UNIVERSITI PUTRA MALAYSIA

AN APPROACH TO THE DEVELOPMENT OF HYBRID ARCHITECTURE OF EXPERT SYSTEMS

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By

MOAWIA ELFAKI YAHIA

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Dedicated to my wife; Maha,

my kids; Moneeb, *and* Duha,

my mother and the family

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Moawia E. Yahia

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BPNN	Back-propagation Neural Network
DBMS	Database Management System
DSE	Diagnostic Sensitivity
DSP	Diagnostic Specificity
DSS	Decision Support System
ES	Expert System
FN	False Negative
FP	False Positive
FTP	File Transfer Protocol
GA	Genetic Algorithm
IHS	Intelligent Hybrid System
KAM	Knowledge Acquisition Module
LP	Learning Program
NASA	National American Space Agency
NES	Neural Expert System
NKB	Neural Knowledge Base
NL	Network Label
NM	Network Matrix
NN	Neural Network
NS	Network Structure
OCR	Object Character Recognition

OOP	Object-Oriented Programming
PNN	Probabilistic Neural Network
PRE	Pre-processing Rough Engine
RIR	Retained Inference Result
RNES	Rough Neural Expert System
RNIE	Rough Neural Inference Engine
RS	Rough Set
RSL	Rough Set Library
TN	True Negative
TP	True Positive
UIM	User Interface Module
VLSI	Very Large-Scale Integration

Abstract of dissertation presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy.

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August 1999

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The knowledge acquisition process is a crucial stage in the technology of expert systems. However, this process is not well defined. One of the promising structured source of learning can be found in the recent work on neural network technology. Neural network can serve as a knowledge base of expert system that does classification tasks. The combination of these two technologies emerges new systems called neural expert systems. Neural expert systems allow us to generate a knowledge base automatically from training examples. Also, they have an ability to handle partial and noisy data. Despite the advances of these systems, debugging their knowledge bases is still a big problem. Neural networks still have some problems such as providing explanation facilities, managing the architecture of network and accelerating the training time.

The concept of a rough set has been proposed as a new mathematical tool to deal with uncertain and imprecise data. Using this tool to approach the problem of data reduction and data dependency has emerged as a powerful technique in applications of expert systems, decision support systems, machine learning, and pattern recognition. Two methods based on rough set analysis were developed and merged with the development of neural expert systems forming a new hybrid architecture of expert systems called a rough neural expert system. The first method works as a pre-processor for neural network within the architecture, and it is called a pre-processing rough engine, while the second one was added to the architecture for building a new structure of inference engine called a rough neural inference engine. Consequently, a new architecture of knowledge base was designed. This new architecture was based on the connectionist of neural network and the reduction of rough set analysis.

The proposed design was implemented using an environment of object-oriented programming. Four objects and three modules were developed using C++ programming language. The performance of the proposed system was evaluated by an application to the field of medical diagnosis using a real example of hepatitis diseases. Data for this application was obtained from researchers working on a related study. Also, the proposed work was compared with some related works. The comparing results indicate that the new methods have improved the inference procedures of the expert systems. The findings from this study have showed that this new architecture has some properties over the conventional architectures of expert systems.

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

SATU PENDEKATAN KEPADA PEMBANGUNAN SENI BINA HIBRID SISTEM PAKAR

Oleh

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Proses perolehan pengetahuan merupakan satu peringkat yang genting dalam teknologi sistem pakar. Walau bagaimanapun, proses ini masih tidak jelas. Satu sumber pembelajaran yang lebih berstruktur boleh ditemui dalam penyelidikan terbaru ke atas teknologi rangkaian neural. Rangkaian neural menyediakan asas pengetahuan bagi sistem pakar yang melakukan tugas-tugas klasifikasi. Kombinasi daripada dua teknologi ini menghasilkan sistem baru yang dipanggil sistem pakar neural. Sistem pakar neural membolehkan kita menghasilkan asas pengetahuan secara automatik daripada contoh-contoh latihan. Selain itu, ia juga berkebolehan untuk mengendalikan data spara dan data hingar. Meskipun terdapat pelbagai kelebihan sistem ini, namun menyahpepijat asas-asas pengetahuannya masih menjadi satu masalah yang besar. Rangkaian neural masih mempunyai beberapa masalah seperti kemudahan menyediakan penerangan, mengurus reka bentuk rangkaian dan meningkatkan kelajuan masa latihan.

