UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MOBILE ROBOT MOTION PLANNING BASED ON MOTION OF ARTIFICIAL POTENTIAL FIELD (APF)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotics and Automations) (Hons.)

by

FARIS ADAM BIN MOHD GHAZALI
B050910217
900730065185

FACULTY OF MANUFACTURING ENGINEERING
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ABSTRAK

Pada masa kini, robot mobil telah digunakan di dalam banyak sektor sebagai contoh di kilang, rumah, dan juga, sebagai penjejak periuk api. Pelbagai sektor menyebabkan robot perlu bekerja dalam pelbagai keadaan sekeliling yang mana sudah pasti mempunyai pelbagai halangan. Untuk memastikan robot bekerja dalam keadaan yang baik dimana ia mestilah berjaya untuk sampai ke sasaran yang dikendaki tanpa sedikitpun berlanggar dengan halangan yang terdapat di kawasan sekelilingnya, algoritma yang baik mesti diwujudkan. Masalah utama dalam robot mobil adalah untuk ia menempuh pelbagai objek didalam keadaan sebenar. Repot ini akan melakar dan memabangunkan satu algoritma robot yang mampu untuk mencari sasaran dalam keadaan sekeliling yang mengandungi pelbagai jenis halangan dengan menggunakan teknik-teknik yang telah digunakan oleh pengkaji. Semua algoritma yang telah dilakar akan di terapkan di dalam perisian MobotSim. Terdapat masalah yang berkaitan dengan kitaran limit yang timbul semasa membuat analisis dan lakaran algoritma untuk menyelesaikannya telahpun di perkenalkan. Untuk kerja pada masa akan datang, langkah penyelesaian kepada kitaran limit hendaklah diterapkan di dalam perisian MobotSim dan hendaklah di analisa hasilnya. Repot untuk semester ini mengandungi pengenalan, sorotan bahan rujukan,perkaedahan,dan juga rujukan.

ABSTRACT

Nowadays, mobile robot has been used in many sectors for example factory, household, and also mine clearance. Different kind of sectors shows that the robot needs to work in different kind of environment which of course consists of different obstacles. In order to ensure the robot to work in proper manner by successfully reach its target without colliding with the obstacles, the good algorithms should be created for. The main problem of mobile robot behavior is to face the variety of objects in the real environment. This report will design and develop a mobile robot algorithm that can seek for target in environment consists of different kind of obstacles by using the previous method that has been used by the researchers. All of the algorithms that have been design are being implemented in MobotSim Software. There are a problems regarding the limit cycle that arose during the analysis and the design algorithm to solve it has been proposed. For the future works, the proposed solution for the limit cycle needs to be implemented in MobotSim Software and analyze the results. The report for this semester consists of the Introductions, Literature Review, Methodology and Results.

DEDICATION

This "Projek Sarjana Muda" is lovingly dedicated to my respective parents, Mohd Ghazali bin Abdul Aziz and Anisahnor binti Abdul Jalil who are from the start give a lot of inspiration and motivation. They also give me the guide and increase my spirit to fight against any task and problems. Without their love and support, the project would not have been made possible.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

APF	-Artificial Potential Field
PFM	-Potential Field Method
VFF	-Virtual Force Field
VFH	-Vector Fied Histogram
IR	-InfraRed
mobot	-Mobile robot in MobotSim Software

CHAPTER 1

INTRODUCTION

1.1 Introduction

Mobile robot is come from two terms. One is mobile and the other one is robot. According to the free dictionary website, mobile mean capable of moving or of being moved readily from place to place. While robot is define as a mechanical device that sometimes resembles a human and is capable of performing a variety of often complex human task on command or by being programmed in advanced. Mobile robot is defined by Firat (2004) as an autonomous system capable of traversing a terrain with natural or artificial obstacles. Its chassis is equipped with wheels/tacks or legs and possibly a manipulator setup mounted on the chassis for handling of work pieces, tools or special devices.

