DEVELOPMENT OF AUTONOMOUS MOBILE ROBOT NAVIGATION USING RFID

BY

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A dissertation submitted in fulfilment of the requirements for the degree of Master of Science (Mechatronics Engineering)

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ABSTRACT

Navigation techniques in mobile robotics system have gained significant research interest over the past few years. The mobile robot must be able to navigate through a known or unknown environment based on its necessities and applications. This can be achieved by determining its positions and selecting a suitable motion control. Conventional techniques include landmark or dead-reckoning with excessive number on sensors which increases complexities. Several other researchers have been done using both active and passive Radio Frequency Identification (RFID) Signal but there is still need for a more simple and suitable navigation system. This research has been done to present an effective navigation technique using passive RFID reader and tags. The proposed algorithm provides not only the estimation of the robot position in the environment but also the orientation of the autonomous robot. Polar coordinate system has been adopted on the navigation environment where the RFID tags are placed in a grid-like pattern with constant distance. The research objectives have been fulfilled via simulation and experimental validation through hardware implementation. The experimental results show effective and reliable results and the novelty lies in the use of simple technique to achieve the objectives. As a whole, this work has investigated and analyzed several navigation techniques and adopted the best technique for practical application with satisfactory results.

خلاصة البحث

تقنيات الملاحه في الروبوتات المتحركة اكتسبت اهتمام بحثي كبير في السنوات الاخيرة. الروبوتات المتحركة يجب ان تكون قادرة على التنقل عبر بيئات معروفه وغير معروفه بالاعتماد علي حاجاتها وتطبيقاتها. هذا يمكن ان يحدث بواسطة تحديد اتجاهاتها واختيار متحكم في السرعه مناسب. التقنيات التقليدية تتضمن نقاط الاستدلال والحسابات الميتة مع عدد كبير من الحساسات يؤدي الى زيادة التعقيد. العديد من الابحاث الاخرى استخدمت اشارات تحديد ترددات الراديو السلبية والايجابية لكن الحاجة الى لنظام سهل ومناسب للملاحه مازالت موجودة. هذا البحث يقدم لتقنيات تنقل فعاله باستخدام قارئ RFID السلبي و الاوسمة التي لن توفر فقط تقدير الاتجاه في البيئة ولكن التكيف مع الظروف في الروبوتات ذاتية التحكم. النظام الاحداثي القطبي تم تبنيه في بيئة التنقل حيث RFID وضعت على شبكة مثل الرسم مع ازاحات ثابته. اهداف البحث تم تنفيذها بواسطة المحاكاه والتجارب بواسطة التطبيق العملي.نتائج التجارب اثبتت فاعليتها وقابليتها للتطبيق والشيء الجديد يقع في استخدام طرق بسيطة لتحقيق الهدف. ككل, هذا العمل هدف الى بحث وتحليل عديد من تقنيات التنقل وتبني الافضل للتطبيقات العمليه مع نتائج مرضية

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Mechatronics Engineering.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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To my Beloved Parents, Younger Brothers and well wishers

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LIST OF ABBREVIATIONS

PWM	Pulse Width Modulation
RFID	Radio Frequency Identification
IDE	Integrated Development Environment
FLC	Fuzzy Logic Control
CCD	Charge-Coupled Device
CMOS	Complementary Metal-oxide Semiconductor
RSS	Received Signal Strength
RSSI	Received Signal Strength Identification

LIST OF SYMBOLS

ϖ	angular velocity
$r\varpi$	radius of the wheel

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Nowadays, Omni directional mobile robot navigation system has gone through great improvement in the robotics and control system design. Navigation is the most critical part in mobile robot system that needs to be considered in determining desired position. By using RFID as a means to navigate desired position, it can be more convenient to apply as it is a method which depends on storing and retrieving data by the use of data-carrying devices. RFID is used to identify an object and assist in determining its location and orientation.

Mobile robot navigation, as a whole, is evolving to be an attractive challenge in industry and also research. It is undergoing a major transformation in scope and dimension in both indoor and outdoor. Navigation of a mobile robot allows the robot to determine its own position in its frame of reference and find its target location. This can be divided into three main parts such as localization, path planning and map building.

Localization means determination of the mobile robot's position and orientation in its environment. The sensor used and effector uncertainties affect localization. Path planning is an effective extension for localization where it requires determining the robot's current position and its target position. Whereas, map building or cognition allows the robot to decide on how to respond and achieve the robot's objectives.

