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"I hereby declare that I have read through this report entitle "Environment Mapping Using Multiple Robot" and found that it has comply the partial fulfilment for the awarding the degree of Bachelor of Mechatronics Engineering with honours."

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ENVIRONMENT MAPPING USING MULTIPLE ROBOT

LEE PEI KEE

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

2017

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DECLARATION

I declare that this report entitles "Environment Mapping using Multiple Robot" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

To my beloved mother and father

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Throughout the entirety of the project, I was in contact with various people, researchers, and academicians all of whom plays an important role in completion of this report. I place on record, my sincere thank you to Universiti Teknikal Malaysia Melaka (UTeM) for providing me with all the necessary facilities for the research. I feel grateful for having chance to meet many wonderful people and professionals who provide a good experience throughout this bachelor program.

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ABSTRACT

Navigation is needed for any tasks that are related to environment mapping. Navigation can be defined as the combination of three fundamental abilities which are self-localization, path planning and map-building. Localization, mapping, obstacle avoidance, path planning, and motion control are the basic capacities of the mobile robot. Simultaneous localization and mapping (SLAM) is one of the techniques for navigation to enable the robot to move autonomously and observes its surrounding in an unknown surrounding. Nowadays, the rescue robots are able to achieve many tasks, however they are mainly depending on the remote control and lack of the ability to explore the site. It is clearly demonstrated the need of rescue robots to respond to the collapse environment that cause by disaster. Rescue environment is considered a typical unstructured environment which no information about the surrounding. The objective of this study is to implement SLAM algorithm for environment mapping by using multiple mobile robot. The performance of the system will be compared in term of time taken and accuracy with single robot and multiple robot by using Extend Kalman Filter based SLAM. The experiments are conducted by using Pioneer P3dx robot that equipped with ultrasonic sensors and laser ranger with fusion strategy. The mobile robot will observe the surrounding environment by using ultrasonic sensors and laser range finder to detect the obstacles. Extend Kalman filter for robot localization is predicting the new state and correcting with the new observation measurement. The result of the experiment shows that multiple robot able to complete the mapping process faster than a single robot which improved by 17.6%. Besides, the accuracy of all estimated landmarks is improved after increase the number of the mobile robot. The accuracy of the estimated landmark is improved by 14.16%.

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ABSTRAK

Navigasi merupakan tugas yang diperlukan dalam pemetaan persekitaran. Navigasi dikategorikan kepada tiga tahap kebolehan asas iaitu penyetempatan diri, perancangan laluan, dan pembinaan peta. Penyetempatan, pemetaan, penghindaran halangan, perancangan laluan dan kawalan pengerakan adalah keupayaan asas untuk robot mudah alih. Penyetempatan serentak dan pemetaan (*SLAM*) adalah salah satu teknik untuk navigasi dengan membolehkan robot untuk bergerak secara autonomi dan memerhati sekeliling di persekitaran yang tidak diketahui. Pada masa kini, robot penyelamat dapat mencapai tugas-tugas yang banyak tetapi sebahagian besarnya bergantung pada alat kawalan dan kekurangan keupayaan untuk meneroka. Robot penyelamat haruslah mampu untuk bertindak balas kepada persekitaran yang dilanda bencana. Persekitaran menyelamat boleh dianggap sebagai persekitaran tidak berstruktur dimana tiada maklumat di kawasan sekeliling. Objektif kajian ini ialah untuk mengaplikasikan logaritma *SLAM* untuk pemetaan persekitaran dengan menggunakan robot mudah alih. Prestasi system dianalisa dengan membandingkan jangka masa yang diambil untuk melaksanakan pemetaan dan ketepatan dengan menggunakan *Extend Kalman Filter* berasaskan *SLAM*. Eksperimen akan dijalankan dengan menggunakan robot P3dx perintis yang dilengkapi dengan pengesan ultrasonik dan pengesan laser. Robot mudah alih akan memerhati persekitaran dengan menggunakan pengesan ultrasonik dan pencari laser untuk mengesan halangan. *Extend Kalman Filter* akan digunakan untuk Penyetempatan robot bagi meramal koordinat baru dan membetulkan dengan sukatan pemerhatian baru. Hasil eksperimen menunjukkan bahawa peningkatan jumlah robot dapat melengkapkan proses pemetaan lebih cepat daripada sebuah robot. Masa melengkapkan proses pemetaan telah bertambah baik sebanyak 17.6%. Manakala, ketepatan untuk tanda tertentu telah bertambah baik sebanyak 14.16 %.