Mobile robot can be classified in two types, which are the environment that they can travel and the device that they used to move. Most commonly, mobile robot use leg, wheel and tracks. There are bunch of behavior that mobile robot navigate for examples, line-following, wall-following and autonomously guided. Every mobile robot has its own specialties of goals, but all of them actually have same focus or behaviors to make it enable to complete the task given. The behaviors are about to seek and search for the given target and avoid any obstacles that it faces on its way towards the target.

However, in developing a mobile robot, there are few challenges and problems that need to face by the developers. One of them is to develop suitable mechanical structure based on the task that will be given to it and another one is to develop an algorithm that is suit with any kind of environment. The developing of the algorithm that can enable the robot to seek for the target while avoiding any obstacles it meets are quite a challenge to the robot developers. By developing the robot behavior using the mobile robot simulation with variety of obstacles can make the developers have more knowledge on the mobile robot behavior in real environment because it is simpler to modify the mobile robot in simulation rather than in real world. This is due to real mobile robot will take a lot of time, energy and money if the developers want to make changes to it behavior or modification. By using mobile robot simulation in early stage of development will reduce the time, energy, and cost of modification of real mobile robot.

1.2 Problems Statement

Mobile robot common tasks are to move and reach a target given and to avoid any obstacles that it faces on its way to the target. Straight away developing a mobile robot would take time, energy and money. Implementing the designed mobile robot in the simulation is the best way to reduce cost, energy and time. This is due the parameters of the robot can be set easily and any changes of sensor direction, sensors distance, and sensors placement would be easy when using the simulation software. But somehow, to make the mobile robot in simulation to be near to in real world robot, it needs to have real design on the robot platform and also its behavior. Without actual data of real mobile robot, the simulated robot would not be as same as the real robot. Therefore, developing simulated mobile robot require the developers to design it like a real robot. The problem statement is; developing a mobile robot that can achieve a specific goal in cluttered environment with many objects placed on the floor is a challenging task in mobile robotics.

1.3 Objective

From the problem statement above, the main objective is to develop a mobile robot that can achieve a specific goal with avoiding the multiples object on the floor. There are also other objectives that need to be achieved at the end of this report. They are:-

i. To develop a motion algorithm for local path planning of mobile robots,
ii. To make the motion algorithm to be fuzzy,
iii. To test the algorithm in environment with variety of obstacles.

1.4 Scope

This report is all about to solving the real time mobile robot algorithm when given specific target in the unknown environment consists of variety of obstacles. There is no physically development of mobile robot and all of the developments were in the MobotSim Software. The problems that state above will be solve by using the artificial potential field (APF) added with some other techniques. There will be an implementation of fuzzy logic in developing and modifying the algorithms. The solution is consider being useful to all type of mobile robot or mobile agent that will generate a path planning decision and navigate through unknown environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Mobile Robot

Mobile robot can be defined as an autonomous system capable of traversing a terrain with natural or artificial obstacles. Its chassis is equipped with wheels or legs and possibly a manipulator setup mounted on the chassis for handling of special devices, work pieces, or tools. A lot of pre-planned operations are executed based on a pre-programmed navigation strategy taking into account the current status of the environment. (Dudek and Jenkin, 2000).This definition is cover to any intelligent machine which moves with respect to environment within limited human interaction. Mobile robots can be classified by significant properties as locomotion (Legged, wheeled, limbless, etc.), suspension (Rocker-bogie, independent, soft, etc.), steering (kid, Ackerman, explicit), control algorithm (Fully-Autonomous, semi-autonomous), body Flexibility (Uni body, multi body), usage area (Rough Terrain, even surface, etc.).

