REASONING OF THE STUDENT'S PERFORMANCE BASED ON ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

YEAP CHUN NYEN

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Computer Science)

Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia

OCTOBER 2009

To my beloved parents and family members

ACKNOWLEDGEMENTS

First of all, I would like to say my gratitude to the one and only to our mighty God for giving me the strength, good health and talent to complete the second part of this research project as one of the requirement for the conferment of the Master Degree.

I would also like to thank my beloved parents and family for giving me all the support since the beginning of the course. Not to forget my respectful, talented, supervisor Assoc. Prof. Dr. Norazah Binti Yusof who helped me throughout these one and half year course and also with this research project.

Furthermore, I would like to dedicate thousands of appreciation to all my beloved lecturers and friends who had given me the motivation and inspiration to make this research project a dream come true. May God bless you all with love and happiness in this world and the world after.

ABSTRACT

This research project introduces a systematic approach for the design of a fuzzy inference system (FIS) based on a class of neural networks to assess the students' performance. Fuzzy systems have reached a recognized success in several applications to solve diverse class of problems. Currently, the combination of fuzzy systems and neural networks is the most successful applications of soft computing techniques with hybrid characteristics and learning capabilities. The developed method uses a fuzzy system augmented by neural networks to enhance some of its characteristics like flexibility, speed, and adaptability, which is called the adaptive neuro-fuzzy inference system (ANFIS). Assessment and reasoning the student performance is not an easy task, especially when it involves many attributes or factors. Moreover, the knowledge of the human experts is acquired to determine the criteria of students' performance and the decisions about their level of mastery but most of the information is incomplete and vague. To overcome the problem, these projects will carry out the reasoning of the student's performance based on ANFIS. The method can produce crisp numerical outcomes to predict the student's performance. The results of the ANFIS approach will be compared to human expert FIS approach.

ABSTRAK

Projek penyelidikan ini memperkenalkan satu pendekatan yang sistematik untuk reka bentuk satu *Fuzzy Inference System* (FIS) berdasarkan satu kelas Rangkaian Neural (*Neural Network*) bagi menilai prestasi pelajar-pelajar. Sistem kabur telah mencapai kejayaan dalam pelbagai aplikasi untuk menyelesaikan pelbagai masalah. Kini, gabungan sistem kabur dan rangkaian neural merupakan satu aplikasi yang berjaya dalam teknik komputeran lembut, ia mempunyai ciri-ciri hibrid dan keupayaan untuk belajar. Teknik yang menggunakan sistem fuzzy ini gabung dengan rangkaian neural untuk meningkatkan beberapa ciri-cirinya, seperti kelonggaran, kelajuan, dan kebolehsuaian, dinamakan *adaptive neuro-fuzzy inference system* (ANFIS). Pentaksiran dan penaakulan terhadap prestasi pelajar bukan satu tugas yang mudah, terutamanya apabila ia melibatkan banyak sifat ataupun faktor yang lain. Lagipun, pengetahuan diperolehi daripada pakar domain untuk menentukan kriteria pembelajaran pelajar dan juga keputusan tentang tahap penguasaan mereka. Memandangkan perolehan maklumat daripada pakar domain adalah tidak lengkap dan tidak pasti. Untuk mengatasi masalah ini, projek-projek ini akan menjalankan taakulan prestasi pelajar berdasarkan ANFIS. Kaedah ini boleh menghasilkan hasil-hasil berangka rangup untuk meramalkan prestasi pelajar itu. Keputusan-keputusan bagi pendekatan ANFIS akan dibandingkan dengan pendekatan FIS pakar manusia.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF ABBREVIATIONS	xvi
	LIST OF APPENDICES	xvii
1	**INTRODUCTION**	1
	1.1 Introduction	1
	1.2 Problem Background	3
	1.3 Problem Statement	4
	1.4 Project Aim	5
	1.5 Project Objectives	5
	1.6 Project Scopes	6
	1.7 Significance of the Project	6
	1.8 Project Plan	7

