View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Universiti Teknikal Malaysia Melaka (UTeM) Repository

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Information and Communication Technology

IMPROVED FUZZY-PID CONTROLLER IN FOLLOWING COMPLICATED PATH FOR LEGO MINDSTORMS NXT

Nurul Nadirah Binti Mohamad Khairi

Master of Science in Information and Communication Technology

2017

© Universiti Teknikal Malaysia Melaka

IMPROVED FUZZY-PID CONTROLLER IN FOLLOWING COMPLICATED PATH FOR LEGO MINDSTORMS NXT

NURUL NADIRAH BINTI MOHAMAD KHAIRI

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Information and Communication Technology

Faculty of Information and Communication Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

© Universiti Teknikal Malaysia Melaka

DECLARATION

I declare that this thesis entitled "Improved fuzzy-PID controller in following complicated path for LEGO Mindstorms NXT" 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 : Nurul Nadirah Binti Mohamad Khairi

Date : ……..……

© Universiti Teknikal Malaysia Melaka

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of Master of Science in Information and Communication Technology.

Signature	:	…….……..
Supervisor Name	:	Dr. Sharifah Sakinah Binti Syed Ahmad
Date	:	……..……..……

© Universiti Teknikal Malaysia Melaka

DEDICATION

Specially dedicated to my beloved parents, family members and fellow friends

© Universiti Teknikal Malaysia Melaka

ABSTRACT

Line follower robots are monotype mobile robot having the ability to follow a line very accurately. Though many researchers are studying regarding line follower robot controller but most of the concepts are concentrated on theoretical design. The performance of the conventional type of controller in controlling line follower robot is still being a popular topic to be discussed. The traditional controller cannot deal with uncertainty data such as the amount of light whether it is too high or too low light that received by the light sensor which leads to the inaccurate movement of the line follower robot. This research presents an application of improving fuzzy-PID controller method in controlling LEGO Mindstorms NXT while following the complicated path with more accurate and high velocity. LEGO Mindstorms NXT with single light sensor is used as a line follower robot to tracking the complicated black line drawn on the white surface. The investigation of existing method for line following application will help in identifying the best controller method of inspecting the pattern of line follower robot movement. At the end of the research, the movement of LEGO Mindstorms NXT robot is more accurate with high complexity of line by using improved fuzzy-PID controller. The improved fuzzy-PID controller also increases the velocity of the robot when tracking the complicated path.

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Robot pengikut garisan adalah sejenis robot mudah alih yang mempunyai keupayaan untuk mengikuti garisan dengan sangat tepat. Walaupun ramai penyelidik sedang mengkaji mengenai pengawal robot pengikut garisan tetapi kebanyakan konsep tertumpu kepada reka bentuk teori sahaja. Prestasi pengawal jenis konvensional mengawal robot pengikut garisan masih menjadi satu topik popular yang akan dibincangkan. Pengawal tradisional tidak boleh berurusan dengan data ketidakpastian seperti jumlah cahaya samaada terlalu tinggi atau terlalu rendah jumlah cahaya yang diterima oleh pengesan cahaya yang membawa kepada pergerakan yang tidak tepat daripada robot pengikut garisan. Kajian ini membentangkan penggunaan pengawal untuk meningkatkan kaedah kawalan kabur-PID dalam mengawal LEGO Mindstorms NXT ketika mengikuti jalan yang rumit dengan halaju yang lebih tepat dan tinggi. LEGO Mindstorms NXT dengan pengesan cahaya tunggal digunakan sebagai robot pengikut garisan untuk mengesan garis hitam yang rumit yang dilukis pada permukaan putih. Siasatan tentang kaedah bagi permohonan garisan pengikut yang sediaada akan membantu dalam mengenal pasti pengawal kaedah terbaik dalam memeriksa corak pergerakan robot pengikut garisan. Pada akhir kajian, pergerakan LEGO Mindstorms NXT robot adalah lebih tepat dengan garisan yang mempunyai kerumitan yang tinggi dengan menggunakan pengawal kabur-PID yang ditambah baik. Pengawal kabur-PID yang ditambah baik juga meningkatkan halaju robot apabila menjejaki garisan yang rumit.