There are four main aspects of navigation involved to determine the success in navigation: perception, localization, cognition and motion control(Siegwart & Nourbakhsh, 2004). Perception includes interpretation of robot sensors to extract meaningful data; localization refers to determining the robot's position in the environment; cognition mentions the decisions to make in order to achieve goals; and motion control, where the robot controls motor outputs to achieve the desired trajectory(Siegwart & Nourbakhsh, 2004).

Various researches were done and are still continuing to enhance the mobile robot navigation systems. The research scopes can cover different methods in robot perceptions, on the use of suitable sensors; localization techniques, such as map-based localization, Markov localization, vision-based localization, landmark-based localization: artificial landmark and natural landmark, globally unique localization, route-based/line-based localization, RFID-based: passive RFID and active RFID and dead reckoning based; cognition techniques includes control strategies such as fuzzy logic control, artificial neural networks etc.; and the motion control techniques include the type of motor used to achieve the desired trajectory (Siegwart & Nourbakhsh, 2004).

Throughout the timeline of researches, it is crucial for the researchers to develop an efficient, effective, low cost and simplified navigation strategy for the mobile robot with specific objectives and tasks. The uses of different types of mobile robots for it specific purpose is also a challenge for the researchers. This depends on the kinematic and dynamic models of the mobile robots. There are robot manipulators, stationary robots used in manufacturing industries to assemble object parts, carry out special tasks such as pick and drop etc. There are also legged mobile robots and wheeled mobile robots. For legged mobile robots, leg configuration and stability is important for locomotion. In case of wheeled-mobile robots, the trajectory depends on the type of wheel used and its position mounted on the robot. Omnidirectional wheel can move in any direction and said to be holonomic and standard wheels are non-holonomic. The locomotion of wheeled mobile robots depend on degree of mobility, degree of steerability, robot maneuverability as a whole, degrees of freedom and types of robots; holonomic or non-holonomic. The choice is totally based on the task the robot performs and therefore; it is a challenge to choose the right type of robot for its task.

The research aims to build an Omni-Directional Mobile Robot Navigation system using RFID (Radio Frequency Identification). A navigation algorithm is developed where the mobile robot is interfaced with RFID which allows it to determine its position in its navigating environment. Its orientation and path planning localization is determined by digital compass. This navigation mainly focuses on RFID system using customized RFID tag architectures. RFID system involves RFID reader, tags and software. When RFID reader scans the tags within its reading range, a pulse of radio energy is sent out to the tags which send back its specific ID number. RFID tags have specific ID number which makes it easy for the reader to allocate and know its position. During navigation, the robot must independently find the path based on the algorithm to identify the tag ID mentioned in the coding.

The use of RFID is valuable as it is abundant, inexpensive and flexible technology which can come in various uses. Recently it’s being widely used in mobile robot navigation. RFID system communicates within a range determined by the output power of reader and the way it is designed. The RF field from an antenna extends into space and the strength of the field disappears with respect to the distance of tag. The type of antenna determines the shape of the field. Whereas, and the range is influenced by the pattern between the tag and antenna. This research is done to provide a mobile robot to navigate in its environment with an optimizing, less complex algorithm to reach its target and perform a specific action. During its navigation, it will also consider any obstacles that come in its way. Its application can be widely used in indoor environments; such as hospitals, health industry, communication industry, libraries, human identification and areas where it is less convenient for human interaction. Offline and real time simulations of the navigation algorithm will be analyzed. The real-time simulations will come from the experimental results.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

To enhance the navigation strategy as well as uphold enterprise economic benefit optimized navigation is a major concern. The development of suitable algorithm and strategy for navigation has shown to be not an easy issue. Most of the existing navigation technologies provide localization with its own shortcomings, affecting the results of the navigation process. Among the navigation techniques, RFID based navigation has demonstrated better reliability. The RFID tags location may not be restricted or restricted based on its application. If it is not restricted, the readers will unknowingly travel in its unknown environment trying to locate them. Here active RFID can be used to calculate the distances between the different sensing tags to find its actual location. While using passive RFID, the sensing range is small so this might not be achievable but its actual position can be identified when the reader is very close to the tag. There is a matter of computational complexities using active RFID and this can be quite costly as well. The detail of which will be explained in Chapter 2: Literature review. Therefore the problems highlighted to resolve for this research work are summarized below: