NEW APPROACH OF MOBILE ROBOT NAVIGATION BASED ON MIRROR PETRI NET METHOD

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DEDICATION

My wife Ita Nurhayati,
My daughters Sarah Annisa Gunardi, Khansa Azalia Gunardi and
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Especially for my kindly supervisor that give encouragement and support,
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ABSTRACT

Navigation is one of the important problems which must be solved in the development of mobile robot technology. The movement of a mobile robot from one place to another is expected to be fast and precise, even in conditions where there are many obstacles. At a crossroad, a robot has a choice to move straight, turn left or turn right. Many studies have focused on the movement of the robot from one place to another without taking into consideration about its movement back its original location. This thesis focuses on the movement of a mobile robot which moves from one position to the target position and then return to its original position using the mirror petri net method. The mirror petri net method is developed based on the petri net method, which is one of the modeling methods that can be applied to various types of systems. The formation of the mirror petri net model is made separately when departing and returning which will use the same marking value but will result in different navigation, when a mobile robot is stop it becomes moves, when it moves it becomes stop, when it turns left will becomes turn right, when turning right it becomes turn left except when the movement of the intersection which does not turn left or right then the movement of the robot remains straight. In conclusion, the mirror petri net method is effective for moving mobile robots from the origin position to the target position and return to the origin position. This is proven in all the experiments where the mobile robot can move to a selected room and return to its original position.

ABSTRAK

Navigasi adalah salah satu masalah penting yang mesti diselesaikan dalam pembangunan teknologi robot mudah alih. Pergerakan robot mudah alih dari satu tempat ke satu tempat memang dijangka pantas dan tepat terutama dalam keadaan banyak halangan. Apabila berada di persimpangan jalan, terdapat pilihan sama ada robot itu akan bergerak lurus, belok kiri atau belok kanan. Banyak kajian lepas tertumpu kepada pergerakan robot yang mengahala ke satu tempat sahaja dan tidak melihat kepada pergerakan robot yang boleh kembali ke tempat asalnya. Fokus tesis ini adalah kepada pergerakan robot mudah alih yang bergerak dari kedudukan asal ke kedudukan yang ditetapkan dan boleh kembali ke tempat asal menggunakan kaedah ‘mirror petri net’. Kaedah ‘mirror petri net’ dibangunkan berdasarkan kaedah petri net, yang merupakan salah satu kaedah model yang boleh digunakan ke atas pelbagai jenis sistem. Pembentukan model ‘mirror petri net’ dibuat berasingan apabila ia bergerak dan kembali ke kedudukan asal yang akan menggunakan penandaan yang sama tetapi keputusan navigasi yang diterima adalah berbeza. Apabila robot mudah alih bergerak, ia menjadi berhenti, apabila ia membelok ke kiri ia menjadi ke kanan, apabila ia membelok ke kanan ia menjadi ke kiri kecuali apabila pergerakan di simpang yang tidak membelok ke kiri atau ke kanan maka pergerakan robot kekal lurus. Kesimpulannya, kaedah ‘mirror petri net’ sangat bagus untuk pergerakan robot mudah alih yang bergerak dari kedudukan asal ke kedudukan yang ditetapkan dan kembali semula ke kedudukan asal. Ia boleh dibuktikan dalam eksperimen yang dilaksanakan di mana robot mudah alih boleh bergerak dan dikemudikan untuk pergi ke salah satu bilik yang telah dipilih dan kembali ke kedudukan asalnya.

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LIST OF SYMBOLS

$\|\cdot t\|$	The set of input place of transition t
$\|t\cdot\|$	The set of output place of transition t
$\|\cdot p\|$	The set of input transition of transition p
$\|p\cdot\|$	The set of output transition of place p
$\forall$	For every
$\in$	Element
tj	The j^{th} transition of petri net
pi	The i^{th} place of petri net
*	Two conditions when departing and when returning

LIST OF ABBREVIATIONS

A	Incidence matrix
I	Input
M	Marking
M’	New marking
M0	Marking zero
M1	Marking one
p1	Place one
t1	Transition one
Mk	New marking
Mk-1	Last marking
MPN	Mirror petri net
O	Output
P	Place
p	Place
PN	Petri net
RFID	Radio Frequency Identification
T	Transition
t	Transition
u	Firing vector
W	Weight

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CHAPTER 1

INTRODUCTION

1.1 Research background

The movement of robots from the initial position to the target destination is currently in great demand with various methods such as Particle Swarm optimization [1-4], fuzzy logic [5-8], dead reckoning [9-10], Bee Colony Algorithm [11-12].