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENTS

Alhamdulillah, all praise to the Almighty Allah, the Most Gracious, Most Merciful and Most Benevolent for giving me an opportunity to further my study for higher education and giving me strength and patience in completing this thesis.

First of all, I would like to gratefully and sincerely thank my research supervisor Dr. Sharifah Sakinah Binti Syed Ahmad for his guidance, ideas and advices to complete my research and most importantly for developing myself towards a better person.

I would also like to express my greatest gratitude to PM Dr. Abdul Samad Bin Shibghatullah from Faculty of Information and Communication Technology, co-supervisor of this research for his advice and suggestions.

Last but not least, I would like to thank to all my family and friends involved in this research for their motivation and continuous support. Thank you for everyone for your help and contribution and I am very grateful for it.

© Universiti Teknikal Malaysia Melaka

TABLE OF CONTENTS

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

© Universiti Teknikal Malaysia Melaka

LIST OF APPENDICES

© Universiti Teknikal Malaysia Melaka

LIST OF ABBREVIATIONS

e	-	Error Signal
u	-	Control Signal
r	-	Desired Input Value
K_p	-	Proportional Gain
K_i	-	Integral Gain
K_d	-	Derivative Gain
PID	-	Proportional Integral Derivative

© Universiti Teknikal Malaysia Melaka

LIST OF PUBLICATIONS

Journal

1. Nurul Nadirah Mohd Khairi and Sharifah Sakinah Syed Ahmad, 2017. The Effectiveness of LEGO Mindstorms NXT in Following Complicated Path Using Improved Fuzzy-PID Controller. *International Journal of Innovative Science and Research Technology (IJISRT)*, 2 (7), pp. 155-161.

2. Nurul Nadirah Mohd Khairi, Sharifah Sakinah Syed Ahmad, Abd. Samad Shibghatullah, 2017. Improved Fuzzy-PID Controller in Following Complicated Path for LEGO Mindstorms NXT. *Journal of Mechanical Engineering (JMechE). – to be publish.*

Proceeding

1. Nurul Nadirah Mohd Khairi, Sharifah Sakinah Syed Ahmad, Abd. Samad Shibghatullah, 2017. Improved Fuzzy-PID Controller in Following Complicated Path for LEGO Mindstorms NXT. In: *Proceedings of Mechanical Engineering Research Day 2017*, Malacca Malaysia, 30 March 2017. Centre for Advanced Research on Energy, pp. 474-475.

© Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.0 Introduction

Nowadays, robotics is an exciting field to discuss about. The definition of robot based on The Robot Institute of America (1979) can be simplified as: "A reprogrammable, multifunction manipulator designed for moving materials, tools, or specialized through various programmed motions for the performance of a variety of tasks". Webster dictionary define a robot as: "An automatic device that performs functions normally ascribed to humans or a machine in the form of a human." In other word, system that consists power supplies, sensors, control system, manipulators and software that working all together to perform a project is called as robot. The combination of structural engineering, mechanical engineering, physics, electrical engineering, computing and mathematic will formed a process of designing, building, programming and testing a robot. In some situation, this will involve the medicine, biology and chemistry field. The dangerous job which humans prefer not to do, or are unable to do for example like in a space or deeply in the sea which hard for humans to survive in the extreme environments will be took over by the robot.

In additional, robots are human like machines capable of doing duty they are programmed to do. They have shown significance in decreasing human work especially in industries. In manufacturing tasks, speed and efficiency have long been improved by robotic systems (KUKA, 2000). In the electronics industry like producing interspersed

© Universiti Teknikal Malaysia Melaka

circuits, or repeated tasks such as gathering circuit boards, robots has perform tasks requiring high preciseness. A robot has replace humans in many industries especially in repeated or dangerous situations. However, in all of these cases robotic systems are used in small, usually self-reliant, sections of the manufacture line.

Currently, in some cases like shift partially gather product sections between stations on the manufacture line people are still required to deliver components from warehouses. The path of conveyer belts is hard to alter if the manufacture line changes and they need a significant amount of floor space, particularly if several belts converge on one section of the manufacture line. The robots that are produced are quite expensive, time consuming to produce and do not tend to be very flexible. In order to perform the desired task, a model of the environment and the robot are used. To maintain these models, strong data about the condition of the robot and the environment is prescribed. To revise these models, the sensors and processors is required. The rate of the other component to design the robot is not important (Andrew, 2001).

