UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

DEVELOPMENT OF MOBILE ROBOT AND LOCALIZATION SYSTEM

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DEVELOPMENT OF MOBILE ROBOT AND LOCALIZATION SYSTEM

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature: ………………………………………….

Supervisor Name: ………………………………….

Date: ……………………………………………….

DECLARATION

I declare that this thesis entitle "Development of Mobile Robot and Localization 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	:	Khairul Anuar Bin Juhari
Date	:	

DEDICATION

To my beloved wife and my family

ABSTRACT

Mobile robot is currently being actively developed for both civilian and military use to perform dull, dirty and dangerous activities. Mobile robot is autonomous in nature, capable of operating over a wide variety of terrain and can be characterized by different speed, sensor range and weapons capabilities. Thus, the research involves designing an indoor mobile robot and creating algorithm for the mobile robot to localize. As such, the purpose of this thesis is to develop the localization of the mobile robot based on Extended Kalman Filter (EKF) method. The process begins with the mobile robot mechanical design where a selection of wheel types and types of locomotion are selected. Then the odometry corrections using a method called University of Massachusetts Benchmark (UMBmark) method has been used to improve the encoder readings. As a part of the research contribution, a Circular Bencmark (CBmark) method is created in order to improve the motor speed by calibrating the encoder speed readings on each motor. Then the algorithm is built based on EKF method and tested via simulations. The simulation runs on two different cases that require the mobile robot to move to the target location while the time to accomplish and the distance between the mobile robot center gravity (cog) are taken. Then, the same algorithms are put on the hardware and the experiment runs same as in simulations. The performance of the mobile robot is compared between simulations and the real experiment based on graph of performance.

ABSTRAK

Pada hari ini, robot bergerak sangat meluas digunakan di dalam ketenteraan dan awam untuk melaksanakan aktiviti yang berbahaya, kotor dan berisiko tinggi di mana manusia tidak mampu melaksanakan tugas tersebut. Robot bergerak pada asasnya mampu berfungsi dengan sensiri tanpa bantuan manusia dan boleh beroperasi di pelbagai kawasan dan boleh dibezakan melalui kelajuannya, jarak bacaan penderia dan kebolehan senjata. Oleh itu, objektif kajian ini melibatkan pembinaan robot bergerak di dalam bangunan dan mencipta algoritma bagi pergerakan robot. Kajian ini juga menggunakan kaedah "Extended Kalman Filter" (EKF) bagi proses penetapan lokasi robot. Proses bermula dengan pembinaan rekabentuk mekanikal di mana pemilihan tayar dan kaedah locomotif dipilih. Setelah itu, pembetulan ke atas penderia odometer dijalankan dengan menggunakan kaedah "University of Massachusetts Benchmark" (UMBmark). Sebagai sebahagian daripada penglibatan terus terhadap kajian ini, kaedah "Circular benchmark" (CBMark) telah diperkenalkan. Kaedah CBmark ini akan meningkatkan ketepatan bacaan kelajuan motor dengan menambahbaik bacaan kelajuan pada enkoder motor. Setelah itu, algoritma bagi robot bergerak dicipta dengan menggunakan kaedah "Extended Kalman Filter" (EKF). Kemudian, algoritma ini diuji melalui perisian simulasi komputer dan ia juga diuji keatas robot bergerak melalui 2 tuigasan berbeza. Kemajuan robot bergerak dari segi kepantasan masa yang diambil untuk melengkapkan setiap tugasan akan dibandingkan dengan simulasi komputer dan keputusan diolah di dalam bentuk graf.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

ΔS_r	-	Distance travel of right wheel/encoder
ΔS_l	-	Distance travel of left wheel/encoder
b	-	Axle distance between right wheel and left wheel
π	-	Pi = 3.1415
v_r	-	Velocity of right wheel = quad pulse/seconds (QPPS)
v_l	-	Velocity of left wheel = quad pulse/seconds (QPPS)
v_{avg}	-	Velocity average = quad pulse/seconds (QPPS)
P	-	Position of robot in global coordinate
$\{W\}$	-	World coordinate frame
$\{R\}$	-	Robot coordinate frame
E_{count}	-	Encoder count per revolution of motor
$E_{encoder}$	-	Encoder resolution given by manufacturer
N_{ratio}	-	Motor gearhead ratio given by manufacturer
$D_{(diameter)}$	-	Diameter of wheel
$Dtravel_{(distance\ travel)}$	-	Travel distance of wheel for one rotation
$S_{(desired\ speed)}$	-	Actual motor speed
$x_{c.g;cw/ccw}$	-	Center of gravity of x-axis for mobile robot
$y_{c.g;cw/ccw}$	-	Center of gravity of y-axis for mobile robot
$r_{c.g,cw}$	-	Absolute offset of center gravity for clockwise direction
$r_{c.g,ccw}$	-	Absolute offset of center gravity for counter clockwise direction
Σ^j_{INt}	-	New position predictedbased on Extended Kalman Filter (EKF)
H^j	-	Jacobian matrix
H^{jT}	-	Matrix response

$\hat{P}_t$	-	Correlation matrix
R_t^i	-	Matrix of measurement error
Σ_{INt}^{j}	-	State update mobile robot position
z_t^i	-	Coordinate frame of sonar sensor

CHAPTER 1

INTRODUCTION

1.1 Introduction to mobile robot

Mobile robotics is a young field. It includes many engineering and science disciplines from mechanical, electrical and electronics engineering to computer, cognitive and social sciences. For example, AGV (Autonomous guided vehicle) robot autonomously delivers parts between various assembly stations by following a special electrical guide wires installed in the floor. Using these wires as a guideline, the mobile robot can autonomously navigate itself from one place to another place.

In general, mobile robots consist of wheel or terrain known as a mobile mechanism and also sensors that are integrated with a controller and it can be operated neither human nor autonomous (Guivant, 2000). Additionally the system has fully automated way known as localization and controlling its path according to prediction using mathematical method or logics. In robotic applications, localization means the ability to determine position of a robot in its frame of references and then to plan a path towards some goal locations (Guivant, 2000).

Furthermore, localization also consists of combinations of the three fundamentals which are self-localization, path planning and map building. Self-localization means the ability of a robot to locate its position in a global map, while path planning refers to the way a robot makes its decision for its target and map building requires the robot to locate and mark its position while it navigates. As shown in Figure 1.0 the blind man represents a mobile robot platform that has the capability of doing motions and its sensory is controlled by a puppy and a kitten. This represents the problem of navigation that can be translated to a 3 differences of terminology; localization, position and navigation (Guivant, 2000). The localization will keep questioning on how the robot locate itself in the environment given. The second situation keeps asking about the position of the robot and the third situation is the navigation where the robot plans its path that results in achieving the goal.

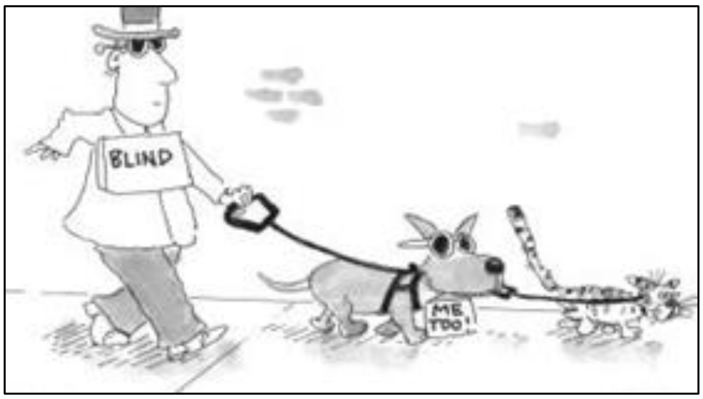

Figure 1.0 The blind man (Edwing, 1998).

Over the past 4000 years ago, these problems have been determined that it takes the basic process of measuring distance, correlation and triangulation to successfully build and managed the accuracy of Mediterranean area (Guivant, 2000).

In robotics applications, there are many methods that have been studied by previous researchers. For example from Figure 1.1, Samperio (2010) developed a quadruped robot that uses a visual localization to navigate in a dynamic environment. The robot would need to locate a landmark within its surroundings and create an algorithm which determines any entity of interest in the global references.