Unfortunately, this kind of robot only has one goal. In reality, robots need to move from the one position to the target goal and return to the original position. Robots like this are usually widely used as food delivery robots, delivery of patient data in hospitals and delivery robots in warehouses.

Moving robots in such a way is challenging because the application needs to control these robots to depart and to return. The mobile robot will encounter many obstacles such as crossroads, and the choice of turning left, turning right or going straight. The movement of the robot is greatly influenced by the navigation model to guide the mobile robot to go to the target position and return to its original position.

This research presents how a mobile robot can navigate using marking values and the Mirror Petri Net (MPN) approach moves from one position to a target position and back to the original position.

Navigation is a fundamental requirement of autonomous mobile robots. The word navigation can be defined as the process of determining the position, location, course, and distance travelled to a known destination [13]. Navigation is used in robot localization for a robot to perform a required task. Localization is a very important issue for a mobile robot to move autonomously to achieve the desired position in any environment [14 -17].

For mobile robots, autonomous navigation is the most basic and important technology. To realize autonomous navigation, a mobile robot must know its location, and destination, as well as how it can achieve a goal [18]. When implementing autonomous navigation using traditional methods, such as geometric environmental model, the current sensor information estimates the position of the robot on the map, and determines the direction of its movement. This traditional method is effective if there are no major changes such as the destination position path.

Mobile robot cannot execute all operations related to the navigation without the localization information. As the mobile robot moves around its environments, its actual position and orientation always differ from the position and orientation that it is commanded to hold [19-21].

Materials handling is the moving of materials or products by any means, including storage [22]. It is not only used in a production house but also in the following service sectors.

1. Material handling: used by highly automotive, electronic factories and loading unloading stations.
2. Warehouse: used in e commerce warehouses for transporting the material.
3. Commercial: baggage transportation system at the airport, supermarket, mall and floor treatment like wash swapping and scrubbing.
4. Energy and defense: transporting materials to places which are unreachable by humans, bomb and mine mapping, retrieval and disposal nuclear plant inspection, steam generator and pipeline inspection.
5. Medical service: deliver food, water, medicine and administrative reports, handle hazardous material, and disposal of medical waste.

When moving, robots need proper navigation, like humans. If it runs without proper navigation information, human motion is the same as a robot that moves without a sensor, a robot can hit objects around it. The mobile robot navigation can be classified into 2 parts, namely indoor navigation system and outdoor navigation system.

The indoor navigation system uses an environment map technique where the image sequence is used to determine important environmental perceptions [23-28], . Knowledge of the previous environment can be used as a source for the classification of indoor navigation.

Outdoor navigation is more difficult because it generally has a wider range, full of obstacles and tracks that are not structured for robots [29-31]. Motion planning strategies also need to be considered to achieve optimal results.

The autonomous mobile robot guidance system is defined and vehicles are controlled to follow the path ways. mobile robot use the guidance path system chooses a path based on programmed path. It uses the measurement taken from the sensor and compares them to the value given to them by a programmer. When mobile robot approaches a decision point if only has to decide whether follow the path.

Autonomous Mobile Robot is a viable solution to improve logistics capabilities. Mobile robots are generally used in industry to automatically transport goods to a specific location. Its journey from one place to another is challenging because the robot must move to reach the destination accurately. Along the journey, the robot will encounter crossroads and must decide whether to turn right, turn left or go straight. A greater challenge is the movement of the mobile robot to return to its original place after it has made its delivery. , This is where proper navigation model is needed for a mobile robot.

Most commonly used guidance technologies in mobile robots are [32-34]:

1. Landmarked-based navigation

   Landmarked-based navigation technique is based on identification and subsequent recognition of distinct features of an object in the environment that may be prior known or extracted dynamically. The different technologies used in landmarked-based navigation are embedded guided wire and taped type system.

2. Behaviour-based navigation

   This type of paradigm was credited to suit unstructured environment as it can be incorporated with large number of sensors. The behaviours of the best navigation technique also require high computational power, neural network, genetic algorithm and several combinations of them. Behaviour Navigation system uses laser range navigation technology for mobility.

3. Vision-based navigation

   Vision-based robot navigation is defined as the technique that guides a mobile robot to a desired destination, or along a desired path in an environment, by avoiding static and dynamic obstacles, primarily using vision sensors. In general, vision-based robots have a vision system that perceives the external environments.

