UNIVERSITI PUTRA MALAYSIA

A FRAMEWORK OF MODIFIED ADAPTIVE NEURO-FUZZY INFERENCE ENGINE

MD. JAKIR HOSSEN

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A FRAMEWORK OF MODIFIED ADAPTIVE NEURO-FUZZY INFERENCE ENGINE

By

MD. JAKIR HOSSEN

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

September 2012

DEDICATIONS

To my dearest parent Late Md. Abdul Latif and Late Mst. Nurjahan Begum

And

To my beloved wife Godhuli Hossen with lovely sons Ornob Hossen and Ahnaf Hossen

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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September 2012

Chairman: Assoc. Prof. Abdul Rahman Bin Ramli, PhD

Faculty: Institute of Advanced Technology

Neuro-fuzzy inference engine and/or system is knowledge based data processing system and can manage the human reasoning course and create decisions based on uncertainty and imprecise situations. Neuro-fuzzy systems are globally employed for pattern recognition, industrial plant control, system predictions, modeling and other decision making purposes. Neuro-fuzzy systems are very popular among researchers in various advanced promising fields to help solve problems with a small number of inputs (three or less). However, there are limitations faced by all popular neuro-fuzzy inference system architectures when they are applied to systems with a large number of inputs (more than three). One of the vital significant issues for constructing a high quality neuro-fuzzy system is the creation of the knowledge base, which mainly consists of membership functions and fuzzy rules. This thesis proposes a framework of modified adaptive neuro-fuzzy inference engine (MANFIE) for a diversity of practical applications in order to resolve the benchmark problems of a large number of inputs

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datasets. A modified *apriori* algorithm was employed to reduce the number of clusters effectively on the basis of common data in the clusters of every input to obtain a minimal set of decision rules based on datasets. The Takagi-Sugeno-Kang (TSK) type fuzzy inference system was chosen and constructed by an automatic generation of clusters as well as membership functions and minimal rules through the use of hybrid fuzzy clustering and the modified *apriori* algorithms respectively. The developed TSK type fuzzy inference engine is called modified adaptive fuzzy inference engine (MAFIE) and its parameters were then adjusted by the hybrid learning algorithm using adaptive neural network architecture towards improved performance which is called MANFIE. The performance of MANFIE was compared with existing methods in a diversity of practical benchmark applications such as pattern classifications, time series predictions, modeling with inverse learning control and mobile robot navigation. The MANFIE has shown the ability to reduce and form the robust minimal rules (Rules reduced on average 97.95% and 96.90% accuracy for pattern classifications, rules reduced on average 97.15%, 75% and 98.43% for time series predictions, modeling with inverse learning control and mobile robot navigation respectively) to make an appropriate structure and minimize the root mean square error (RMSE - 0.024, 0.149 for time series predictions, 0.007 for modeling with learning control, 0.027 for mobile robot navigation) with the best accuracy. The results of benchmark problems have shown improvement, competitiveness and satisfaction by showing a better system performance index with a less number of rules in each high input application. This study suggests that the MANFIE is a suitable modified framework as an adaptive neuro-fuzzy inference engine and is ready to be applied to practical application problems.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RANGKA KERJA ENJIN INFERENS NEURAL-KABUR ADAPTIF YANG DIUBAHSUAI

Oleh

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Inferens enjin neural-kabur adalah satu sistem memproses pengetahuan berasaskan data dan boleh mengendalikan aliran pemikiran manusia dan membuat keputusan berasaskan situasi yang kurang pasti atau tepat. Sistem neural-kabur digunakan secara global di dalam kerja-kerja pengawalan loji industri, ramalan sistem, pembentukan model sistem, membuat keputusan yang lain seperti menganalisa data dalam kajian-kajian perubatan. Sistem neural-kabur sangat terkenal di kalangan penyelidik di dalam pelbagai bidang yang berkembang maju dalam menyelesaikan masalah yang melibatkan bilangan input yang kecil (tiga atau kurang). Walaubagaimanapun, terdapat beberapa limitasi yang dihadapi dalam kebanyakan senibina sistem inferens neural-kabur apabila digunakan dalam sistem yang melibatkan bilangan input yang besar (lebih daripada tiga). Salah satu daripada isu yang sangat penting untuk membina sistem neural-kabur yang berkualiti tinggi ialah mencipta asas pengetahuan yang mengandungi fungsi keahlian dan peraturan kabur. Kajian ini mencadangkan rangka enjin inferens neural-kabur yang adaptif yang diubahsuai (MANFIE) untuk digunakan di dalam pelbagai aplikasi amali

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bagi menyelesaikan masalah tanda aras yang melibatkan bilangan input set data yang besar. Algoritma apriori yang telah diubahsuai digunapakai untuk mengurangkan bilangan kelompok secara berkesan berasaskan data yang sama dalam kelompok setiap input untuk mendapatkan set peraturan keputusan yang minima berdasarkan set data. Sistem inferens kabur jenis Takagi-Sugeno-Kang (TSK) telah dipilih dan dibina dengan penjanaan kelompok secara automatik menggunakan perkelompokan kabur hibrid dan juga fungsi keahlian dan peraturan minima dengan menggunakan algoritma apriori yang telah diubahsuai. TSK jenis enjin inferens kabur yang telah dibina juga dipanggil parameter adaptif dan kemudianya diubah dan diselaraskan oleh enjin inferens logik kabur (MAFIE) dan algoritma pembelajaran hybrid menggunakan rangkaian neural adaptif untuk mencapai sistem yang berprestasi lebih baik yang dinamakan MANFIE. Pencapaian MANFIE telah dibandingkan dengan kaedah-kaedah yang sedia ada di dalam aplikasi tanda aras yang pelbagai seperti klasifikasi corak, ramalan siri masa, pembentukan kawalan pembelajaran terbalik dan navigasi robot bergerak. MANFIE telah menunjukkan kemampuan mengurangkan dan membentuk peraturan minima yang mantap (peraturan dapat dikurangkan pada purata ketepatan 97.95% dan 96.90% untuk klasifikasi corak, peraturan dapat dikurangkan pada purata 97.15% untuk ramalan siri masa, 75% untuk pembentukan kawalan pembelajaran terbalik dan 98.43% untuk navigasi robot bergerak) bagi membentuk struktur dengan pengurangan ‘root mean square error’ (RMSE - 0.024, 0.149 untuk ramalan siri masa, 0.007 untuk pembentukan kawalan pembelajaran, 0.027 untuk navigasi robot bergerak) sebagai satu ketepatan yang terbaik. Keputusan dari masalah tanda aras ini telah menunjukkan penambahbaikan, persaingan dan kepuasan yang menunjukkan indeks pencapaian sistem yang lebih baik dengan keperluan bilangan peraturan yang rendah di dalam setiap

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aplikasi input yang tinggi. Kajian ini mengesyorkan MANFIE adalah satu enjin inferens neural-kabur adaptif yang sesuai dan sedia diaplikasikan di dalam masalah aplikasi amali.

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I certify that a Thesis Examination Committee has met on **3rd September, 2012** to conduct the final examination of Md. Jakir Hossen on his thesis entitled **"A Framework of Modified Adaptive Neuro-Fuzzy Inference Engine"** 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 Doctor of Philosophy.

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DECLARATION

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

_____

MD. JAKIR HOSSEN

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