EMBEDDED INTERVAL TYPE-2 NEURO-FUZZYCONTROLLER IN MOBILE ROBOT NAVIGATION WITH WEIGHTLESS NEURAL NETWORK

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I hereby declare that this thesis entitled “Embedded Interval Type-2 Neuro-Fuzzy Controller in Mobile Robot Navigation with Weightless Neural Network” 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.

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To my beloved family

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In the Name of Allah, Most Gracious, Most Merciful

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ABSTRACT

Providing sufficient intelligence for embedded controller in mobile robot is desirable, to allow its interaction and operation under the conditions of imprecision and uncertainty present in the real environment with limited computational resources. Type-1 fuzzy logic controller (T1FLC) is a successful solution in many real time applications. However in some applications such as motion control in mobile robot, equalization of nonlinear time-varying channels, and medical, T1FLC cannot fully accommodate the linguistic and numerical uncertainties. This research presents an experimental work of enhanced solution, interval type-2 fuzzy logic controller (IT2FLC) that is proven to handle the uncertainties that give better performance than T1FLC. Nevertheless, IT2FLC involves extra computational overhead, associated with the computation of type-reduced fuzzy set procedure, reducing the robust performance especially when operating on embedded platform. Hence in this research, an integration of IT2FLC and weightless neural network (WNNs), called interval type-2 neuro-fuzzy controller (IT2NFC) is proposed which is capable of learning, classifying and optimizing the rule-base to reduce the computational overhead and improve the robustness. WNNs strategy allows fast learning, easy hardware implementation and appropriate to be employed in embedded controller. The proposed intelligent controller is implemented using modular pyramid architecture with 8 bit microcontrollers. The WNNs utilizes previous sensor data, analyzes the situation of the current environment, and classifies geometric features including the corridor, open-space, left-corner, right-corner, U-shape and T-shape. The IT2FLC decides the mobile robot action based on the rules associated with the classified situation. Three navigational behaviors; obstacle avoidance, wall following and goal seeking are used to evaluate the robust performance of the proposed intelligent controller. The experimental results show the proposed IT2NFC has yielded promising outcomes with 98.5% recognition rate, 36% rule-reduction and only 57 Kb memory usage. These indicate that the mobile robot is able to recognize the environmental pattern and achieve robust performance with less computational cost. Furthermore, it has successfully performed different navigational tasks better than other controllers including logic function, T1FLC and type-1 neuro-fuzzy controller (T1NFC).

ABSTRAK

Penyediaan kepintaran yang cukup untuk kawalan terbenam pada robot boleh-bergerak adalah diperlukan bagi membolehkan ia berinteraksi dan beroperasi di bawah keadaan yang tidak tepat dan tidak menentu yang wujud dalam persekitaran nyata dengan sumber komputasi yang terhad. Kaedah kawalan logik jenis-1 (T1FLC) adalah penyelesaian yang berjaya di dalam banyak aplikasi masa nyata. Walaubagaimanapun, di dalam beberapa aplikasi seperti kawalan gerakan robot boleh-bergerak, penyamaan saluran masa berbeza yang tidak linear, dan bidang perubatan, T1FLC tidak boleh menguruskan ketidaktepatan linguistik dan numerik. Kajian ini mengemukakan kerja eksperimen peningkatan penyelesaian, iaitu kawalan logik kabur jenis-2 interval (IT2FLC) yang telah terbukti boleh mengatasi ketidakpastian dan memberikan prestasi yang lebih baik daripada T1FLC. Namun begitu, IT2FLC melibatkan komputasi yang overhed bagi set prosidur reduksi-jenis himpunan kabur yang mengurangkan prestasi tegap terutama ketika beroperasi pada platfom terbenam. Oleh itu dalam penyelidikan ini, IT2FLC diintegrasikan dengan rangkaian neural tanpa pemberat (WNNs) dipanggil kawalan neuro-kabur interval jenis-2 (IT2NFC), telah dicadangkan dimana ianya mampu mempelajari, mengklasifikasi dan mengoptimumkan peraturan asas untuk mengurangkan komputasi. Strategi WNNs membolehkan kawalan melakukan pembelajaran yang cepat, pelaksanaan perkakasan yang mudah dan sesuai untuk dilaksanakan dalam kawalan terbenam. Kawalan pintar yang dicadangkan di laksanakan menggunakan senibina piramid modular dengan 8 bit kawalan mikro. WNNs memanfaatkan data penderia terdahulu, menganalisa keadaan persekitaran semasa dan mengklasifikasikan ciri-ciri geometri termasuk koridor, ruang terbuka, sudut kiri dan kanan, dan bentuk U dan T. IT2FLC menentukan tindakan robot boleh-bergerak berdasarkan peraturan yang berkaitan dengan situasi yang diklasifikasikan. Tiga tingkah laku navigasi iaitu mengelak halangan, mengikuti dinding dan pencarian gol digunakan untuk menilai prestasi ketegapan kawalan pintar yang dicadangkan. Hasil keputusan eksperimen menunjukkan IT2NFC yang dicadangkan adalah tegap dan menghasilkan keputusan yang memberangsangkan iaitu 98.5% kadar pengenalpastian, 36% pengurangan peraturan dan hanya 57 Kb penggunaan memori. Ini menunjukkan robot boleh-bergerak tersebut mampu mengenalpasti corak persekitaran dan mencapai prestasi tegap dengan kos komputasi yang kurang. Disamping itu, ia juga berjaya melakukan tugas navigasi yang berbeza dengan mengatasi kawalan lain termasuk fungsi logik, T1FLC dan kawalan neuro-kabur jenis-1 (T1NFC).

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