THE MOBILE ROBOT SYSTEM FOR MAPPING AND LOCALISATION UTILISING SINGLE LASER RANGE FINDER IN STATIC ENVIRONMENTS

by

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LIST OF ABBREVIATIONS

1NN	1 Nearest Neighbour
2D	2-Dimensions
3D	3-Dimensions
AI	Artificial Intelligent
ANN	Artificial Neural Network
AUV	Autonomous Underwater Vehicle
CDF	Cumulative Distribution Function
DCV	Direct Current Voltage
DP	Dynamic-Programming
DSP	Digital Signal Processing
EDF	Empirical Distribution Function
EKF	Extended Kalman Filter
GA	Genetic Algorithm
GPS	Global Positioning System
GUI	Graphic of User Interface
ICP	Iteration Closest Points
INS	Initial Navigation System
KNN	K Nearest Neighbours
LDA	Linear Discriminant Analysis
LM	Local Map
MANOVA	Multivariate Analysis of Variance
MYR	Malaysian Ringgit
PC	Personal computer
PCA	Principle Component Analysis
RFID	Radio Frequency Identification
RSSI	Received Signal Strength-Indicator
SDK	Software Development Kits
SLAM	Simultaneous Localisation And Mapping
SNR	Signal To Noise Ratio
TOF	Time Of Flight
UAV	Unmanned Aerial Vehicle

UGV	Unmanned Ground Vehicle
USB	Universal Serial Bus
WSN	Wireless Sensor Network

LIST OF SYMBOLS

D / d	Distance
cm	Centimeter
m	Meter
x	Coordinate at horizontal axis
y	Coordinate at vertical axis
θ	Theta/angle
σ	Standard deviation
^{o}	Degree

Sistem Robot Mudah-Alih Untuk Pemetaan dan Penyetempatan Menggunakan Satu Laser Pencari Julat Untuk Digunakan Di Dalam Persekitaran Statik

ABSTRAK

Sistem robot mudah alih dengan keupayaan untuk melaksanakan pemetaan dan penyetempatan mempunyai potensi untuk digunakan dalam pelbagai aplikasi seperti dalam dan di luar bangunan, di kawasan yang diketahui dan tidak diketahui, di luar talian dan dalam masa yang sebenar serta di dalam persekitaran yang statik dan dinamik. Pada masa ini, penggunaan robot mudah alih menggunakan ultrasonik, inframerah, RFID dan lain-lain sebagai penderia untuk pemetaan dan penyetempatan. Walau bagaimanapun, penggunaan penderia-penderia ini mempunyai batasan dan keburukan termasuk memerlukan rujukan untuk penyetempatan, memerlukan pengiraan yang tinggi, pemprosesan data yang perlahan kerana faktor penderia tersebut dan juga keputusan pengukuran penderia yang kurang tepat. Jadi, kajian ini mencadangkan penggunaan satu laser untuk robot mudah alih pemetaan dan penyetempatan bagi persekitaran yang statik. Laser yang digunakan adalah RP Lidar, dan penggunaannya membolehkan robot mudah alih untuk melaksanakan pemetaan dan penyetempatan di tempat yang dikenali, tidak diketahui, serta persekitaran dalaman yang berstruktur. Penggunaan laser secara tunggal ini boleh menolak kaedah penggunaan multi penderia dalam satu system untuk melaksanakan pemetaan dan penyetempatan. Sebuah robot mudah alih kawalan jauh telah diperkukuhkan dengan RP Lidar bagi membolehkan ia berfungsi secara autonomi. Pemetaan dan penyetempatan algoritma telah dibangunkan menggunakan pendekatan imbasan pemadanan dan mengeksploitasi pengimbasan kelajuan tinggi RP Lidar. KNN dan algoritma berasaskan peraturan telah diuji secara simulasi dan dalam persekitaran yang sebenar. Penilaian juga telah dilakukan terhadap sistem ini pada persekitaran dalaman yang berstruktur dan statik. Keputusan ujian menunjukkan bahawa sistem robot mudah alih berjaya memperolehi lokasi dirinya dengan ketepatan yang tinggi, iaitu, 90% dan ke atas. Selain itu, ia mampu untuk mengemudi ke lokasi sasaran dalam persekitaran statik. Pemetaan robot mudah alih dan sistem penyetempatan dengan penggunaan tunggal laser RP Lidar dapat menggantikan pendekatan menggunakan kaedah multi penderia dalam satu system dan ia juga berjaya menjalankan fungsinya dengan ketepatan yang tinggi untuk persekitaran statik.