A line follower robot is mostly a robot model to tracking and follows a pre-defined black line or path on a white surface. In order to detect the line or path, various controller methods can be employed. The choice of these controller methods would affect the pattern of robot movement whether it will be stable or unstable. In robotics industry field, line following robot successfully perform in semi to fully self-governing area. In this conditions, these robots capacities as segments transporter to circulate items starting with one production point then onto the next where rail, transport and platform arrangements are not available (Aziz et al., 2004). However, to add on to the complexity of the line in the line following, the number of sensor and type of controller methods plays a role in optimizing the robots performance in line following. To beat the uncertainty of the obscure

© Universiti Teknikal Malaysia Melaka

and element robot behaviour, a versatile powerful fuzzy controller was proposed by Giap et al. (2008); Lyapunov hypothesis was utilized to ensure the solidness of the tracking mistakes. A more modern and intelligent path method in view of human driving conduct for versatile robots with nonholonomic requirements was proposed by Liu (2009).

General operating of the line following robot are as follow (Pakdaman, 2009); First is catching line position with an optical sensor posted on the front of the robot. For the most part, it utilizes a few numbers image-reflectors. Subsequently, the process of sensing requires high resolution and high dependability. Next is utilizing steering mechanism to control the robot to detect any line. This is only one actual servo operation, and such compensation is necessary to stabilize the movement phase detection by using digital PID filter or any other servo algorithm; Other than that, the speed is controlled according to the state of the lane. Speed is limited when passing a curve due to the resistance of the tires and floor. This sort of robot can be utilized for military purposes, delivery services, transportation system, and application help blind. In addition, there are many of the annual robot competition organized by universities or industries worldwide. They usually ask the robot teams to build a small robot with specific aspect and weight according to the competition rules.

In this research, LEGO Mindstorms NXT is developed to use as a demonstration purpose where LEGO Mindstorms NXT will act as a line follower robot to analyse the effectiveness of proposed system in controlling line follower robot. Generally, in 1960s Dr. Seymour Papert began his work toward LEGO Mindstorms that has its background in the pioneering work of Logo, a computer language and a philosophy of education at the Artificial Intelligence Laboratory and continued at the MIT (Massachusetts Institute of Technology) Media Laboratory.

© Universiti Teknikal Malaysia Melaka

Papert is probably the first person to suggest that children need to program a computer, absurdly vital idea at the time. This idea led to the theory of learning that proposed by Papert called constructionism which shows that learning is an active process of the idea to build a unique and personal to each student and this would be facilitated when students build something in this world which is the object of social and shared reflection (Fred, 2000). Papert's Logo programming languages, and later LEGO Mindstorms, inherit from this set of ideas. Apart from use LEGO Mindstorms for demonstrational purposes, LEGO Mindstorms is used by many school and universities as a tool for educational purposes.

In some computer science undergraduate courses, the LEGO Mindstorms has been used across the curriculum. From teaching fundamental programming concepts like procedures and variables. (Fagin et al., 2001), to artificial intelligence (Klassner, 2002), the LEGO Mindstorms have helped the structure of existing courses by added an incipient and exhilarating element. The line following application is one of the interesting courses to improve student understanding of how robots "think" and as a tool to improve student ability of critical thinking. There a lot of LEGO Mindstroms robotic competition for school and universities students. Apart of programmed the robot with simple program, this student groups are tested to program the robots by using light sensors to follow a pre-defined black line. However, the feedback of this student that we received from the questionnaires given to them, line following is addressed as a most difficult part of program the robot. Only 10% of this student is successful to follow the black line until the end of the track. Unfortunately, the pattern of robot movement is worse and increases the time to finish the whole track although the track is using only straight line.