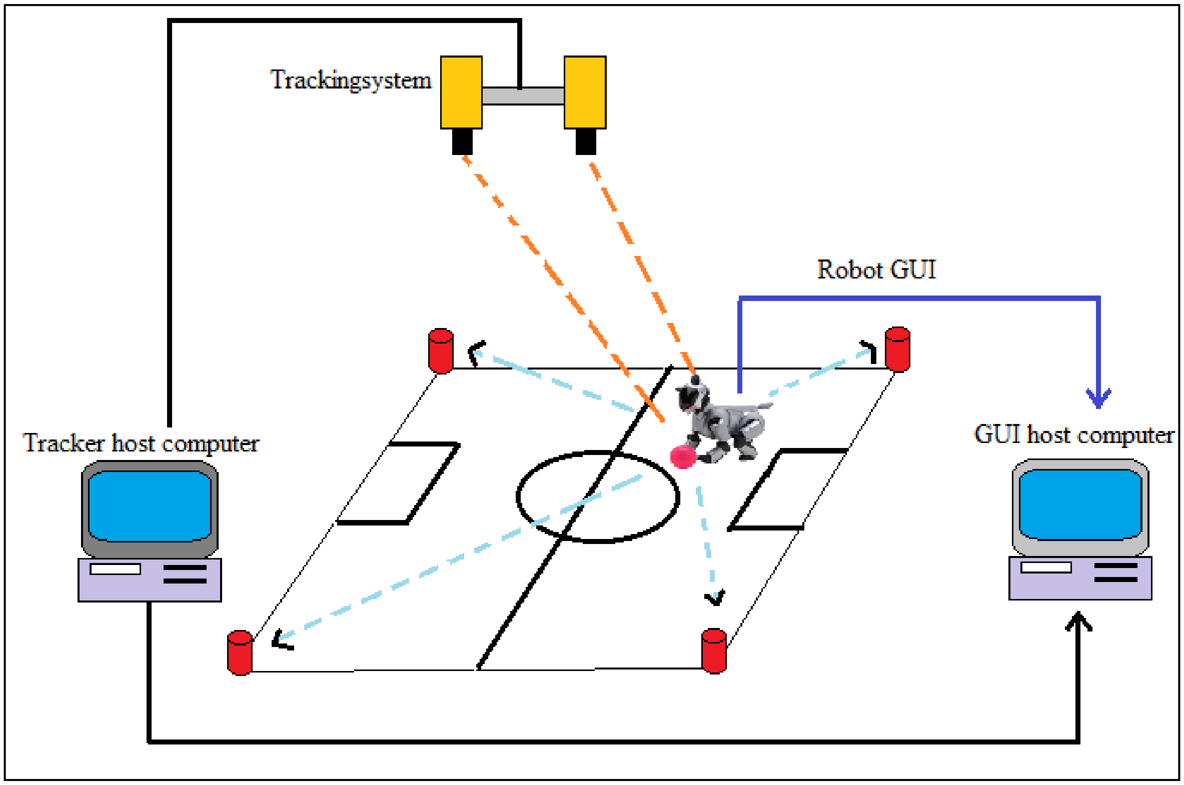

Figure 1.1 Complete configuration of human-robot interface (Samperio, 2010).

Jung (2011) had come out with procedures than can be used for robot to navigate based on dead reckoning sensor and absolute position measurement. The method is called University of Massachusetts Benchmark (UMBmark) method. This method can be used for tuning the encoder and improve the encoder reading. The UMBmark use an offline method to tune the encoder reading and it calibrated the encoder to improve the accuracy.

1.2 Problem statements

Conventionally, in order to use mobile robot in industries, manufacturers have to take many considerations into account in planning the layout for the robot to follow especially when using a line following mobile robot. This type of mobile robot could waste many valuable spaces, in the other words the space that could be used for other machines must be kept clear to make a way for the mobile robot path. This means, conventional path of the mobile robot are planned based on the availability of spaces that the robot could move and not robust. A fixed sensor such as one sensor for one program of the robot also may cause the limitations to the robot. Fix sensor in this context refer to the dead reckoning sensor such as an encoder and other positioning sensor which can only give one reading at a certain time. For example, a mobile robot uses line following sensor to move according to the path given and the sensor only detect the line to navigate. If there are any changes on layout, the engineer has to reprogram the mobile robot and as a result, a delay in time will occur. In order to encounter this problem, a type of mobile robot that has a robust system is suggested. The mobile robot should have the ability to track the changes of its environment while it's moving. This requires the capability of navigation and localization.

1.3 Objectives

The objectives of this project are listed as follows:

- To design and fabricate a mobile robot.
- To develop the localization system of mobile robot based on Extended Kalman Filter (EKF) method.
- To validate the performance of the mobile robot localization system.

1.4 Scope of limitations

In order to achieve the objective, there are a few limitations that need to be considered. These limitations are as listed below,

- The design phase of the mobile robot refers to the creation of the mechanical part of the robot and not using any advanced machine to fabricate.
- Robot will navigate autonomously in predefined area of playing field and filled with artificial landmarks.
- Localization results are based on indoor applications only and tested on a hard surface floor to minimize the errors especially the trajectory errors. The robot also designed to be used in indoor environment only with standard flat surface floor.
- Maximum speed of the robot has been limited 50 rpm (round per minutes) to reduce unattended errors due to low cost sensors and the motor gear reduction ratio. The operation of the robot also limited to 30 minutes for a single operation due to the limited current supplied from the battery to the robot electronic control and motors.
- Another issues on global references frame also been countered and all positions estimations and prediction level of percentage is less than the actual result due to the manufacturer technical specifications.