Guidance and Navigation such as star field or GPS mobile robots can be used in several applications. Mobile robot also can be substitute with human workers when the working area is dangerous such as in highly chemical concentration area, high temperature area and also in highly extreme weather. For indoor use, there are floor cleaning robots and servant robots that can help to ease human life. It is not a dream that, in near future robots will be a part of our daily life. (Dudek and Jenkin, 2000)

2.2 The Potential Field Method

Potential field idea is actually taken from the natural for instance, a charged particle navigating a magnetic field, and a small ball rolling down a hill. Potential field methods (PFM) for obstacle avoidance have gained increased popularity among researchers in the field of robots and mobile robots during past few years. The idea of virtual forces acting on a robot has been suggested by Andrews and Hogan (1983), and Khatib (1985). In these approaches obstacles exert repulsive forces onto the robot, while the target applies an attractive force to the robot. The sum of all forces, the resultant force R, determines the subsequent direction and speed of travel (Koren and Borenstien, 1991).

They all move according on how strength the field or how high the hill. This situation also can be applied to the robot behavior by creating an artificial potential field. When apply it to the robot, it will attract the robot towards the goal.

For instance, let’s assume that the robot operates in an environment without any obstacle and what it needs to do is just seek for the goal. To do that in conventional planning, one should calculate the relative position of the robot to the goal, and then apply the suitable forces that will drive the robot to the goal.

In potential field approach, we simple create an attractive field going inside the goal. The potential field is defined across the entire free space, and in each time step, we calculate the potential filed at the robot position, and then calculate the induced force by this field. The robot then should move according to this force. Figure below illustrate the goal in the potential field method.

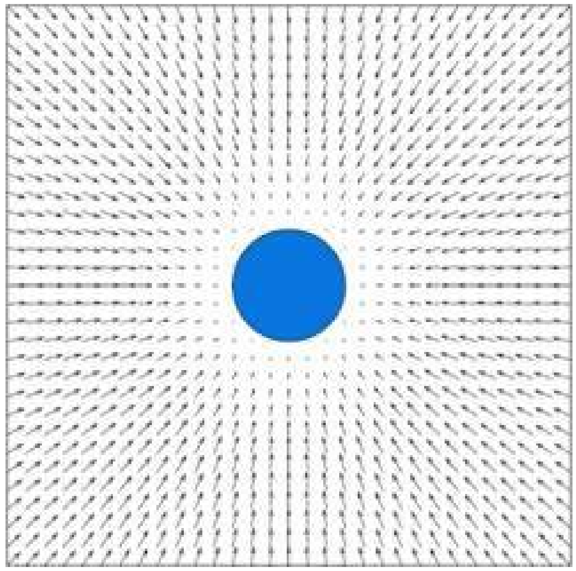

Figure 1: APF target concept (Hani, 2007)

The potential field method also can be applied to the environment that has obstacles. In potential field method, the obstacles will act as the repulsive field. If the robot approaches the obstacle, a repulsive force will act on it, and it will push away the robot.

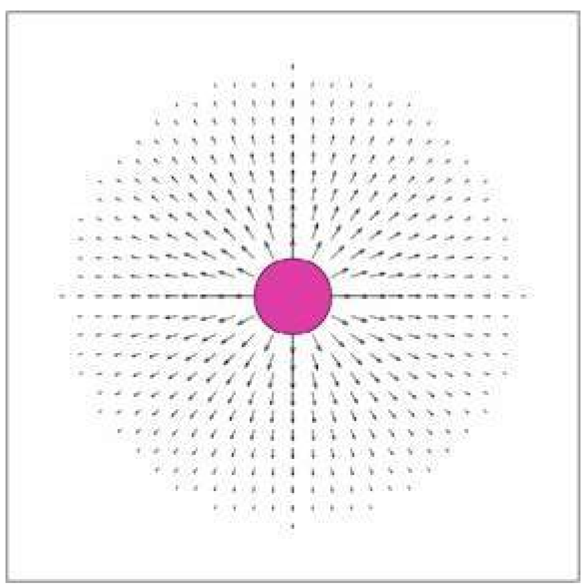

Figure 2: APF obstacle concept (Hani, 2007)

Both seeking and avoiding behavior can be combining in the robot behavior. The robot will act repelling when near repulsive field which identically an obstacle and attracting to the attractive force known as the goal. Figure below illustrate the robot behavior when apply both seeking and avoiding theory.

