UNIVERSITI PUTRA MALAYSIA

DESIGN AND EVALUATION ON ADAPTIVE FUZZY SPEED CONTROL OF MOBILE ROBOT

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Mohammad Hamiruce bin Marhaban, PhD

Faculty : Engineering

Wheeled mobile robots are widely used in various fields such as agriculture, industry, land mining, military, space explorations, and other applications in which the environment is inaccessible or hazardous to human, such as in nuclear plants. This thesis mainly focuses on investigation of fuzzy logic approach capability in order to control the speed of a four-wheel mobile robot in an indoor environment. This research deals with adaptive fuzzy speed control of mobile robot in an indoor environment with variable slope. Two different method are used for tuning mechanism consist of on-line tuning of output gain and output membership functions. Given a reference trajectory, the performances of these methods are compared with fuzzy PI controller (FPIC), through experimental evaluations. The first method is self-tuning fuzzy logic controller by means of updating output scaling

factor. Depending on the process trend, the output scaling factor (SF) of the controller is modified by an updating factor (α), in an online fashion. The value of α is determined through a rule-based adaptive mechanism defined over error and the pitch angle of the robot. In the second adaptive method, membership functions tuning, a direct adaptive fuzzy controller is used to modify the locations of the output membership functions, adaptively. The controller has a fuzzy rule base that can adopt different output membership functions for each fuzzy rule to improve the performance of the fuzzy controller, in spite of changes in the plant. The effectiveness of the control system is verified through real time experiments in an indoor environment with different slope. Both data acquisition and control algorithm are developed by using LabVIEW. A four-wheel mobile robot, PUTRABOT2, is used to conduct the experiments. Performance comparison between the fuzzy PI controller and adaptive fuzzy controllers are made in terms of several performance criteria including rise time, settling time, peak time, peak overshoot, integral absolute error (IAE) and integral time weighted absolute error (ITAE). Comparative results for various processes in term of different angle of ramp (15, 20 and 25 degree) show that the adaptive fuzzy controllers outperform the fuzzy PI controller to minimize the rise time, settling time IAE and ITAE, except peak overshoot. This research paves the way towards the adaptive control of mobile robots in the face of plants uncertainty and would be appreciated by urban and industrial applications.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

REKA BENTUK DAN PENILAIAN ATAS KAWALAN HALAJU SAMAR MUDAH SUAI UNTUK ROBOT BERGERAK

Oleh

MOHAMMADREZA ABDOLLAHI

April 2011

Pengerusi : Profesor Madya Mohammad Hamiruce bin Marhaban, PhD

Fakulti : Kejuruteraan

Robot bergerak beroda digunakan secara meluas di dalam pelbagai bidang seperti pertanian, perlombongan, ketenteraan, penjelajahan angkasa dan lain-lain aplikasi di mana persekitarannya tidak dapat didatangi atau berbahaya kepada manusia, seperti loji nuklear. Tesis ini memberi fokus utama kepada penyelidikan tentang kebolehan pendekatan logik samar di dalam mengawal halaju untuk pengemudi gelincir robot bergerak empat-roda di dalam persekitaran bilik dengan cerunan berbeza. Dua kaedah berbeza digunakan untuk mekanisma penalaan yang mengandungi penalaan perolehan output dalam talian dan fungsi keahlian. Berdasarkan isyarat rujukan, prestasi kaedah ini dibandingkan dengan alat kawalan samar PI melalui ujikaji

penilaian. Kaedah pertama ialah penalaan sendiri kawalan logik samar menggunakan faktor skalar output. Berdasarkan aliran proses, faktor skalar output atau output scaling factor (SF) bagi alat kawalan diubah menggunakan faktor pengemaskinian atau updating factor (α) gaya dalam talian. Nilai α diperolehi melalui mekanisme dasar-peraturanmudahsuai yang didefinasi melalui ralat dan sudut pic robot. Di dalam kaedah mudah suai kedua, mekanisme fungsi keahlian, kawalan mudah suai terus digunakan untuk merubah lokasi fungsi keahlian output, secara mudah suai. Alat kawalan mempunyai peraturan asas samar yang boleh menerima pelbagai fungsi keahlian output untuk setiap peraturan samar bagi memperbaiki prestasi alat kawalan samar, walaupun terdapat perubahan persekitaran loji. Keberkesanan sistem kawalan ini dipastikan melalui ujikaji di dalam persekitaran bilik dengan cerunan berbeza. Kedua-dua pemerolehan data dan algoritm kawalan dibina menggunakan perisian computer LabVIEW. Pengemudi gelincir robot bergerak empat roda, PUTRABOT2 digunakan di dalam ujikaji. Perbandingan prestasi di antara alat kawalan logik samar konvensional dan kawalan logic samar mudah suai dibuat dari segi beberapa criteria prestasi termasuk masa bangkit, masa enapan, masa puncak, puncak melampau, ralat mutlak keseluruhan dan ralat mutlak berpemberat masa keseluruhan. Keputusan perbandingan untuk pelbagai proses dari segi sudut tanjakan berbeza (15, 20 dan 25 darjah) menunjukkan kawalan logik samar mudah suai mengatasi prestasi kawalan logik samar PI bagi meminimumkan masa bangkit, masa enapan, ralat mutlak keseluruhan dan ralat mutlak berpemberat kecuali puncak melampau. Penyelidikan ini membuka jalan menuju kawalan mudah suai robot bergerak di dalam persekitaran loji yang tidak pasti, dan lebih dihargai oleh applikasi bandar dan industri.

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Peace and blessing upon Prophet Mohammad (S.A.W).

I certify that a Thesis Examination Committee has met on 29 April 2011 to conduct the final examination of Mohammadreza Abdollahi on his thesis entitled "**DESIGN AND EVALUATION ON ADAPTIVE FUZZY SPEED CONTROL OF MOBILE ROBOT**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science degree.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for other degree at University Putra Malaysia or at any other institution.

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MOHAMMADREZA ABDOLLAHI

Date: 29 April 2011

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