	1.9	Organization of Report	7
2	**LITERATURE REVIEW**		8
	2.1	Overview	8
	2.2	Artificial Neural Network	9
	2.3	Fuzzy If-Then Rules	10
	2.4	Gaussian Function Method	11
	2.5	Fuzzy Inference Systems	12
	2.6	Adaptive Neuro-Fuzzy Inference System (ANFIS)	15
		2.6.1 ANFIS Architecture	15
	2.7	Related Researches of ANFIS	19
		2.7.1 Case Study 1: Road Safety Evaluation From Traffic Information Based on ANFIS	19
		2.7.2 Case Study 2: ANFIS Modelling of a Twin Rotor System	21
		2.7.3 Case Study 3: A Neuro Fuzzy Inference System for Student Modeling In Web Based Intelligent Tutoring Systems	22
		2.7.4 Summarization of Related Researches of ANFIS	24
	2.8	Related Researches of Reasoning of the Student's Performance	25
		2.8.1 Case Study 1: An Adaptive Neuro-fuzzy Model for Prediction of Student's Academic Performance	25
		2.8.2 Case Study 2: Neuro Fuzzy Reasoner for Student Modeling	27
		2.8.3 Case Study 3: Learning Achievement Evaluation Strategy Using Fuzzy Membership Function	29
		2.8.4 Case Study 4: Evaluating student's	30

learning achievement using fuzzy membership functions and fuzzy rules
2.8.5 Case Study 5: A fuzzy system for Evaluating students' learning achievement 32
2.8.6 Summarization of Related Researches of Reasoning the Student's Performance 36
2.9 Summary 37

3 METHODOLOGY 38
3.1 Overview 38
3.2 Research Framework 39
3.2.1 Phase 1: Problem Analysis 43
3.2.1.1 Information from resources and technical papers 43
3.2.1.2 Research Studies 44
3.2.1.3 Identify problem, objectives, aim, and scopes of the study 44
3.2.1.4 Research Planning 45
3.2.2 Phase 2: Design 45
3.2.2.1 Data representation and criteria design for the reasoning of the student's performance 45
3.2.3 Phase 3: Implementation and testing 49
3.2.3.1 Apply the human expert FIS approach on the experiment for reasoning of the student's performance 49
3.2.3.2 Apply the ANFIS approach on the experiment for reasoning of the student's performance 51
3.2.3.2.1 Increment of training datasets 52
3.2.4 Phase 4: Result analysis and discussion 54

	3.2.5	Phase 5: Report Writing	54
3.3	Hardware and Software Requirement		54
	3.3.1	Hardware	55
	3.3.2	Software	55
3.4	Summary		56
4	**EXPERIMENTAL RESULT AND ANALYSIS**		57
4.1	Overview		57
4.2	Criteria of the Student's Performance		58
4.3	Human Expert Fuzzy Inference System		59
	4.3.1	Fuzzification	60
	4.3.2	Creating Fuzzy Rules	64
	4.3.3	Combining Outputs into an Output Distribution	65
	4.3.4	Defuzzification of Output Distribution	65
	4.3.5	Experiment on Tuning the Parameter of Membership Functions of the Human Expert FIS	66
	4.3.6	Testing the Human Expert FIS with 81 Input Data Patterns	67
4.4	Development of Adaptive Neuro-Fuzzy Inference System		68
	4.4.1	ANFIS Model Structure	69
4.5	Experiments and Result Analysis		72
	4.5.1	Testing on 81 Input Data Patterns	73
	4.5.2	Training with Different Training Datasets	77
		4.5.2.1 54 Training Datasets	77
		4.5.2.2 64 Training Datasets	79
		4.5.2.3 69 Training Datasets	81
	4.5.3	Testing on 81 Input Data Patterns based on Different Training Datasets	84
	4.5.4	Testing on 1500 Random Input Data Patterns	86

	4.5.5 Discussion of the Classification Result	88
	4.6 Summary	89
5	**CONCLUSION AND FUTURE WORK**	91
	5.1 Overview	91
	5.2 Summary of the Project	91
	5.3 Contribution of the Study	93
	5.4 Conclusion	94
	5.5 Suggestions for Future Works	95
	REFERENCES	96
	APPENDIX A	99 – 101
	APPENDIX B	102 – 104
	APPENDIX C	105 – 117
	APPENDIX D	118 – 178