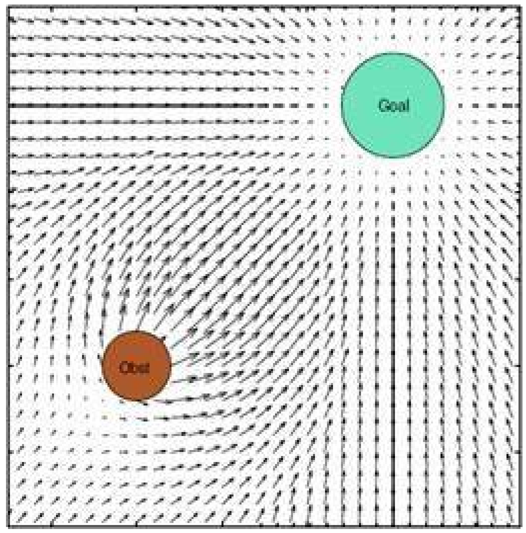

Figure 3: APF of obstacle and goal (Hani, 2007)

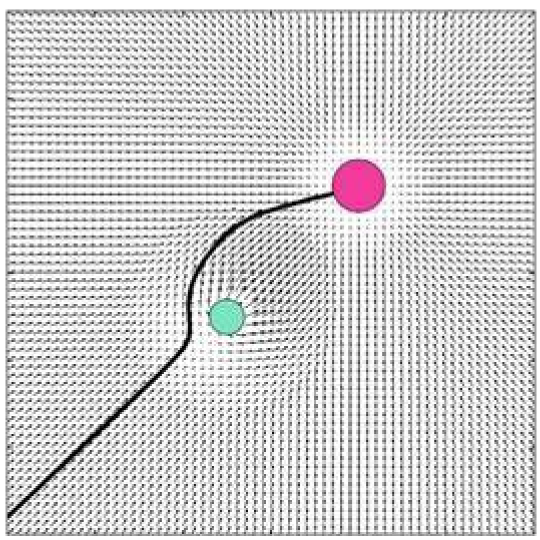

Figure 4: Mobile robot path in APF (Hani, 2007)

2.3 Local versus Global Path Planning

Path planning, or motion planning, is the act of finding a path to go from a location to another location. Path planning is important for a mobile robot to plan its way to the target in an identical or unknown environment with the obstacles as a challenge. There are many approaches to solving path planning, but usually it involves a local and global path planner (psurobotics, 2012). One of the priorities for a mobile robot that can perform tasks without human supervision is to have a plan of collision-free path is to. Path planning involves the problem of finding a continuous path from the initial position to the target that avoids obstacles in the environment. The path planning problem is well known in mobile robotics (Hwang and Ahuja, 1992) and has been typically approached in two different ways; local and global path planning method. (Dieguez et al., 2002)

Local path planning concept is like a blind person with his white cane walk into his kitchen. He might know his destination but he did not know the obstacles that he will face to reach his destination. The blind person will wave his white cane (sensors for mobile robot) along his way to his destination in order to protect him from hitting any objects placed in the kitchen. He will face with the unknown obstacles and need to avoid it. In addition, the blind person actually needs to be near to the objects in order to feel it existence. Same with the mobile robot which is technically blind due to limited sensor range that can only detect any obstacles when the obstacles is entering the sensors range (white cane for blind person). This is what the local path planning concept that require the robot to be near the obstacles and simultaneously avoid it.

While the global path planning is like normal sightseeing human that entering the kitchen and he know everything including the obstacles that he will face and it destination. So, when entering the kitchen, he has planned to take a short distance towards the target with considering the obstacles avoidance. Examples of global planning method are visibility graph, generalized Voronoi graph (Nagatani et al., 1998) connectivity graph (Lozano-Perez, 1983), cell decomposition (Latombe, 1991) and artificial potential field (Khatib, 1986). All of these techniques calculate the optimal path which is free of obstacles using an environment model that generally describes only static obstacles and the geometry of the working areas. Make mobile robot navigation algorithms have been developed assuming that a detailed map of the environment is available, which cannot be defined in most applications. Indeed, practical autonomous mobile robot applications need to be able to deal with unpredictable changes in the environment (Dieguez et al., 2002).