Konsep set kasar telah dicadangkan sebagai alatan matematik yang baru berhubung dengan data-data yang tidak pasti dan tidak tepat. Alatan ini yang digunakan terhadap masalah pengurangan dan pergantungan data telah menjadi teknik yang hebat dalam aplikasi-aplikasi sistem pakar, sistem sokongan keputusan, pembelajaran mesin, dan pengecaman corak. Dua kaedah yang berasaskan analisis set kasar telah dibangun dan digabungkan dengan pembangunan sistem pakar neural menjadikan satu seni bina sistem pakar hibrid yang baru dipanggil sistem pakar neural kasar. Kaedah yang pertama bertugas sebagai pra-pemproses bagi rangkaian neural dalam seni bina tersebut, dan ia dipanggil sebagai pra-pemprosesan enjin kasar, sementara yang kedua pula telah ditambah kepada seni bina tersebut untuk membina struktur enjin taabir baru dipanggil enjin taabir neural kasar. Akibatnya, satu seni bina yang baru bagi asas pengetahuan telah direka bentuk. Seni bina baru ini berasaskan kepada gabungan rangkaian neural dan pengurangan analisis set kasar.

Reka bentuk yang dicadangkan telah dilaksanakan menggunakan persekitaran pengaturcaraan berorientasikan objek. Empat objek dan tiga modul telah dibina menggunakan bahasa pengaturcaraan C++. Prestasi sistem yang dicadangkan telah dinilai melalui aplikasi dalam bidang diagnosis perubatan menggunakan contoh sebenar penyakit hepatitis. Data untuk aplikasi ini diperolehi daripada kerja penyelidik-penyelidik dalam kajian berkaitan. Cadangan kerja ini juga dibandingkan dengan beberapa kerja berkaitan. Keputusan perbandingan menunjukkan bahawa kaedah baru telah memperbaiki prosedur taabir bagi sistem pakar. Penemuan kajian ini menunjukkan bahawa seni bina baru ini telah mempunyai beberapa kelebihan berbanding seni bina konvensional sistem pakar.

CHAPTER I

INTRODUCTION

Background

In recent years, models for developing appropriate hybrid systems using *Artificial Intelligence* (*AI*) technologies have appeared. One reason of this approach is to build more powerful systems that can reduce drawbacks of implementing a single AI technology alone (Goon, 1995; Kandel, 1992; Medsker, 1992; Soucek, 1991).

The development of integrated technologies of *Neural Network* (*NN*) and *Expert Systems* (*ES*) has shown some advancement. The complementary features of neural networks and expert systems allow the combination of these two technologies to make more powerful systems than can be built with either of the two alone (Medsker, 1994). This integration comes to emerge new systems called *Neural Expert Systems* or *Connectionist Expert Systems*, firstly introduced by Gallant in 1988 (Gallant, 1988).

Neural expert systems are expert systems that have neural network for their knowledge bases. Most important features of these systems are the learning algorithm that allows us to generate a knowledge base automatically from training

examples, and the ability to handle partial and noisy data. Despite the advances of this system, debugging its knowledge base is still a big problem. Also the architecture of neural network and accelerating the training time are important issues.

Rough Set Theory, introduced by Pawlak in 1982 (Pawlak, 1991; 1995), is a new mathematical tool to deal with vagueness and uncertainty. It has proved its soundness and usefulness in many real life applications. Rough set theory offers effective methods that are applicable in many branches of AI. The idea of rough set consists in approximation of a set by a pair of sets called *lower and upper approximations* of the set. The definition of the approximations follows from an *indiscrenibility relation* between elements of the sets, called *objects*. Objects are described by *attributes* of a qualitative or quantitative nature.

Rough set approach to expert system appears in rule induction of expert system by providing two sets of rules; certain rules and possible rules (Slowiniski, 1992). This approach is weak and not practical when the number of attributes is very large. Therefore, the useful approach is one considering the reduction of attrributes. Also the rough set can be a useful tool for pre-processing data for neural networks by applying its concept of attribute reduction to reduce the network's input vector, and hence to scale down the size of the whole architecture of the network.

Objectives of the Research

The main goal of the research is to show the emergence of rough set theory by providing new methods of it, and to merge these methods with the integration of

expert systems and neural networks. So the main objectives of the research can be derived from the goal as:

1) To develop a new method for pre-processing input to neural network based on rough set analysis. The method involves a new algorithm for reduction of neural network's input size. The method can be used as a pre-processing rough engine for knowledge acquisition of expert system that has neural network for its knowledge base.

2) To design a hybrid architecture of expert systems based on neural networks and rough sets. This architecture is composed from a pre-processing engine, a knowledge base and an inference engine. The structure of knowledge base is a product of combination of neural network and pre-processing rough description, instead of rules in the conventional expert systems.

Importance of the Research

The most difficult stage of building an expert system is the knowledge acquisition process. However, this process is not well defined. One of the promising structured sources of learning can be found in the recent work on neural networks. Neural network can serve as a knowledge base of expert system that does classification tasks (Gallant, 1988). The big issue here is how we can manage the architecture of the neural network. So this raises a question of how to develop an efficient tool that can help with the task.