The Mobile Robot System for Mapping and Localisation Utilising Single Laser Range Finder in Static Environments

ABSTRACT

A mobile robot system with the ability to perform mapping and localisation has the potential to be applied in various applications such as indoors and outdoors, known and unknown, offline and real time as well as static and dynamic environments. At present, implementations for these mobile robots utilise ultrasonic, infrared, RFID and similar sensing modalities. However, such implementations have severe limitations including the need of reference for localisation, high computational requirements, slow processing due to sensing requirements and may also be less accurate. Hence, this thesis proposes the utilisation of single laser range finder for mobile robot mapping and localisation system for static. The laser range finder used is the RP lidar, and its utilisation enables the mobile robot to perform the mapping and localisation in known, unknown, as well as structured indoor environments. The implementation of the laser range finder negates the need of multiple sensing modalities to perform the mapping and localisation. A remote control mobile robot was augmented with a single RP Lidar laser range finder and transformed to enable it to function autonomously. The mapping and localisation algorithm were developed using scan-matching approach and exploits the high-speed scanning of the RP Lidar. KNN and rule-based algorithm were implemented for decision making and the testing was performed both in simulation and as well as real world in real time. The evaluations of the proposed system were performed in static and structured indoor environments. The results of the testing showed that the mobile robot system was able to perform self-location with high accuracy, 90% and above. Also, it was able to navigate to the target location in static dynamic environments. The mobile robot mapping and localisation system with the use of single RP lidar laser range finder was able to replace the multiple sensing modalities approach and it was able to perform with high accuracy for static environments.

CHAPTER 1

INTRODUCTION

1.1 Introduction

During the last few decades, there has been an increase in the implementation of mobile robot systems to assist humans. These applications of mobile robots include operations in hazardous and volatile environments unsuitable for human operators such as underwater pipe investigations. Also, the benefits of using mobile robots have the additional advantage of possible higher accuracy and speed of operation.

The use of mobile robots has also seen successful implementations in various fields, such as home appliances (Roomba, 2016), military (Karthikeyan; Bolton, 2015), exploration (Tack, 2012; Clemens, 2016), search and rescue (Kunjin, 2012), tracking (Abel, 2004; Ivanjko, 2005; Huili, 2011) and positioning (Ghidary, 1999).

In mobile robot system, mapping and localisation can be considered as priority parts. Both are usually incorporated together in order to facilitate the mobile robot to move in a particular environment autonomously. Also, they can be applied to expand capability and function of a mobile robot. For example, in order to move to a target, a mobile robot needs information regarding its position and target position. Therefore, to get position information, an environment information is needed. The environment information can be represented in a map form. Based on the map, a mobile robot is able to locate itself in the environment. Also, it can estimate the path to the target. This example shows how the mapping and localisation is important to assist a mobile robot to navigate autonomously in an environment.

Many studies have been conducted to develop and design the mapping and localisation algorithms, methods and techniques in order to ensure a mobile robot is able to work accordingly. Most of the algorithms, methods and techniques that have been proposed and developed cannot work in general field, for example, indoor mapping algorithm cannot work for outdoor environment. In other word, most of the developed algorithm only can be applied in specific application and environment.

Recent studies regarding mobile robot for mapping and localisation system can be considered to have advanced with better technology. The applications are as expansive as mentioned above. This phenomenon occurs with the growing sensing modality technology, computerisation and the advent of new electronic devices. Also, it is expected to grow continuously.

The advancement of these technologies allows the mobile robot system to be used in wider research and applications as well as to solve many issue and problems. Even though the new technologies help to solve the mobile robot problems, it is still lacking especially in unstructured mapping, dynamic localisation, and large-scale environment. This thesis approaches issues regarding utilisation of single sensing modality for mapping and localisation and a strategy to build an accurate reference map.

1.2 Problem Statements

Based on previous and recent studies, there are many approaches and methods to set up a mobile robot system for mapping and localisation. As environment and issues to be solved are determined, a mobile robot system can be set up.

Typically, the research work on mapping and localisation system and algorithm development is based on these three subjects:

i. Mapping based on known pose.

ii. Localisation based on the reference map.

iii. Simultaneous localisation and mapping (SLAM).

Each subject carries its own issues and solution methods. Step (i) and step (ii) are related and they are also known as the fundamental technique to create the localisation algorithm. Here, the known pose is defined as the mobile robot scanning position. It is recognised and initialised at the early stage of work. Based on the scanning results at these known pose, the environment map can be constructed and is known as reference map. Finally, the reference map is used to localise the mobile robot position based on its current scanning.

Next, SLAM is describable as a technique where the mobile robot needs to map and localise its position at the same time. Most of the mobile robot system and its algorithm are considered complicated with high computational demands. The main requirement for this system is fast processing in terms of its scanning ability and data processing capacity. The use of this system can provide benefits to many applications, especially in exploration (Clemens, J., 2016).

