Faculty of Electrical Engineering

DESIGN AND DEVELOPMENT OF MOBILE ROBOT THEMATIC MAPPING USING FLEXIBLE ELLIPSE SHAPE REGION

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DESIGN AND DEVELOPMENT OF MOBILE ROBOT THEMATIC MAPPING USING FLEXIBLE ELLIPSE SHAPE REGION

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DECLARATION

I hereby declare that this thesis entitled “Design and Development of Mobile Robot Thematic Mapping using Flexible Ellipse Shape Region” 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 : MOHD HAFIZ BIN TAIB

Date :

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 Electrical Engineering.

Signature : ……

Supervisor Name : MUHAMMAD FAHMI BIN MISKON

Date :

DEDICATION

To my beloved family, family in law and wife

ABSTRACT

Map is used to associate the entity of normal data distribution of an environment and also be used as a reference to detect changes in monitoring application. However, there is limitation in the use of a map if the designer of a robot needs to consider its resources, such as usage of memory space. The available map has a problem in terms of rigid structure or rigid perception of robot heading and indirectly uses a lot of memory space. Therefore, a new mapping technique called flexible ellipse shape region is proposed in this study. The ellipse boundary can be changed to accommodate normal data distribution of environment and it allows perception of robot heading to be mapped to normal data distribution from 0° until 360°. The objective of this study is to design and validate a new mapping technique, called flexible ellipse shape region. The performance of the map will be compared with grid map, perception based map and flexible region map in terms of memory space, access time and accuracy of map. Number of region is used to measure memory space of different maps. Meanwhile, the access time is calculated using time complexity, while accuracy of map is measured using new technique of confidence region. The experiments were conducted using Amigobot mobile robot in an L-shaped environment equipped with sonar sensor. The robot also has to carry a light sensor and a temperature sensor. The results of the experiments have shown that flexible ellipse shape region used 0.13%, 5%, 13.04% of memory space when being compared to grid map, perception-based map and flexible region map when being mapped with non-directional sensor data. In terms of access time, flexible ellipse shape region has used less time when being compared to perception based map and flexible region map. However, flexible ellipse shape region uses more access time when being compared to grid map. Lastly, map accuracy of flexible ellipse shape region is found to be higher, which is about 55.5% when being compared to flexible region map when being mapped with non-directional sensor data.

ABSTRAK

Peta digunakan untuk memaparkan entiti taburan data normal persekitaran dan digunakan sebagai rujukan untuk mengesan perubahan seperti dalam aplikasi pemantauan. Akan tetapi terdapat had untuk menggunakan peta jika pereka bentuk robot memerlukan pertimbangan bagaimana sumber yang terdapat pada robot seperti penggunaan ruang memori dapat dioptimumkan. Peta sedia ada mempunyai masalah dari segi struktur yang rigid dan persepsi robot yang rigid dan secara tidak langsung menggunakan memori yang banyak. Oleh itu teknik peta yang baru yang dipanggil rantau fleksible berbentuk elips telah dicadangkan. Sempadan elips boleh bertukar untuk menampung taburan data normal persekitaran dan ia membenarkan persepsi robot untuk memetakan taburan data normal persekitaran daripada 0° until 360°. Objektif tesis ini adalah untuk mereka bentuk dan mengesahkan satu teknik pemetaan yang baru yang dipanggil rantau fleksible berbentuk elips. Prestasi peta ini akan dibandingkan dengan peta grid, peta berasaskan persepsi dan peta rantau fleksible dari segi ruang memori, masa mengakses dan ketepatan peta. Jumlah bilangan rantau digunakan untuk mengira ruang memori bagi peta yang berbeza. Sementara itu masa mengakses peta dikira dengan menggunakan kompleksiti masa. Kemudian ketepatan peta diukur dengan menggunakan teknik baru bagi rantau keyakinan. Eksperimen dijalankan dengan menggunakan robot mudah alih Amigobot di dalam persekitaran berbentuk L. Amigobot telah disediakan dengan sonar sensor. Robot mudah alih juga membawa sensor cahaya dan sensor suhu. Keputusan kajian daripada beberapa eksperimen menunjukkan rantau fleksible berbentuk elips menggunakan 0.13%, 5%, 13.04% ruang memori berbanding grid map, peta berasaskan persepsi dan peta rantau fleksible apabila memetakan data yang tidak sensitif pada arah. Dari segi masa mengakses rantau fleksible berbentuk elips menggunakan masa yang lebih sedikit apabila dibandingkan dengan peta rantau fleksible dan peta berasaskan persepsi. Walaubagaimanapun rantau fleksible berbentuk elips menggunakan masa yang lebih banyak apabila dibandingkan dengan peta grid. Akhir sekali, ketepatan peta bagi rantau fleksible berbentuk elips adalah lebih tinggi kira-kira sebanyak 55.5% apabila dibandingkan dengan peta rantau fleksible apabila memetakan data yang tidak sensitif pada arah.

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2. **TAIB, M. H**., MISKON, M. F., SAKIDIN, H. & SHA'ABANI, M. N. A. H. 2014. Defining the Boundary of Regions in Thematic Map Using Flexible Ellipse Shape Region. *Australian Journal of Basic and Applied Sciences (AJBAS 2014)*, 171-186.

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 here. Lastly this chapter ends with an outline of the thesis.