In scientific means, local path planning is usually gives a high-resolution low-level path only over a segment from global path A to B, avoiding small obstacles and dealing with motion planning: angles of turn, and also appropriate velocities. While a global path planner usually generates a low-resolution high-level path from A to B, avoiding large obstacles and dealing with navigation around the arena. Below are both local path planning and global path planning concepts that been illustrated using mobile robot.

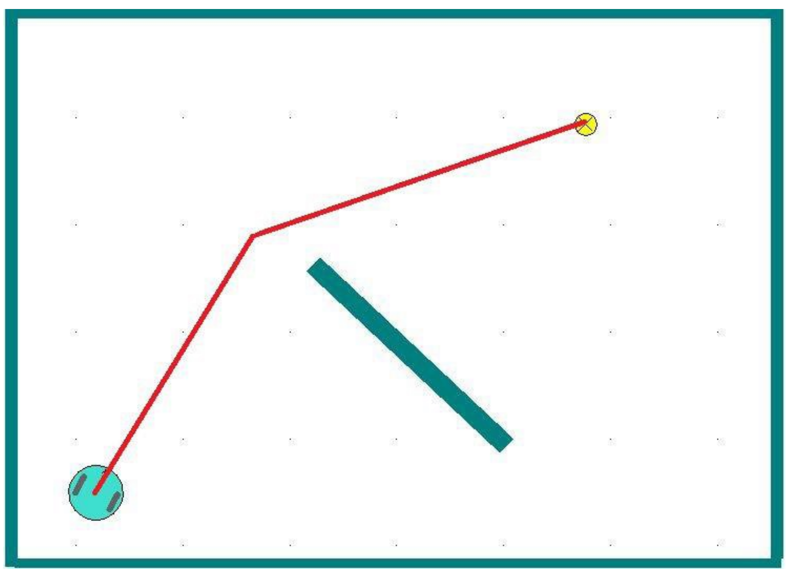

Figure 5: Global path planning

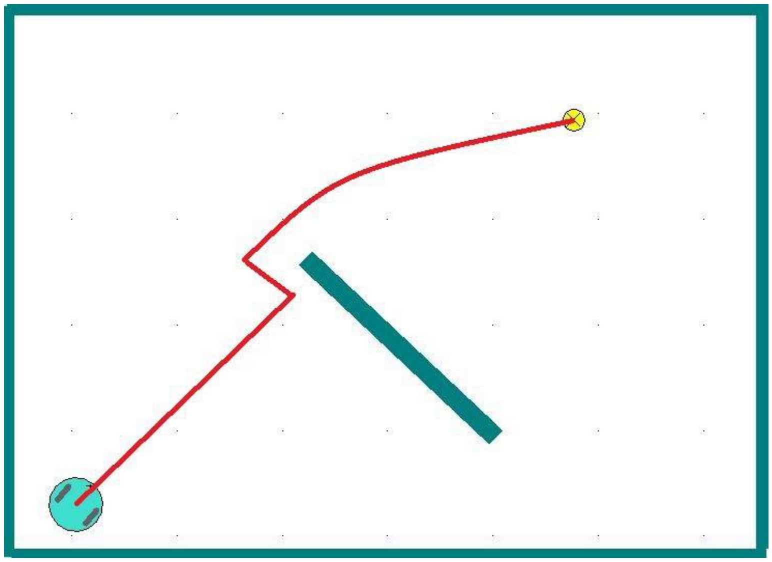

Figure 6: Local path planning

Local path planning gives a useful manner to solve many types of navigation problems by constructing a local map of the environment in real time. But, these approaches are a little bit slow in responding to real time contingencies. On the other hand, this mixed scheme requires certain intelligent decisions that assure the correct operation of the whole system. These might be the reason why local path planning modules is not very frequent in be implement in mobile robot behavior. (Dieguez et al., 2002)

The type of path chosen is depends on the size of the working environment. If it is large working environment, the developers usually use the global path planning while working in the small area, the local path planning is required.