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Comparison of related researches	24
2.2	Fuzzy rules for student classification	28
2.3	Comparison of related researches	36
3.1	Research Framework	40
4.1	The criteria for the student's performance	59
4.2	The input variables of the Fuzzy Inference System	63
4.3	18 initial fuzzy rules determine by human experts	64
4.4	The experiment results of different parameters for each Gaussian MFs	66
4.5	Outcomes of the Human Expert FIS model based on 81 input patterns	67
4.6	The input patterns for training the ANFIS	74
4.7	The 81 input patterns for testing the ANFIS model	75
4.8	Outcomes of the ANFIS model based on 81 input patterns	76
4.9	The input patterns for training the ANFIS	77
4.10	(a) & (b) Outcomes of the ANFIS model based on 54 training data	79
4.11	Increment 10 training patterns	80
4.12	(a) & (b) Outcomes of the ANFIS model based on 64 training data	80

4.13	Increment 5 training patterns	81
4.14	(a) & (b) Outcomes of the ANFIS model based on 69 training data	81
4.15	The input variables of the ANFIS	82
4.16	Outcomes of the human experts' FIS and four ANFIS models based on different training datasets	87
4.17	Percentage of successful classifications correctly	88

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Diagram of a neuron	9
2.2	Gaussian shape function Gaussian(x: 2,5)	11
2.3	Fuzzy inference system	12
2.4	Commonly used fuzzy if-then rules and fuzzy reasoning mechanisms.	14
2.5	(a) A two input first-order Sugeno fuzzy model with two rules; (b) Equivalent ANFIS architecture.	16
2.6	Another ANFIS architecture for the two-input two-rule Sugeno fuzzy model.	18
2.7	(a) ANFIS architecture for a two-input first-order Sugeno fuzzy model with nine rules; (b) Partition of the input space into nine fuzzy regions.	18
2.8	Structure of fuzzy inference system: Consisting of 3 inputs (mean density, mean velocity and plane visibility), 1 output (LOS) & a series of rules.	21
2.9	ANFIS architecture for a six input single-output Sugeno fuzzy model	26
2.10	NFR Structure	27
2.11	The NFR model for student classification	29

2.12	Block diagram of the three node fuzzy evaluation system	33
3.1	Work flows of the research methodology	42
3.2	T-score distribution for time taken to answer question	47
3.3	Human Expert FIS model	50
3.4	ANFIS approach to generate complete fuzzy rules	51
3.5	Work flows of the increment training datasets	53
4.1	Four inputs and single output for the Human Expert FIS	60
4.2	Four inputs' Gaussian membership functions (a)Score (b)Time (c)Number of Tries (d)Number of Help	62
4.3	Fuzzy reasoning procedure for Human Expert FIS model of Student's Performance	63
4.4	ANFIS model structure	70
4.5	Fine tuned membership functions of (a) Score, (b) Time, (c) No. of Tries, and (d) No. of Help as input variables.	83
4.6	Comparison between ANFIS outputs based on 54 training datasets and checking data	84
4.7	Comparison between ANFIS outputs based on 64 training datasets and checking data	85
4.8	Comparison between ANFIS outputs based on 69 training datasets and checking data	86
4.9	Comparison of classification result for both input data patterns	89

LIST OF ABBREVIATIONS

ANFIS	-	Adaptive Neuro-Fuzzy Inference System
ANN	-	Artificial Neural Network
COG	-	Center of Gravity
FIS	-	Fuzzy Inference System
HM	-	Has Mastered
LOS	-	Level of Safety
MM	-	Moderately Mastered
MSE	-	Mean Square Error
NF	-	Neuro Fuzzy
NH	-	Number of Helps
NM	-	Not Mastered
NT	-	Number of Tries
S	-	Score
SP	-	Student’s Performance
T	-	Time
TRMS	-	Twin Rotor Multi-Input Multi-Output System

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	81 Fuzzy Rules	99
B	Results of the ANFIS based on 18 Fuzzy Rules and Testing on 81 Input Data Patterns	102
C	Results of Testing on 81 Input Data Patterns based on Different Training Datasets	105
D	Results of Testing on 1500 Random Input Data Patterns based on Different Training Datasets	118

CHAPTER 1

INTRODUCTION

1.1 Introduction

Evaluation and reasoning of student's learning achievement is the process of determining the performance levels of individual students in relation to educational objectives (Saleh & Kim, 2009). A high quality evaluation system able to provide grounds for individual improvement and ensures that all students receive fair evaluation so as not to limit students' present and future opportunities. Thus, the fuzzy system should regularly be reviewed and improved to ensure that it is precise, fair, and beneficial to all students (Saleh & Kim, 2009). Hence, the reasoning of the student's performance fuzzy system needs the transparency, logical reasoning, and easy implementation.

