Treat Opaqueness of HHFNNs via Rule Extraction Using GA for CVDs Diagnosis

by

Cui Yuanlian

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in Electrical and Computer Engineering

Faculty of Science and Technology
University of Macau

2013

Approved by _____
Supervisor

_____

_____

_____

Date _____

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at the University of Macau, I agree that the Library and the Faculty of Science and Technology shall make its copies freely available for inspection. However, reproduction of this thesis for any purposes or by any means shall not be allowed without my written permission. Authorization is sought by contacting the author at

Address: N/A

Telephone: (853)-63743414
Fax: N/A
E-mail: maomaoqiupanda@gmail.com

Signature _____

Date _____

University of Macau

Abstract

Treat Opaqueness of HHFNNs via Rule Extraction Using GA for CVDs Diagnosis

by Cui Yuanlian

Thesis Supervisor: Prof. Dong Mingchui

Department of Electrical and Computer Engineering

Nowadays, e-home healthcare becomes a very hot topic and draws great attention. Cardiovascular diseases (CVDs) are responsible for over 17.3 million deaths per year and are the leading causes of death in the world. Therefore developing an e-home system for diagnosing CVDs is of great importance and in demand.

Hemodynamic parameters (HDPs) can be obtained through analysis of the sphygmogram curves which are easy to sample from human wrist and have abundant physiological information. A hierarchical system combining fuzzy logic and artificial neural networks (ANNs) for CVDs diagnosis through three grouped HDPs with different confidence coefficients was proposed by our research team few years ago and proved its high diagnostic accuracy.

However, neural networks (NNs) regarded as opaque models represent knowledge in digitized form in their hidden nodes and link weight matrix, which is not-understandable by human and leads to their rather low degree of comprehension. My thesis research mainly focuses on redressing the opaqueness of NNs and proposes an approach of providing exclusive explanation to the final result generated by hierarchical heterogeneous fuzzy NNs (HHFNNs).

There are several different methods in literature developed for providing such explanation capability for NNs. Among them, the means, called extraction rules from trained NNs, is accepted as the best way of extracting the knowledge represented in the NNs. The means of deriving an explanation structure from trained NNs that can give users insight into the decision-making processes of the trained NNs, thus allows users to verify what clinically sound basis is utilized by NNs for making decisions. And the rules created at the end are more understandable for human than any other representation (i.e. decision trees, semantic networks or directional graphs etc.).

Rule extraction from trained HHFNNs is proposed for CVDs diagnosis. Since the HHFNNs are composed of two types of NNs, the comparatively delicate structure implies a relatively universal rule extraction approach. Thus a pedagogical method of extracting fuzzy IF-THEN rules using genetic algorithm (GA) is proposed, which treats NNs as black boxes and is independent of NNs' architecture and training algorithm. The proposed method is verified using real clinical site-sampled data and the results tend to be acceptable.

Key words: hierarchical heterogeneous fuzzy neural networks, fuzzy logic, rule extraction, genetic algorithm, fuzzy IF-THEN rules