1.1 Background

Mapping is a technique to display and assign the entity for normal data distribution of an environment. Typical use of a map in robotics field is to determine a robot pose. A lot of researches have been done in this area. Sebastian Thrun in (Thrun, 2002) has described in details the characteristics of different mapping approaches (mainly for indoors environment). Other than determining robot pose, map is also used to have awareness of a robot surrounding (Toda et al., 2012, Mansley et al., 2011). The latter use of a map is described as *thematic map* (Radhadevi, 2013, Fauvel et al., 2013) or a map that represents the spatial pattern of attribute or theme. The objective of the map is to allocate the status of a normal data distribution with respect to where the measurement is taken in the environment. This research concentrates on the study of thematic map for mapping normal data distribution of an environment particularly for novelty detection. Example application

of such map is monitoring application (Boehm et al., 2013) or for adaptation or learning (Miskon and Russell, 2009a).

1.2 Motivation of Research

Computer memory is getting cheaper these days and cloud allows online storage (Almorsy et al., 2011). However, there are applications that still require considering memory space for storage. The problem of swarm robotic (Boubou and Tagawa, 2011) and micro robotic (Jaramillo et al., 2013) in terms of power supply, physical size and physical weight of the robot is taken seriously. As an example, flying micro robot (Heng et al., 2011) is restricted to carry the power supply. Thus, even though the price of memory is reasonable nowadays, designers are still thinking ways of how the robot's resources, such as memory space could be optimized. When memory space can be reduced that means more area can be mapped.

1.3 Problem Statement

Mapping normal data distribution is defined as mapping the commonly observed measurement with sensors. It is a task that cannot be taken lightly. This is because it varies from place to place or time to time. That is one of the difficulties in its modelling or mapping.

Furthermore conventional map such as grid map (Einhorn et al., 2011) and quadtree map (Cocaud and Jnifene, 2010) needs to be predefined and have a rigid structure (non-flexible). It causes these maps to use a lot of memory space. If the robot having small

physical size use conventional map such as grid map to map the normal data distribution of environment, this will reduce the size of the environment to be mapped, demands more energy and memory space. This is the reason why flexible region map has been introduced.

Flexible region map (Miskon and Russell, 2009b) has a flexible structure. The structure can grow and merge. The advantage of the map being, if the normal data distribution of environment has similar readings, the usage of memory space of flexible region map is less than conventional map. If the usage of memory space can be optimized that means more area can be mapped. However the flexible region map has a limitation if the normal data distribution of an environment is not aligned to 4 discrete values of robot heading such as 0°, 90°, 180° and 270°. If flexible region map faces the problem then the usage of memory space of the map is increased. Therefore, to solve the problem a new map called flexible ellipse shape region is proposed in this study.

Flexible ellipse shape region is a type of flexible maps. It is also able to grow and merge. When using the ellipse to define the boundary instead of rectangle, the angle of robot perception is not limited anymore because the boundary of the map can map the normal data distribution from 0° until 360°. For this reason, under certain condition the usage of memory space for the flexible ellipse shape region is less than flexible region map. This allows memory space to be optimized.

Another issue in the field of mapping is the access time (Miskon, 2009). When the normal data distribution is mapped using the flexible mapping technique, the access time to get the information from the map is not as direct as conventional grid map. Study on this performance parameter has not been conducted yet, therefore the performance of flexible maps in terms of access time is unknown. In this study, it is hypothesized that the flexible types of maps demand more access time as compared to the grid map.

The accuracy of the map is one of the topics in the study of mapping. The accuracy in this study is defined as how accurate the map can represent the normal data distribution of an environment (Jachalsky, 2010). When using flexible mapping technique, the boundary of the maps could change. Hence the measurement of the accuracy of map or how accurate the boundary created to bound the area of similar data distribution. If similar normal data distribution is mapped using flexible region map and flexible ellipse shape region, the accuracy of map of flexible region map is found to be higher because the total area of flexible region map is more flexible than ellipse shape region. This statement is based on general equations of rectangle and ellipse as shown in equation (1.1) and equation (1.2) where A_R is the area of rectangle boundary for flexible region map and A_E is the area of ellipse boundary of flexible ellipse shape region.

$$A_R = lenght \times width \tag{1.1}$$

$$A_E = major \times minor \times \pi \tag{1.2}$$

1.4 Objective of Research

The objective of this research is to propose and validate a new idea to overcome the problem of mapping normal data distribution of environment. It is based on the following points :

1. To design and develop a new map with flexible structure using ellipse shape boundary.

2. To design and develop a new map with flexible perception of robot heading using ellipse shape boundary.
3. To investigate the performances of different types of maps perceived by different types of sensors using different routes in terms of memory space, access time and accuracy of map.

1.5 Scope of Study

The scope of the research is as follows :

1. The experiments use Amigobot to collect normal data distribution of environment.
2. There are three types of normal data distribution of environment that will be collected, namely sonar data, ambient temperature and ambient light.
3. The experiments use sonar sensor, ambient temperature sensor and ambient light sensor.
4. There is one of the experiments that collect data of a lamp in a dark lab.
5. The test is conducted in a laboratory environment (L-shape).
6. The software used for developing offline maps is Matlab R2009a.

1.6 Significance of Study

There are many benefits when mapping normal data distribution using mobile robot. One of the advantages due to the mobility of mobile robot is it provide the opportunities and allows a static sensor to overcome its limitation such as limited work range (Russell, 2007). Hence, installation of static sensor was not practical because it