The purpose of this study is research on fuzzy rule base which are able to reasoning the student's performance. In general, the performance of student in their study which is very important because through this method then we able to aware how good of the students achieved in their study and the understanding of the

students. The Adaptive Network Fuzzy Inference System (ANFIS) will be use as a technique to reasoning the student's performance. ANFIS stands for adaptive network-based fuzzy inference system or semantically equivalently, adaptive neuro fuzzy inference system. ANFIS is proposed by Roger Jang from the Tsing Hua University, Taiwan, is a neural network that is functionally equal to a Sugeno fuzzy inference model. ANFIS can serve as a basic for constructing a set of fuzzy if-then rules with appropriate membership functions to generate stipulated input-output pairs. (Jang, 1993). According to Prof. Ajith Abraham, a Neuro-Fuzzy (NF) system is a combination of Artificial Neural Network (ANN) and Fuzzy Inference System (FIS) in such a way that ANN learning algorithms are used to determine the parameters of FIS. ANN and FIS are both very powerful soft computing tools for solving a problem without having to analyze the problem itself in detail (Abraham, 2000).

Furthermore, neural networks possess a variety of alternative features such as massive parallelism, distributed representation and computation, generalization ability, adaptability and inherent contextual information processing. On the other hand, fuzzy sets constitute the oldest and most reported soft computing paradigm. They are well suited to modelling different forms of uncertainties and ambiguities, often encountered in real life. The objective of the hybridization through ANFIS has been to overcome the weaknesses in one technology during its application, with the strengths of the other by appropriately integrating them.

An ANFIS is proposed as a core neuro-fuzzy model that can incorporate human expertise as well as adapt itself through repeated learning. An adaptive network is a multi-layer feedforward network in which node performs a particular function on incoming signals. The form of the node functions may vary from node to node. In an adaptive network, there are two types of nodes: adaptive and fixed. The function and the grouping of the neurons are dependent on the overall function of the network. Based on the ability of an ANFIS to learn from training data, it is possible to create an ANFIS structure from extremely limited or no mathematical representation of the system (Toha *et. al*., 2008). The ANFIS architecture can identify near-optimal membership functions of fuzzy logic for achieving desired

input-output mappings. The network applies a combination of the least square method and the back propagation method for training fuzzy inference system (FIS) membership function parameters to emulate a given training data set. The system converges when the training and checking errors are within the acceptable bound. This architecture has demonstrated high performance in many applications. The ANFIS generated in the MATLAB allows for generation of standard Sugeno style fuzzy inference system or a fuzzy inference system based on sub-clustering of the data (MathWorks, 1995).

The current study focuses on the development of ANFIS by using 18 initial fuzzy rules that are certain based on the human experts' experience and knowledge about the students' performance. These 18 decisions are shown in the Table 4.3 (Norazah Yusof *et al*., 2007). This method might help students, their parents, and evaluators in obtaining more reliable and understandable results for a students' performance. It is important to point out that the aim of proposed method it is to strengthen the present rules by providing additional information for decision making.

1.2 Problem Background

Student accessing the quiz and test in e-learning are normal activities to evaluate the student performance. Normally, score is used as a factor for identifying the student performance. However, it is a challenge when more factors involve in determine the student performance, such as time to answer question, numbers of try to answer question correctly, and numbers of help needed. The reasoning of the student's performance for multiple factors is difficult. Thus, lecture unable to evaluate every student in a short time. If lecturer do so, then will cost a lot of time and the results of evaluation may not accurate or not convergence.

