in forward direction only.

All the information of the corridor is detect using vision sensor and send to laptop as input data for algorithm. The laptop as the platform to run the algorithm. The output of the algorithm is the command that send to mobile robot as the control of movement. The communication between mobile robot and laptop is through WLAN connection. The WLAN module of the mobile robot is work as server while the laptop as its client.

Since the camera use is normal camera without the night vision, so the environment factor which is lighting condition must be fixed to visible condition. Most of the indoor corridors having limited light from the sun, so most of the corridor having the electric light. The electric light can light up the corridor to 500 and above. The navigation system only can work under this lighting condition.

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CHAPTER 2

LITERATURE REVIEW

2.1 Type of Robot

Robot is an importance platform to test and stimulate an algorithm of navigation system in corridor. There are 3 type of robot used in previous work to perform this operation which are mobile robot [2] [3] [4] [5] [6] [7] [8], humanoid [9] and micro air vehicle (MAV) [10]. The mobile robot is used to perform this task due to the control of the mobile robot is easy. The combination of rotation of each motor in either clockwise (cw) or counterclockwise (ccw) will result in different motion. The Table 2.1 below will show the motion of mobile robot and its corresponding motor rotation combination.

Table 2.1: Relation of direction of motor and the motion of mobile robot

Motion of mobile robot	Rotation of left motor	Rotation of right motor
Go forward	cw	cw
Go reverse	ccw	ccw
Go left	ccw	cw
Go right	cw	ccw

However, the mobile robot only can move in flat surface. Humanoid robot can be overcome this kind of problem. Humanoid robot can move in the rough surface of corridor such as stair but hard to control it motion. The leg of the humanoid robot, NAO having 6 degree of freedom (DoF) [11]. In order to move one step, the control algorithm of humanoid robot required to calculate all angle for each of the motor. This will increase the complexity of the system. MAV is better that humanoid robot in overcome surface problem because it did not move at surface. At the same time, the factor influence it control also increase. The environment factor such as wind and the mass of sensors at MAV will affect it performance. To run a new algorithm, the robot with easy control is better because this is easy to troubleshoot the problem in the algorithm. Hence, the mobile robot is the better choice.

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2.2 Type of Sensors

Sensor is the key to let a system or robot to become intelligence. The sensors to perform navigation task having many types. First type of sensor is combination of Global Positioning System (GPS) and Inertia Measurement Unit (IMU) [12] [7]. GPS is used to pinpoint location for a device, the accuracy of GPS is in range of few meter and ineffective in indoor environments. Function of IMU used to getting the direction of a device moving but it is having a cumulate error when it uses for a long time period. The combination of GPS and IMU can overcome the weakness of each other by increase the accuracy of the GPS and eliminate the cumulate error of IMU.

Next, the laser sensor such as lidar or laser scanner is another type sensor used in navigation system and obstacle avoiding system [4] [5] [6] [7]. Laser sensor is used to calculate the distance between object ahead and sensor. Laser sensor is very fast respond, easy to use and use less processing power. However, many laser sensors required to get enough information of surrounding because laser sensor only can detect the distance of a surface which is perpendicular to laser sensor. The angle of each sensors is an importance issue in order to create a 3D map.

Besides that, camera also can be use as vision sensor [2] [9] [13]. Camera is easy to setup by fixed it position on a robot. Vision sensor is can get large information about environment by real time analysis of image frame by frame. For example, in [10] was used stereo camera to build a 3D image, this can get the information in term of range data, 3D virtual scan and 3D occupancy map. This will be causing this sensor required a hardware with high processing power to analyze it, so the response time of this sensor depend on the specification of the hardware.

Last but not least, Kinect is used in [3] to perform the same operation. Kinect is a combination of vision sensor and laser sensor. From the combination of both sensors, more information can be obtained. From the library of Kinect, user can direct get the information needed with need to know or develop an algorithm. Other than that, the price of Kinect also higher than other sensors.

To getting more information to make a system to more intelligence, the more type of sensor used is better, but this also increase the mass and cost of the system. Camera is the better sensor in term of low mass and cost. Although it required a hardware to processes it data. This can be overcome by making a wireless communication between them.

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2.3 Corridor Scanning Method

For a robot to move automatically in corridor environment, the method to analyze the information collected by sensors is importance. There are 2 method to analyze the data which are 3D map and image processing. For 3D map, laser sensors are required to obtain data at difference angle [3] [4] [5]. By getting the data of distance from each sensor at difference angles and this data is used to do alignment, filtering and bounding. Through this process, the distance between laser sensors at two adjacent angles is estimate, so if the number of sensors is less, this will be causing the 3D map to have many inaccuracies. Hence, large number of sensors required to create a detailed 3D map for better navigation system.

