UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF BEHAVIOR-BASED REACTIVE NAVIGATION SYSTEM FOR MOBILE ROBOT

MOHD GHAZALI BIN MOHD HAMAMI

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By

MOHD GHAZALI BIN MOHD HAMAMI

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

March 2013

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To my beloved parents, wife, daughter and son.

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

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March 2013

Chairman: **Tang Sai Hong, PhD**

Institute: **Engineering**

Robotics technology has been evolved rapidly these last two decades especially in autonomous mobile robots development. One of the most important issues that related to autonomous mobile robots is it navigation systems. Deliberative navigation and reactive navigation are two types of navigation in mobile robot navigations. Reactive navigation in unknown and changing territories without prior knowledge to the environment is one of the most challenging problems in robotics, thus has been investigated by researchers for many years.

Previous researchers gave particular attention to local minimum and multiple minimum problems which trap the robot into an infinite loop during its navigation. This could ruin the objective of good local navigation which a good local navigation should able the robot to navigate the unknown environment safety without having collision with the

available obstacles. To solve the problems and achieve the above objective, a new behavior-based reactive navigation system for mobile robots is developed. The motions of Pioneer 3TM mobile robot were simulated to show the developed algorithm performance. The robot equipped with three rendering sensors and eight sonar sensors to senses and perceives its environment. The robot environment consist of wall obstacles and dead end traps such as simple obstacle corner, U shape dead ends, snail shape, loops and maze which all of it, is assumed to be fully unknown.

The navigation algorithm consist of four main behaviors which target seeking behavior, obstacles avoidance behavior, tracking (wall following and edge following) behavior and emergency stop behavior. All these four main behaviors have been integrated into one complete behavior-based navigation system using competitive integration methods (winner take all network). This developed behavior-based approach, not only enable the robot to search for the target but it also able the robot to escape from any sort of multiple dead end traps. The algorithm also control the robot velocity during its navigation based on the Euclidean distance of the robot and the target and also distance input from the sensors.

In this work, multiple traps may have many types of shape ranges from a simple obstacle corner, U shape dead ends, snail shape until to a complicated loops and mazes. The developed algorithm control the mobile robot and resulted the mobile robot makes optimum logical trajectories towards the target, escape from the dead end traps by avoiding available obstacles and control the robot speed throughout the navigation process. The obtained simulation results were compared with the previous methods to

show the effectiveness and efficiency of the proposed method in term of the navigation path pattern result and its algorithm consideration.

The repeatability tests shown that the developed navigation algorithm able the robot to reach the target with the similar navigation path pattern outcome in each simulation tests. This proved the developed navigation algorithm not only satisfied its objective but also has reliability in its performance.

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

PEMBANGUNAN SISTEM PANDU ARAH REAKTIF BERASASKAN KELAKUAN UNTUK ROBOT BERGERAK

Oleh

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Teknologi robotik telah berkembang pesat sejak dua dekad lalu terutamanya dalam pembangunan robot bergerak berautonomi. Salah satu isu penting yang berkaitan dengan robot bergerak berautonomi ialah sistem pandu arahnya. Pandu arah deliberatif dan pandu arah reaktif adalah dua jenis pandu arah dalam pandu arah robot bergerak. Pandu arah reaktif dalam persekitaran yang tidak diketahui dan berubah tanpa tiada sebarang pengetahuan awal terhadap persekitaran tersebut adalah salah satu masalah yang paling mencabar dalam robotik. Oleh sebab itu, permasalahan ini telah diselidik oleh para penyelidik selama ini.

Para penyelidik terdahulu telah memberikan tumpuan khusus dalam masalah minimum tempatan dan minimum pelbagai yang memerangkap robot ke dalam kitaran infiniti semasa pandu arahnya. Ini dapat menggagalkan objektif pandu arah tempatan yang

bagus, dimana pandu arah tempatan yang bagus, sepatutnya membolehkan robot memandu arah di dalam persekitaran yang tidak diketahui dengan selamat tanpa sebarang pelanggaran dengan halangan-halangan yang ada. Untuk menyelesaikan masalah tersebut dan mencapai objektif di atas, satu sistem baru, pandu arah reaktif berasaskan kelakuan telah dibangunkan. Pergerakkan robot bergerak Pioneer 3TM, telah disimulasikan untuk menunjukkan keupayaan algoritma yang telah dibangunkan. Robot ini dilengkapi dengan tiga sensor pengimbas dan lapan sensor sonar untuk mengimbas dan mengesan persekitarannya. Persekitaran robot terdiri daripada halangan dinding dan perangkap mati seperti halangan simpang mudah, halangan berbentuk U yang mati, halangan berbentuk siput, kitaran dan lorong berselirat dimana semuanya dianggap sebagai tidak diketahui keseluruhannya.

Algoritma pandu arah tersebut terdiri daripada empat kelakuan utama iaitu kelakuan pencarian sasaran, kelakuan pengelakan halangan, kelakuan penjejakan (pengikutan dinding dan pengikutan bucu) dan kelakuan berhenti kecemasan. Keempat-empat kelakuan ini telah di integerasi ke dalam sebuah sistem pandu arah berasaskan kelakuan menggunakan cara integerasi kompetetif (pemenang menguasai keseluruhan jaringan). Pendekatan berasaskan kelakuan yang dibangunkan ini bukan sahaja membolehkan robot untuk mencari sasaran, tetapi juga membolehkan robot melepaskan diri daripada sebarang jenis perangkap mati pelbagai. Algoritma tersebut juga mengawal kelajuan robot semasa pandu arahnya berdasarkan jarak Euclidean antara robot dan sasaran serta input jarak daripada pengimbas-pengimbas.

Dalam usaha ini, perangkap pelbagai mungkin terdiri daripada pelbagai jenis bentuk bermula daripada halangan simpang mudah, bentuk U mati, bentuk siput hinggalah kepada kitaran dan lorong berselirat yang rumit. Algoritma yang dibangunkan, mengawal robot bergerak dengan membolehkan robot bergerak membuat pergerakkan logikal optimum menuju sasaran, melepaskan diri daripada perangkap mati dengan mengelak halangan yang ada dan mengawal kelajuan robot semasa keseluruhan proses pandu arahnya. Keputusan-keputusan simulasi yang diperolehi telah di bandingkan dengan kaedah-kaedah terdahulu untuk menunjukkan keberkesanan dan kecekapan kaedah yang telah dicadangkan dari segi keputusan paten jejak pandu arah dan konsiderasi algoritmanya.

Ujian kebolehulangan menunjukkan bahawa algoritma pandu arah yang dibangunkan, telah membolehkan robot sampai ke sasaran dengan paten jejak pandu arah yang sama pada setiap ujian simulasi. Ini membuktikan bahawa algoritma pandu arah yang dibangunkan bukan sahaja dapat memenuhi objektifnya tetapi juga mempunyai kebolehpercayaan dari segi prestasinya.

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I certify that a Thesis Examination Committee has met on 14 March 2013 to conduct the final examination of Mohd Ghazali bin Mohd Hamami on his thesis entitled " Development of Behavior-Based Reactive Navigation System for 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.

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

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MOHD GHAZALI BIN MOHD HAMAMI

Date: 14 March 2013

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