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CHAPTER 1

INTRODUCTION

This chapter describes the background, motivation and problem statements to give an idea of the contribution of this research study. The objective, scope and significance of the study are also described. Lastly, this chapter ends with an outline of the thesis.

1.1 Background

In mobile robot field, the ability of navigation is one of the vital capability. Navigation is needed for any tasks that are related to environment mapping. Navigation can be defined as the combination of three fundamental abilities which are self-localization, path planning and map-building [1]. Localization, mapping, obstacle avoidance, path planning, and motion control are the basic capacities of the mobile robot [2]. Environment mapping plays an important role in mobile robot application that can help mobile robot to accomplish tasks independently.

Simultaneous localization and mapping (SLAM) is one of the techniques for navigation to enable the robot to move autonomously and observes its surrounding in an unknown surrounding [3]. The challenges of the localization are divided to two type of situations which are the confidence in the estimation of the real pose and when the confidence is insufficient. There are many possible ways to solve SLAM by using several type of sensor such as ultrasonic, sonar, lasers, odometry, GPS and video camera [4]. Environment mapping for robot navigation is involved in two problem which are the building of the map

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and the localization of within the map[5]. These two task are related to each other. SLAM algorithm brings a lot of benefit to urban search, rescue and underwater exploration.

1.2 Motivation of Research

While natural disasters and accident cannot be avoided, rescue robot has become a popular topic of artificial intelligence study, which help in exploration on disaster or accident site. Nowadays, the rescue robots are able to achieve many tasks, however they are mainly depending on the remote control and lack of the ability to explore the site [6]. From 1994 to 2013, Centre for Research on the Epidemiology of Disasters (CRED) reported there are 6873 natural disasters worldwide, which claimed 1.35 million lives on average each year [7]. It is clearly demonstrated the need of rescue robots to respond to the environment collapse that cause by disaster. Rescue environment is considered a typical unstructured environment which no information about the surrounding. The positioning and mapping are vital in this type of environment [8].It is getting necessary to develop a system that can generated map information on the disaster sites to share the information among the rescue mission participants [9].

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1.3 Problem Statement

In recent years, Simultaneous localization and mapping (SLAM) has attracted more and more attention due to its computation's high complexity and cost [10]. Simultaneous Localization and Mapping (SLAM) can be defined as the problem of building a map of an unknown environment and at the same time generate an estimation of the location of the robot. Environment mapping by using mobile robot can defined as the ability of a mobile robot to construct a map and to navigate an unknown environment. Mapping and localization are dependent to each other which often refer to as a chicken and egg problem. The common problem that face by a mobile robot is that how to know its position and orientation and its localization. It can be said that an accurate map is needed for localization whereas an accurate pose estimation is needed to build a map.

Most of the mobile robots perform an exploration in unknown environment are equipped with ultrasonic sensors that used to monitor the surrounding environment [11], [12]. However, it mainly detects the current position which may affect the speed to carry a mapping task, especially when performing fast moving task and crowed area. The mobile robot may have a global navigation problem because the robot cannot explore to the goal state from its initial position in large scale space. Therefore, to solve the problem a concept called fuzzy set concept is introduce as a useful tool for sensory perception.

Another issue about the mapping works are the accuracy and reliability of the sensors. Most of the sensors such as Kinect, infrared, camera, and laser range finder have their own limitation and function [13], [14]. The problem may occur for using an ultrasonic sensor may affect by the interaction of speed of sound, angular uncertainly, and blanking interval. Multiple sensors can be used to enhance the performance of the system.

An accurate localization can be defined as a prior condition to building a good map and necessary for precise localization. The accuracy of the environment mapping is depending on how the robot recognizes the environment and its location. There are so several kinds of sensor measurement and information obtained is usually unreliable. The accurate sensor data and reliable localization are the basic requirement in map building process[2]. Furthermore, there are unpredictable and complex dynamics in a real-world environment. The error in

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position and orientation will increase over the time. This is the reason why Extended Kalman Filter has been introduced.

Odometry can defined as the process of to determine the distance covered by robot using speed of the robot which easily accumulated error with time [15]–[17]. Another challenge for a humanoid robot to perform precisely navigation is the motion odometry is computed from the relative motion of the legs, that often slip. The odometry error is increase over the time. It can be improved by implemented visual features.

Thus, the research question *is does the implementation of multiple robot able to solve accuracy issue when using SLAM algorithm?*

Besides, it is a challenge problem as the consistent mapping depends on the information of the robot's current pose, whereas the self-localization required an accurate map of the environment [18]. Environment mapping by using multiple robots are getting concerned in the past few years. One of the challenges of using multiple robots in environment mapping is the completing time to complete a mapping between each other.