Another method is through image processing method to process the data of a camera [2] [3] [9] [13] [14]. Segmented Hough Transform and Canny's algorithm is the most common method used in the analyze corridor environment. Line segment detector (LSD) is an upgrade version of previous method by refer to methods proposed by Burn et al. method and Desolneux et al.. Both methods are using edge detection and line extraction to get the vanish point of the corridor. However, LSD is faster than pervious method in obtaining the line from an image, but LSD can't get short line from the image [8]. Therefore, it will be loss some of the data in the image. Besides that, block-based image processing method also used to obtain data about the environment [6]. This method using the pixel of the image to get the information. Grouping of the same pixel into a large pixel will increase the respond time but this method only effective in large color different such as road. Hence this method more convenience using in analyze outdoor environment.

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2.4 Autonomous Navigation

Autonomous navigation is required for a robot to travel across a distance without the supervise by a human. Autonomous navigation in indoor and outdoor is difference. In outdoor environment, vehicle is control by a hardware which processing the data from the sensor. There are two way to carry this outdoor task which are combination of vision and sensors [12] [7]or vision and artificial neuron network (ANN) [13]. From the combination of vision and sensors such as GPS and IMU, the system can understand the item at surrounding of vehicle, the position of vehicle, and the direction of the vehicle move. For the vision and ANN method, the system is fully depending on the information collected by the camera only. Therefor the ANN will analyze and getting the data as much as possible to make sure the vehicle can move safely on the road.

In indoor corridors, the navigation methods are easier since the speed of mobile robot is not as fast as outdoor vehicle and did not endanger human life, so lesser safety issues need to consider. Few methods can carry out this task which are vision only or with sensor fusion, ANN and finite state machine (FSM). By using vision, the system can move I at center of the corridor by adjust it direction from the feedback of the vanish point [9]. Moreover, the vision also can help the robot to follow the path from the analysis of the image. For example, the path given is turn left at junction, then the robot will be move straight before it reach the junction until the image processing will a feedback of junction ahead and it will turn left. There is not distance measurement required in the navigation. By adding the sensors fusion, the system more correctly with error modal from the sensor feedback [2]. This will increase the accuracy of the system because compare data from two sources. Next, ANN method is used the analyze the data from image [3] or from sensor such as laser sensor [5] [6] and give the correspond command to control the robot. The few layers ANN system will analyses the data received and give the output to the motor to move from time to time until reach the destination. The last method is FSM, which is generate a route from a topological map in sequence of steps. This method is effective in navigation and did not need to know the actual position of the robot during navigation. On the other hand, this method required a topological map insert to the system and known initial position before any navigation start.

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2.5 Obstacle Avoiding

In a navigation system, obstacles will appear in random along the route, so it is importance to avoid it to success travel to the destination. There are five way to avoid obstacle. First way is obtaining data from 3D map [3]. This 3D map create through the Kinect sensor is update from time to time. Thus, when an obstacle is appeared, the Kinect will update the new data into the map for the system to analyze and making the correction to planned route.

Secondly, bubble rebound algorithm apply in obstacle avoiding [6]. The robot will be rebound in the direction of low density of obstacle when an obstacle is detected at it "sensitive region". The "sensitive region" is an area created around sensors within a range that defined by user. This method capable to avoid all type of obstacle and work in narrow corridors by using low cost sensors and microprocessor only. Even so, this method required a high level of path planning algorithm to bring the robot to destination and it motion also not smooth.

Next, another method can perform obstacle avoiding is "follow the gap method" [7]. This is using the angle of detected obstacle to calculate the gap array and find the maximum gap. Then, the gap center angle is calculated and produce the final heading angle for vehicle to move. This method is only having one turning parameter so turning process is easy, but it is limited by the speed of vehicle.

Fuzzy logic system also can use to avoid obstacles [8]. Few rules are set in the fuzzy logic system. The methods for fuzzification and reasoning are singleton and Mamdani's method, respectively while defuzzification using center of gravity. The performance of this method is better than other in term of travel time but worse in travel distance.

Lastly, stereo vision which can create a 3D image from different angle of vision sensor is having fast obstacle mapping and path planning [10]. Not only that, it also can avoid obstacle in unknown environment. However, this method required external computer to process the data due to heavy processing power to run the algorithm and high-speed communication system for fast data transferring.

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2.6 Research Gap

The type of robot chosen is mobile robot. This is due to the control of this robot is easy, so it is very suitable to testing a new algorithm. To validate a vision-based navigation system, the difficulty of the control needed to decrease to minimum so that the troubleshooting for the system can ignore the control issue.