One problem to be solved in the landmark-based approach is to decide what are suitable to be assigned as the landmarks in the environment. Landmarks should be a distinctive one and easy to be recognized without special costs. In a building intersections, corners, and doors are very important places for navigation and they could be the landmarks. However, occasional problems related to sensors not being able to distinguish between similar landmarks, such as different doors of the same size often occur. This can lead to both inefficiency and mistakes. Although such landmarks with an artificial sign could be reliable and useful, painted marks on walls would require special image processing to extract them from the scene. This would entail a complicated and costly process.

We propose a sensor using passive Radio Frequency Identification (RFID) tags as a landmark. The RFID tags are a passive, non-contact, read-only memory system and can store a unique number for identification of the locations. The tag data can be read from one meter away via electromagnetic waves. The tags are pasted on walls at particular places in a building. Robots just pass by the tags. The tags allow the acquisition of location information at remarkable speeds without the accurate control of robot positions for sensing the tags. The passive RFID tags do not need an on-board power supply like a battery and generate operating power from the received electromagnetic waves. The tags are very light and thin. They, therefore, can be embedded easily in the environment and offer a virtually unlimited operational lifetime.

Radio Frequency Identification as it is commonly known, is an umbrella term that refers to several information and communication technologies that share the capability to automatically identify objects [35-39], locations [40-42], and individuals without any need for manual intervention [43-45]. The RFID is enabled through wireless communication between the computing system and the identified item. The RFID operation is imperceptible to the human senses, a fact that has considerable implications for users of RFID technology in terms of security and privacy protection.

With RFID, the object, location, or individual is marked with a unique identifier code contained within an RFID tag, which is in some way attached to or embedded in the target. A computing device that needs to identify the target employs an RFID reader to search for tags. When it receives an indication that a tag is present in its vicinity, it instructs the reader to request for the code. The retrieved data are then recorded or otherwise processed in whatever way is suitable for the particular application.

There are many variations in the details of this process, which depend on the features of the specific favour of RFID technology used. Notably, higher capacity tags can often hold extra data, depending on the application, in addition to the identifier code.

Nevertheless, all RFID systems have two features in common [46-47].
First, the electricity required for the operation of the tag is transmitted by the reader wirelessly. In many cases, this would be the only power source for the tag. Second, the tag employs a distinctive approach to communicate with the reader in that it modifies the reader's transmission to send out information rather than generate its own signal.

PN are a graphical and mathematical modelling tool applicable to many systems [48]. They are a promising tool for describing and studying information processing systems that are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. As a graphical tool, PN can be used as a visual-communication aid similar to flow charts, block diagrams, and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems. As a mathematical tool, it is possible to set up state equations, algebraic equations, and other mathematical models governing the behaviour of systems. PNs can be used by both practitioners and theoreticians. Thus, they provide a powerful medium of communication between them where practitioners can learn from theoreticians how to make their models more methodical, and theoreticians can learn from practitioners how to make their models more realistic. PN have been proposed for a wide variety of applications. This is due to the generality and permissiveness inherent in PN. They can be applied informally to any area or system that can be described graphically like flow charts and that needs some means of representing parallel or concurrent activities. In this research, a moving robot was designed using the mirror PN method and RFID for planning robot trips. Mirror PN is developed based on the PN method that is used to simulate the movement of a mobile robot, moving from the original place to the target location and returning to its original place, for example, when material handling or delivering goods from a warehouse to a location or files to a hospital.

The PN method is a modelling method that can be applied in various types of systems. A PN model can be seen as a superior visual model because it defines the dynamic process of the system compared to other available models such as flow diagrams or network topologies. It also marks what activities occur in robots and this information provides the data for the RFID.

This research introduces a new framework using the MPN for the evaluation of mobile robot navigation performance modelling. This research describes a new method that focuses on practical aspects for traveling robot from the starting point to the goal point, and the behavior of robots moving forward, turning left and right using PN. The movement is shown by using mathematical analysis of reachability PN. The final result generates the marking value which is translated to mobile robot navigation and applied to RFID.

1.2 Problem statement

The movement of robots from the starting position to the intended destination is currently in great demand with various methods. Unfortunately these types of robot are not able to return to their original position after traveling to the desired destination. These robots are usually used for food delivery, patient data delivery in hospitals and delivery in warehouses. The movement of a robot from one position to the target position and returning to its original

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APPENDIX B

VITA

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