Hence, the research question *is does multiple robot able to complete the mapping process faster than single robot?*

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1.4 Objective of Research

From the research questions stated in the problem statement, the objectives are:

1. To implement SLAM algorithm for environment mapping by using multiple robot.
2. To evaluate and compare the time taken to complete mapping between the single robot and multiple robot when using SLAM algorithm.
3. To evaluate the accuracy of the estimated landmarks between the single robot and multiple robot when using SLAM algorithm.

1.5 Scope of study

The scopes of the research are as follows:

1. The method based SLAM will be simulated.
2. The software used for simulation is V-REP software and Matlab software.
3. The simulation will use Pioneer P3dx mobile robot for environment mapping that equipped with ultrasonic sensors and laser scanner.
4. The ultrasonic sensor detected a surface especially a hard or flat surface to receive ample sound echo.
5. The detect ranging measurement for ultrasonic sensor provides 2cm – 400cm.
6. The map size with the area of 10m x 10m.
7. The map is constructed with 80cm high grey wall.

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1.6 Significant of Study

This research will contribute:

1. Application in UAV and rescue purpose.
2. To improve the accuracy of pose estimation value.
3. To reduce the estimation error and mapping error.
4. To show the effectiveness of using multiple robot in environment mapping.

1.7 Thesis Outline

This report and project is about environment mapping using multiple robot using Pioneer P3dx mobile robot. In this report, motivation for design and develop this system is cover in chapter 1. Besides, the objectives and scope of the system will be stated in this chapter. In the following chapter, the review of previous related work of the environment mapping is discussed. In chapter 2 also, some basic principles and theories are defined and stated. The experiment setup and type of the experiment is discussed in chapter 3. Chapter 4 and Chapter 5 are analyzed and discussed.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Different types of method to solve Simultaneous Localization and Mapping (SLAM) problem are discussed in this chapter. The discussion here focuses more on environment mapping on mobile robot application. This chapter firstly starts with introduction of localization and mapping system. Next, the description of SLAM. Then, the problem of SLAM is identified with several methods and the analysis of SLAM problems are discussed. Lastly, the benefit for SLAM algorithms is discussed.

2.2 Localization and Mapping System

In the era of globalization, the combination of mobile robots, localization and mapping system was being used in many fields and applications such as in medical, industrial, home appliances, tracking system, and positioning. This combination is able to help human work become easier and it may perform the work accurately.

Localization can be described as a major techniques to tracking a position of an object, people, or a certain location and intercepting over network channel [19]. It can be said that, the mobile robot localization has to complete the task by searching a position of a particular target [14]. Localization can be defined as the process of determining the mobile robot's position and orientation accurately relative to a given map of the environment using the data

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obtained from the sensor of the mobile robot [20]. The term of mapping can be presented as a ‘metric’ or ‘topological’ which define as the illustration of environment based on the information from surrounding that represented in a graphical image. The mapping helps localization by giving the location of the target or object positions and helps in describing the environment plan [14].

Robotic mapping can be defined as the ability of a mobile robot to construct a map and to navigate an unknown environment [21]. Robotic mapping has commonly referred as Simultaneous Localization and Mapping (SLAM) and Concurrent mapping and localization (CML) [22]. The task of map building and navigation can be carried out by using mobile robot such as by considering how a team of robots that consists of one navigation and several cartographer robots to perform collective mapping and collective navigation tasks [23]. Mapping algorithms produce environment maps for specific purpose which can classified to three group which is metric maps, topological maps and hybrid maps which are the fusion between metric and hybrid maps. Grid map is the special type of metric maps which is most commonly used in the mapping techniques [2].

To be conclude, environment mapping plays an important role to help mobile robots achieve tasks independently. The relationship between localization and mapping are deeply connected between each other because the localization needs the help of mapping information. In order to solve the interconnection between localization and mapping, the concept of SLAM is extensively studied.

2.2.1 Map Building

Map building interpret the map of any notation describing locations within the frame of reference[1]. Kalman filtering method is used to construct our map which categorized to two stages. First stage is updating and predicting stage that gives the estimated location of the feature points of the map. Second stage is matching stage which the robot will matches the feature point during observation [6].

Kinect is used to collect depth information colour image for mapping building. The depth information is measured by Kinect which used API used by Kinect to minimize the computational load [10]. L. L. Silva has proposed an environment mapping method to build

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