For the sensor part, camera is used due to its ability to get many types of information and lesser weight compare to other. The information that can be extract from camera such as distance, position and direction of moving. The information gain by camera is depend on the analysis algorithm, which are not same as other sensors that only sense particular information only and making the system need to add on new sensor to get new information. In addition, the camera also can record all the route travelled for a record or future use.

To analyze image from the camera, the more information extracted is better, so Segmented Hough Transformation and Canny's algorithm are selected. Although these two algorithms are consuming some time to process the image, but it can get on more detail line from the image so increase the accuracy of the vanish point. To reduce the time taken, the analysis is limit to some area of the image which are the corridor lines lined on.

Since the camera is chosen as sensor, the autonomous navigation and obstacle avoiding are using vision method. In this method, some algorithms are used to obtaining the required data to perform these operations. Since the indoor moving speed and dangerous level is not as high as outdoor, so without help of other sensors also can move safety and follow the path planned. The Figure 2.1 shown the summary of the literature review.

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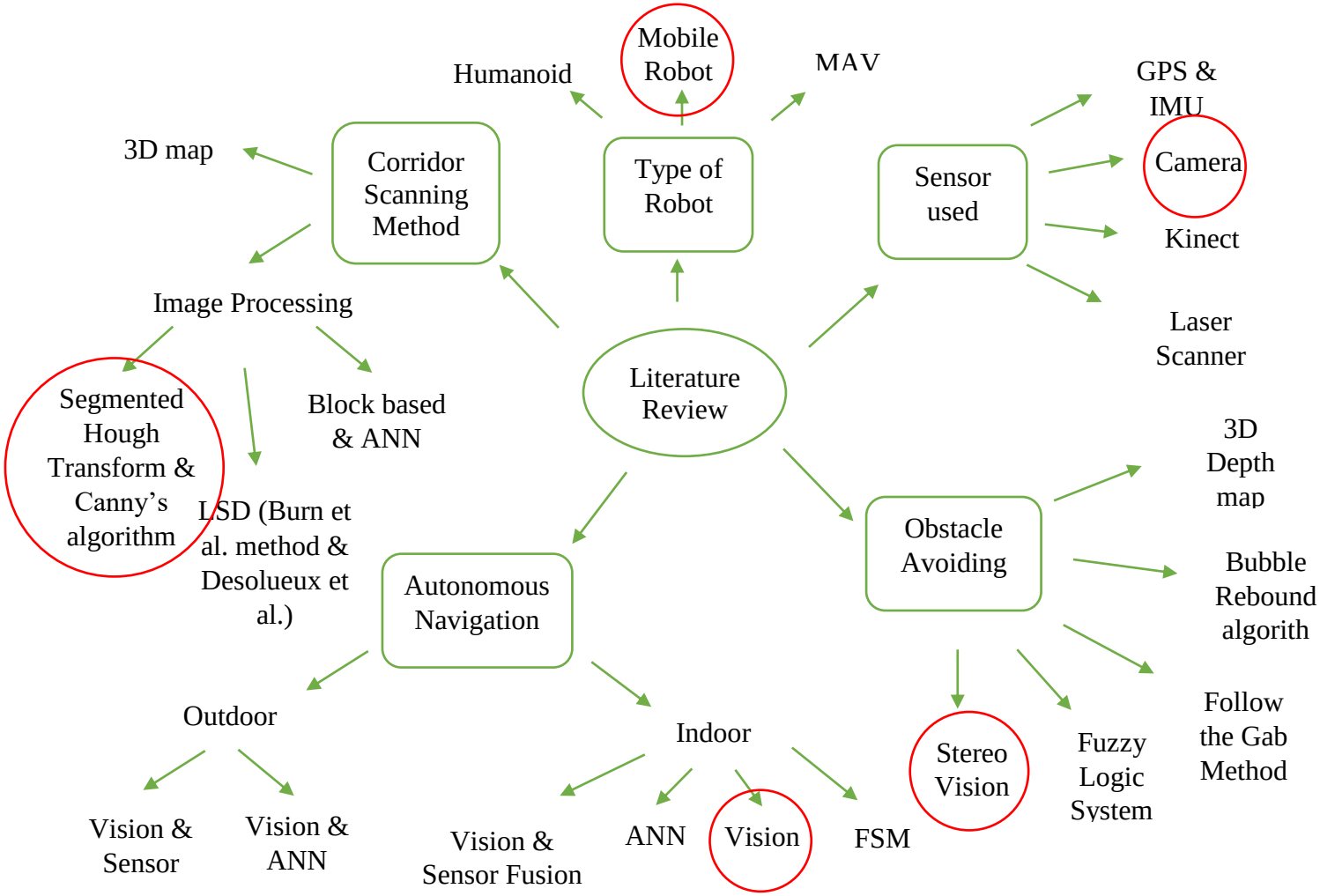

Figure 2.1: Summary of literature review

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