However, each subject has their own limitations. For mapping based on known pose, there are a few issues:

i. To acquire accurate environment scanning results.

ii. To construct precise map (local and global map).

iii. To construct the global map based on a merger of the local maps.

These issues are highlighted because they may influence the accuracy and inaccuracy of the whole localisation results. The localisation process needs the local and global maps (reference maps) to estimate the mobile robot position. Furthermore, the global map can show the mobile robot position in the whole environment and the local map is used to estimate the mobile robot position based on its current scanning.

Basically, there are no specific or proper methods on building a global and reference map. Previous studies have shown that the methods are dependent on the environment, the application and implementation. For example, the global map development is based on the merging of local maps. The scanning position meanwhile may have several inaccuracies due to the mobile robot movement or the weakness of the sensors' capability. Then, there is also a need for a method to correct the scanning results so that the map is accurate and can be matched to the real environment.

The issue regarding the local map is related to the number and size of the map. This is because there are no previous studies that had proposed a formula on how to get the number of local maps about the size of the environment. The reason is similar to the method of building the reference map, which is dependent on the application and implementation.

The main issue regarding localisation is algorithm. Typically, there are three types of methods to construct the localisation algorithm:

i. Scan matching method

ii. Probability method

iii. Kalman filter

These algorithms are applied to calculate and estimate the mobile robot position based on the sensor scanning results and the reference maps. General issues that are related to the localisation algorithms are described below:

i. Improve the accuracy of the mobile robot position.

ii. Optimisation of the sensor scanning results.

iii. The computational complexity to the simple and fast data processing.

iv. Ability to apply in various environment and situation.

v. Dynamic localisation.

vi. Real time result.

Based on step (i) and (ii), as well as the mapping and localisation issue, it can be concluded that the fundamental technique still has limitations and it can be improved and optimised using appropriate sensors and methods.

Basically, the key point in mapping and localisation system is the utilisation of reference and without reference. The reference can be defined as the surrounding information that is obtained from the information source, and the source is not from the mobile robot system. It can be a beacon, a sensor as well as a priori map. Essentially, if the priori map is used, then the environment is classified as a known environment.

For researches that utilised beacons such as wireless sensor network (WSN), such as Mansor, H. (2012), the beacon would provide communication signal such as signal-to-noise-ratio (SNR) and received-signal-strength-indicator (RSSI) to its group. Then, based on these signals, each beacon in the group may determine the location of others beacons. Unfortunately, this set up has limited application which only provides the system to work in a specific and known environment. This also happens to the system which utilises a priori map. It is limited to a known environment.

Some researchers avoid using the reference method as described previously. The set up requires the mobile robot to be independent and depend on itself. At this stage, researchers utilise multiple sensors or multi types of sensors to support the mobile robot to make decision in terms of motion, navigation and position estimation of a target as well as itself. Moreover, this system appears smart and very promising in accuracy and reliability. Also, it is able to attain benefits from all the sensors and improve each sensor's limitation. However, it is limited by its high cost and high computational need because of the slow data processing.

Recently, some researchers have introduced the use of single sensor for the mobile robot mapping and localisation system. This is due to the sensing modality technology that have grown and successfully developed high accuracy and reliability. The most common sensors that are used are ultrasonic and laser range finder. However, ultrasonic sensors must be used with multiple ultrasonic in the system. This is due to the disability of single ultrasonic to perform 360° scan of surrounding area, unless, it includes a motor to allow the ultrasonic to be able to rotate and perform scanning. Yet, the scanning process is quite slow due to the signal transmission between the transceiver in the ultrasonic sensor. Hence, the system mostly fails to achieve real time system.

For the laser range finder, it has proven to be most popular among researchers due to the fast sampling processing which is able to get 2000 data per second. Unfortunately, it is very costly, for instance a laser range finger with four meter scanning range is about MYR 8000. Also, the cost increases as the range expands.

Nevertheless, an alternative new laser range finder is available, called RP lidar. It is developed in 2012 by Robopeak from China. The company managed to develop a relatively inexpensive laser range finder that costs only MYR 1900. As an added advantage, the scanning range is up to six meters. Hence, this thesis proposes to work with the implementation of a single laser range finder, the RP Lidar for mobile robot mapping and localisation system that enables it to work as a real time system in known and unknown, static and dynamic indoor environment.

1.3 Research Objectives

The main objective of this research is to propose for the utilisation of single laser range finder for mobile robot mapping and localisation system that would be able to work in a static environment.

Based on the main objective, several sub-objectives are laid down to support the main objective:

i. To construct proper steps on building reference map and a global map.

ii. To develop a localisation algorithm that is based on the single laser range finder scanning data and enable it to work in real time system.

iii. To implement the mobile robot that would be able to work in static environment with referring to the developed localisation algorithm results.