Generally, the adaptive network fuzzy inference system (ANFIS) is a hybrid intelligent system. It is combining a neural network with a fuzzy system. An artificial neural network is good in learning but acts as a black-box and it learns without the human intervention (Negnevitsky, 2005). Similarly, we able to build a fuzzy inference system if we have knowledge expressed in linguistic rules but the fuzzy system lack of ability to learn and the fuzzy system cannot adjust itself to a new environment. By combining both of them, the neural networks become more transparent and the fuzzy systems become capable of learning (Negnevitsky, 2005). A study need to be done to reason student's performance with multiple factors by using ANFIS technique and to overcome the uncertainty and imprecise information.

1.3 Problem Statement

From the problem background above has been stated clearly the importance of using adaptive network fuzzy inference system in reasoning the performance of the students. Commonly, to evaluate a student performance is based on marks or how much the student able to score in an exercise only or involves the human expert decisions to solutions of problems and reasoning about the student. However, one of the major problems in acquiring human expert knowledge is that much of the information is inconsistent, vague, and incomplete. Designing a fuzzy rule based system involves 'If-Then' fuzzy rules, addressing the universe of discourses and the membership function. This manually fuzzy system will take a lot of time on trial and error on order to define the best fitted membership functions. Besides that, there are no standard methods exist for transforming human knowledge into the rule base. Therefore, this is so vital considering that the human expert knowledge's is insufficient to analyze all possible conditions. Focusing on tuning the membership functions as to minimize the output error measure or maximize performance index is still questionable.

In order to apply the ANFIS to this problem, there will be contained of several factors, such as the score obtained from the exercise, time of finish each question in an exercise, the number of tries for each question by the student, and number of helps has been used by the student when answering the question. From the ANFIS approach, we able to form a complete fuzzy rule base in order to solve the problem of the incomplete and vagueness in the decision made by the human. Therefore, the research question is how efficient using the adaptive network fuzzy inference systems to reason the student's performance.

1.4 Project Aim

The aim of this project is to study the effectiveness of ANFIS and implement it to reasoning the performance of students.

1.5 Project Objectives

In order to accomplish the hypothesis of the study, few objectives have been identifies:

i. To study and analysis on the Adaptive Neuro-Fuzzy Inference Systems.
ii. To analyze the student's performance based on the human experts' fuzzy rule base and ANFIS's complete fuzzy rule base.
iii. To develop student performance model based on ANFIS and test the proposed research.

1.6 Project Scopes

The scopes of this project are defined as follows:

i. Implement adaptive neuro-fuzzy inference systems using Matlab.
ii. Acquire the knowledge of the human expertise to determine the criteria of the students' learning and the decisions about their level of mastery.
iii. Use the 18 initial rules as the training data and 1500 random input data as the testing dataset in the experiment.
iv. Comparison between the classification results of ANFIS and human expert FIS.

1.7 Significance of the Project

This study of this research is to investigate the ANFIS and then implement it to reasoning the performance of the students, by comparing it with human expert FIS. The evaluation will be carried out since there is no extensive comparison in ANFIS and human expert FIS has been done before in the reasoning the performance of the students. The outcome of this study can be used to verify the efficiency of ANFIS and this study will spark future research in ANFIS technique.

In conclusion, the ANFIS can reduce the time of processing of evaluate the students' performance. Human expert FIS will be used as another technique to compare the results with ANFIS.

1.8 Project Plan

This project will be carried out in two semesters. The first part of the project is done in the first semester where the understandings of literature review and methodology that will be used are done. Gathering information about the study is a crucial part of this part since thorough understanding is needed in order to really implement the proposed approach. Most of the information is obtained from articles and journal that can be downloaded from the Institute of Electrical and Electronic Engineering (IEEE) website and ScienceDirect website. The second part of the project is to implement the ANFIS and compare the results with human expert FIS.

1.9 Organization of Report

This report consists of five chapters which are the introduction, literature review, research methodology, experimental result and analysis, and conclusion. The first chapter presents introduction to the study and why this study is being conducted. It also gives the objectives and scope of the study. Chapter 2 provides reviews on ANFIS, FIS and related researches. Chapter 3 discusses on the methodology used to carry out the study systematically. Chapter 4 discusses the experimental results of training and testing data. Chapter 5 is the conclusion and suggestion for future works.