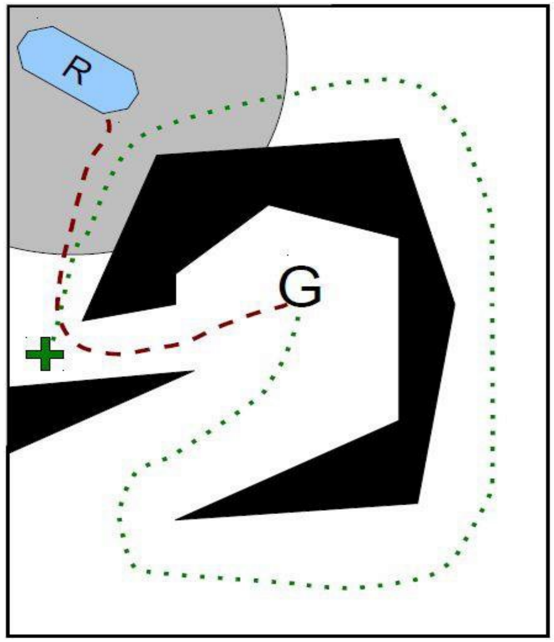

Figure 7 application of local and global path planning in a robot (Haojie et al., 2012).

Figure show that a robot behavior toward its goal. In this situation the short path is develop by the local planning is available, but due to the sharp turn initially being located outside of the range of the local high dimensional planner, which make the robot could not pass through that path. As the robot approaches the impassable area, the sharp turn enters the range of the local controller. At this point the system will recognize that the current path which is local path is no longer executable. Thus, the mobile robot using both local and global path planning will plan and produces a path that goes to the other side of path. At this time the robot will try to use global path planning to ensure it reach the goal (Haojie et al., 2012).

2.4 Trap Situations Due to Local Minima

The well-known and most often-cited problem with APF method is the problem of local minima or trap situations (Andrew and Hogan, 1983). A trap-situation may occur when the robot runs into a dead end for example in the U- shape obstacle. Traps can be created by a variety of different obstacle configurations, and different types of traps are identical. However, trap-situations can be resolved by global recovery or heuristic. But, there will be some side effect due to remedied with heuristic recovery which, the robot will have a non- optimal path towards the target. That is why the heuristic recovery is always being abandoned while integrated global path planning is always being used. When using this method, the local path planning will monitors the robot's path and when a trap-situation is detected the Global path planning is invoked to plan a new path based on the available information.

2.5 Fuzzy Logic

Fuzzy Logic was founded by Lotfi A. Zadeh, a professor for computer science at the University of California in Berkeley in 1965. Basically, Fuzzy Logic is a multivalued logic that can define the intermediate values between conventional evaluations like true/false, yes/no, high/low, and others. Notions like rather high or very cold can be formulated mathematically and processed by computers. Implementations of fuzzy in a system will results on human-like robot response. A fuzzy system is an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy. Fuzzy Logic has being widely used and it is profitable tool for the controlling and steering of systems and complex industrial processes. Fuzzy logic also has been implementing in household and entertainment electronics, as well as for other expert systems and applications like the classification of SAR data.

The very basic notion of fuzzy systems is a fuzzy subset call as memberships. Crisp set is clearly defined value with one interpretation for example 75^{o}F is the same in any system and it is a clearly defined and a measurable value. It is also called as singleton value. As opposed, fuzzy value is a value that is unclear and have many different meanings may be interpreted from it, or different values may be associated with it (Saeed, 2001). Below are the steps of fuzzification set up. Fuzzification is the process of converting input and output values into their membership functions. The result of fuzzification is a set of graphs that describe the degree of membership of different values in different fuzzy variables.