© Universiti Teknikal Malaysia Melaka

Generally, traditional methods include PID controller and a microcontroller to control any dynamic system such as line following system requires the utilization of some cognizance, or model, of the system to be controlled. A categorical model is crucial for the prosperous implementation of a control algorithm. Lamentably, most systems are nonlinear, highly involute, and too arduous or infeasible to model accurately. A mathematical system developed by Zadeh (1965) that is Fuzzy Logic, avails to reduce the intricacy of controlling nonlinear systems. Fuzzy logic expresses operational laws of a control system in linguistic terms instead of the traditionally used mathematical equations.

Many researches implement fuzzy rules on the line following robot. Yousef Moh. Abueejela Mosbah (2010) use fuzzy logic as a controller method in controlling of an autonomous wall following robot. In his method, the sensor reading of distance different at front and rear makes the angular velocity of left, and right wheel will be different thus making a turning movement. The robot has a sense of it in the sense of touch, which is located at the bottom of each of the six legs. Azlan et al. (2007) describe the construction of two small LEGO robot, which is the line and light mobile robot following seem to give a better understanding of the theory of fuzzy logic control and real-life applications for undergraduate training system. However, the current line following system model basically only explain the implementation of a controller method and did not focuses on the capabilities of the robot while following the high complexity of line with good stability and efficient movement. Hence, the effectiveness of controller method in controlling the robot with the high complexity of line in path following is analysed during the experiment process.

© Universiti Teknikal Malaysia Melaka

1.1 Research Problem

Traditional line follower robot easily leaves its track that drawn on the floor because it is giving a slow response to the error occurred. This issue will make the robot movement to be unsmooth and sometimes robot tends to move out from the track. Despite the fact that, the line follower robot can follow the black line, its movement still needs to be enhanced, so to beat that issue, a better controller method is needed to make robot follow the line smoothly and make less error. In general, the control system of the robot line follower is using a PID controller. Putu et al. (2013) stated that disadvantages of PID control system is, if given light sensor value are increasingly sensitive the response (proportional, integral, and derivative responses) will overshoot and undershoot. However, if the light sensor value is made less sensitive to the response (proportional, integral, and derivative responses), there will be a recovery process which takes longer. So will cause the movement of robots are increasingly chaotic and unstable. PID controllers are considered for use in slow procedures (forms with numerous time constants or dead time, for example, temperature circles, which are for the most part free of noise. Fast procedures (forms with brief time constants) are more defenceless to process noise. The use of the subordinate mode results in the enhancement of the noise, because of the subsidiary of the fast changing noise is a vast worth.

Fuzzy control is considered as the most widely used application of fuzzy logic. Hami (2007) found that to design a robust controller which can provide copacetic performance in the face of skeptical and imprecision fuzzy logic controller is credited with being an adequate methodology. The hybrid between PID controller and Fuzzy Logic controller will help to improve the line tracking process in line following system. Hence, the research problem statements of this thesis are:

© Universiti Teknikal Malaysia Melaka

Basically, path or line following is one of the most general problems in robotic industry. Line following is one of the most practical application as it sanctions the robot to moving from one point to another to perform tasks. The situations become worst when robots need to follow the complicated and small thickness of line such as thin sharp curve line. Almost of the application of line following robot is using simple straight line. Usually, extra sensors is added to the line follower robot, the robot movement will resulted in good stability and faster. However, it will increase the cost of operation of the robot because we need more sensor compare to add single light sensor to the robot. The existing methods to control line following robot is still being issue on how to enhance the accuracy and velocity of line follower robot. The traditional algorithm for line follower robot movement is, it will turn left when there is no line detected by the sensor and it will turn right when the line is detected by the sensor. This algorithm is very slow and not smoother, wasting valuable time and battery power. Line follower robot algorithm using conventional PID is much better than the earlier algorithm but the robot still will be unsteady about the line. Disadvantages of PID control system is, if given light sensor value are increasingly sensitive the response will overshoot and undershoot. However, if the light sensor value is made less sensitive to the response, there will be a recovery process which takes longer. So will cause the movement of robots are increasingly chaotic and unstable. On other hand, to design a robust controller which can provide copacetic performance in the face of skeptical and imprecision fuzzy logic controller is credited with being an adequate methodology.

The above research problems are divided into two research problem (RP) and the summary of the above statements is illustrated in Table 1.1.

© Universiti Teknikal Malaysia Melaka