All this limitations has been set for future references and at the end of this research, the results could be used to improve the systems later.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of mobile robot

Nowadays, a desirable mobile robot will be more sophisticated and automated due to the rapid development in science and machines technologies. Mobile robot is a robotic platform that is being used as an extension of human capability such as carrying a heavy load, and exploration. This type of robot is generally capable of operating outdoors and over a wide variety of terrain, functioning in place of humans and controlling using teleoperatedly or autonomously. With the help of sensors and algorithm, the mobile robot can explore the unknown terrain or discoverable terrain itself.

Sensors can provide some limited feedback such as distance travel, position and location to the robot so it can do its job. Maxim (2004) indicates that, in order for the robot to navigate through the environment from point to point, the robot should be able to choose an action to maximize its chances of getting to its goal with the help of sensors. This can be done using probabilistic navigation. Maxim (2004) also indicates two methods in determining the probabilities which are devided into two stages, stage one as planning and stage two as navigation. By assuming the specified goal the robot can be guided to the closest position. This method uses a node lock systems where the nearest node will assist the robot to the goal triggers and triggers the navigation field computation as illustrated in Figure 2.1.

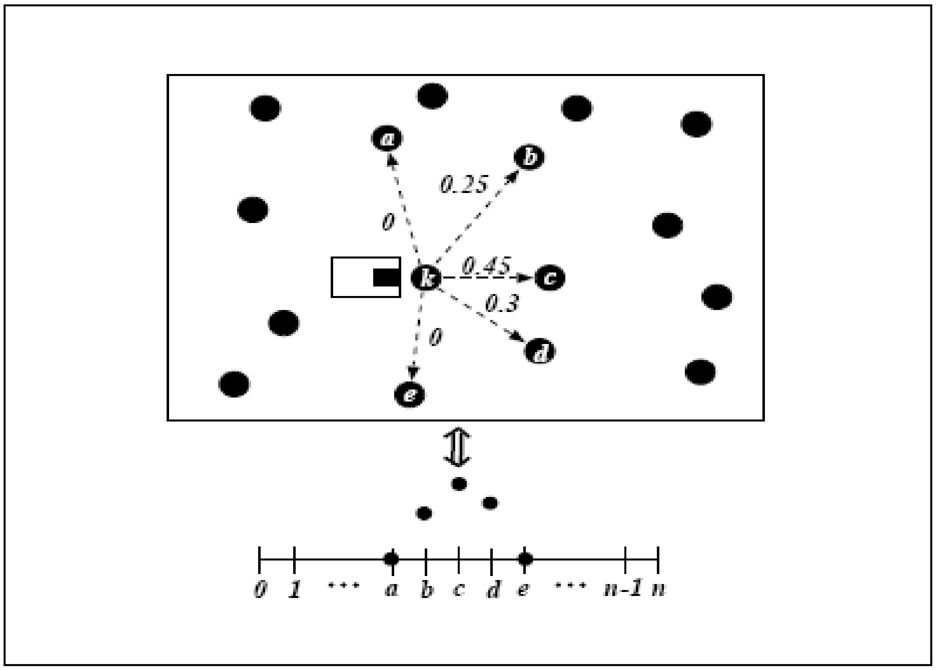

Figure 2.1 Discrete probability distribution of vertex (Maxim, 2004).

Figure 2.1 shows the system model that is used by Maxim (2004) is based on Markovian method. This method will state the robot transition to depend only the current state and action. As a result, by using this method, other robot which may not have to explore the entire space can use the information for navigation. This solution is however inefficient since it is slow in response to the navigation goal changes.

To compare with Guivant (2000), the basic navigation loop is based on dead reckoning sensors that predict the frequency maneuver and low frequency absolute sensors that bounce the positioning errors. By combining dead reckoning sensors and bearing sensors (laser range sensor, ultrasonic sensor range sensor, etc), this land robot could obtain a reasonable prediction of the vehicle trajectory (Guivant, 2000). Recently, ultrasonic sensor has been widely used for most indoor applications but they are not adequate for most outdoor applications due to its limitation and bearing uncertainties (Paola, 2010)**.** Ultrasonic sensor