The concept of a rough set has been proposed as a new mathematical tool to deal with uncertain and imprecise data, and it seems to be of significant importance to AI and cognitive sciences (Slowiniski, 1992). Using this tool to approach the problem of data reduction and data dependency has emerged as a powerful technique in applications of expert systems, decision support systems, machine learning, and pattern recognition.

This tool can be useful in managing the architecture of knowledge base of neural expert system. At first, a decision table has been developed from training example cases. Then by applying the rough set approximation concept to decision table, reduction in attributes can be discovered. So the reduction in network's input vector assists to manage the whole architecture of the network (Yahia, 1997a).

Contributions of the Research

The most contribution of the research is proposing a hybrid system combines the two technologies of neural networks and rough sets as supplement to the expert system technology. Neural network can address the knowledge acquisition bottleneck by gleaning knowledge from training data and storing the information as connection weights. Rough set theory is a new approach to data analysis with advantages of providing efficient algorithms for finding hidden patterns in data, finding minimal sets of data and generating sets of decision rules from data. The three technologies can represent different characteristics of intelligent behaviour and thus the combination of them in the hybrid system can solve more complex and useful problems.

The main contributions of the research could be highlighted as:

1) Designing a new hybrid architecture of expert systems based on neural networks and rough sets.

2) Developing a new algorithm for pre-processing inputs to neural networks based on rough sets analysis.

3) Designing a new structure of knowledge base based on connectionist of neural networks and pre-processing description of rough sets analysis.

4) Developing a new method of inference engine based on neural networks and rough sets.

5) Introducing a new model for implementing the hybrid architecture based on the object-orientation.

6) Developing of expert system of hepatitis diseases as an application of proposed hybrid architecture.

Application

Over the past years a great deal of AI research has been directed towards the development of knowledge based systems (expert systems) for problem solving in medical diagnosis domain. Medical diagnosis is an attractive domain that helps us to illustrate the working of the research. We consider a real life example to apply research's operations. The example deals with a special medical problem (e.g. liver diseases and especially hepatitis diseases).

Our information table, in this case, describes a hospital. So each training example is a patient's case history; the attributes are symptoms and tests; and

decisions are diseases. Each patient is characterised by the results of tests and symptoms and is classified by the doctor (expert) as being on some level of disease severity. So we bring a suitable number of cases from a consultant doctor who performs a study or survey in our case.

Organisation of the Dissertation

The dissertation is organised in accordance with the standard structure of theses and dissertations at Universiti Putra Malaysia. The dissertation has five chapters, including this introductory chapter. The remaining chapters are: literature review, design of hybrid expert system, implementation and evaluation, and conclusions and recommendations.

Chapter II – *Literature Review* covers all literatures related to the topics of the research describing intelligent hybrid systems as a new trend in the field of artificial intelligence. It shows the needs for the hybrid systems, presents their classifications and offers some guidelines in developing such a systems. The chapter focuses on the technology of expert systems, its characteristics and limitations. The chapter discusses the integration of expert systems and neural networks as one of new trends in the field of artificial intelligence. Two models of neural network were clearly described. The chapter presents the back-propagation neural network as a classical model for neural networks, while it introduces the probabilistic neural network as a new model for classification systems. The benefits from using rough sets theory as a new tool for handling uncertainties was also discussed, focusing on its approach to improve the working in expert systems and neural networks.

Through the discussion of all these topics the related works, which were done or currently are going on, were mentioned with some critical views.

Chapter III – *Design of Hybrid Expert System* describes a proposed model for hybrid system. The chapter offers a hybrid architecture of expert systems that based on neural network and rough sets theory, as a new intelligent hybrid system to improve the working on classification expert systems. The chapter describes all components of the new architecture in details. The chapter also introduces the object-oriented programming as an excellent environment tool for developing the proposed hybrid system. As description of the development phase of the model, objects and modules which constitute the system components were clearly defined, designed, and then developed. Finally, one illustration example was offered to explain the described methods and algorithms.

Chapter IV – *Implementation and Evaluation* is devoted to presenting the application of the system model described in chapter III. The chapter contents mainly three parts. The first part is the system learning, which describes the implementation of this model using the developed objects and modules for rough set analysis and neural network learning. The system testing is coming on the second part as an evaluation of the performance of implemented parts of system model by applying them to the field of medical diagnosis. The third part contents the discussion of results of the study. It highlights the main findings with comparison with related study.

Chapter V – *Conclusion and Recommendations* contents concluding remarks of the study with some recommendations of further development. The conclusion part includes a description of features and capabilities of this proposed design of hybrid expert system. The recommendations were presented as guidelines for development a new design with new capabilities that can be added to the system. The chapter also introduces the automated technique of example-based knowledge engineering as a promising area of further development of the hybrid system. Finally, the chapter opens some ways for the proposed system in the coming future of artificial intelligence.