TABLE OF CONTENTS

LIST OF FIGURES IV

LIST OF TABLES VII

LIST OF ABBREVIATIONS VIII

ACKNOWLEDGMENTS IX

CHAPTER 1: INTRODUCTION 1

1.1 Research Background 1

1.2 Overview on Characteristics of ES and ANNs 4

1.2.1 ES 4

1.2.2 ANNs 8

1.2.3 Comparison of ES with NNs 14

1.3 Integrate ES and NNs Properly 15

1.4 Review of Rule Extraction Techniques 17

1.4.1 Advantages of Extracting Rules from NNs 18

1.4.2 Classification Scheme 19

1.4.3 Category 22

1.5 Bottleneck and Research Goals 29

1.6 Organization of This Thesis 31

CHAPTER 2: GLOBAL DESIGN OF THE RESEARCHED SYSTEM 32

2.1 Research Background 32

2.2 Architecture Design 33

2.2.1 Overall System Architecture of CVDs Diagnosis 33

2.2.2 Working Principle and Information Flow 34

2.3 Function Components Design 36

2.3.1 Vital Sign Acquisition 36

2.3.2 Intelligent Models for CVDs Diagnosis 37

2.3.3 Explaining Module 44

CHAPTER 3: RULE EXTRACTION VIA FUZZY CLASSIFIER AND GA 62

3.1 Various NNs for CVDs Diagnosis 62

3.1.1 BP NNs 63

3.1.2 PNNs 67

3.1.3 LVQ 70

3.2 Generating Fuzzy IF-THEN Rules 73

3.3 Extracting Compact Rule Set 77

CHAPTER 4: TREAT OPAQUENESS OF NNS VIA GA 80

4.1 Fuzzy NNs 80

4.2 Extracting Rules from Fuzzy NNs Using GA....82

CHAPTER 5: PROVIDING EXPLANATION FOR HHFNNS 85

5.1 HHFNNs 85

5.2 Fuzzy Rule Extraction Approach Using GA 87

5.3 Process of Providing Explanation for HHFNNs....89

CHAPTER 6: EXPERIMENTAL STUDY 91

6.1 Experimental Database 91

6.2 Experimental Results 94

6.2.1 Experimental Procedure of Providing Explanation for Single NNs 94

6.2.2 Results Comparison of Two Proposed Methods on Single NNs 97

6.2.3 Results of Proposed Approach on HHFNNs 100

CHAPTER 7: CONCLUSION AND FUTURE WORK....102

7.1 Conclusion 102

7.2 Future work....104

BIBLIOGRAPHY....105

APPENDIX A: PUBLICATIONS AND PROJECTS PARTICIPATED....121

LIST OF FIGURES

Number *Page*

Figure 1.1 Generic structure of expert system 5

Figure 1.2 Two neurons with basic components 9

Figure 1.3 Artificial neuron model 9

Figure 1.4 Gallant's connectionist ESs 17

Figure 2.1 Schematic diagram of e-home CVDs diagnosis system 32

Figure 2.2 Overall system architecture of CVDs diagnosis 34

Figure 2.3 Information flowchart of CVDs diagnosis 35

Figure 2.4 Sphygmogram collection 36

Figure 2.5 Intelligent models in healthcare systems 38

Figure 2.6 Architecture of generic layered NNs 42

Figure 2.7 Gaussian membership function with different parameter values 44

Figure 2.8 GA cycle 48

Figure 2.9 Flowchart of GA 49

Figure 2.10 Forms of chromosome genotypes and phenotypes.....50

Figure 2.11 Two types of chromosomes.....51

Figure 2.12 Single point crossover 54

Figure 2.13 Two point crossover 55

Figure 2.14 An example of fuzzy partition by a simple fuzzy grid 59

Figure 3.1 The diagram of offering NNs description by GA plus fuzzy classifier.....62

Figure 3.2 Architecture of BP NNs with single hidden layer 64

Figure 3.3 Architecture of PNNs 68

Figure 3.4 Architecture of LVQ.....71

Figure 3.5 Fuzzy membership functions of PAP 74

Figure 4.1 The diagram of extracting rules from fuzzy NNs via GA 80

Figure 4.2 Block diagram of processing at input layer by fuzzy logic 82

Figure 4.3 The designed form of chromosome.....82

Figure 5.1 System overview of proposed HHFNNs 86

Figure 5.2 Flowchart of GA.....89

Figure 5.3 Function flowchart of fuzzy rule extraction via GA from single NNs.....89

Figure 5.4 Function flowchart of fuzzy rule extraction via GA from HHFNNs 90

Figure 6.1 Medical records and analysis from hospital 91

Figure 6.2 The overall diagram of fuzzy-NNs-GA CVDs diagnosis system with exclusive explanation 94

LIST OF TABLES

Number *Page*

Table 1.1 Characteristics Comparison of ES with NNs....14

Table 2.1 The distinctions between quantitative research and qualitative research 40

Table 6.1 Acronym of physiological pessages and HDPs....92

Table 6.2 Randomly generated initial population....95

Table 6.3 One instance of extracted optimal rule set....95

Table 6.4 NNs' input variables and corresponding diagnostic conclusion....96

Table 6.5 Testing results of two proposed methods on single NNs....98

Table 6.6 Testing results of GA rule extraction from different types of NNs....98

Table 6.7 Some examples of providing explanation to HHFNNs' conclusion....100

LIST OF ABBREVIATIONS

AI. Artificial Intelligence

ANNs. Artificial Neural Networks

BP. Back-propagation

CVDs. Cardiovascular Diseases

DFA. Deterministic Finite-state Automata

ES. Expert System

GA. Genetic Algorithm

HDPs. Hemodynamic Parameters

HHFNNs. Heterogeneous Hierarchical Fuzzy Neural Networks

LVQ. Learning Vector Quantization Networks

PNNs. Probabilistic Neural Networks

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my supervisor Prof. Dong Ming Chui for his inspiring and patient guidance and endless support for my study and thesis research. In terms of research projects, I would like to acknowledge Faculty of Science and Technology, Research Committee of University of Macau and the Science and Technology Development Fund of Macau for financial and technical supports to the research. Also, I would like to thank all the members of our laboratory for their technical helps and friendship. Finally, I would like to express my appreciation to my family for their wholehearted support.

DEDICATION

The author wishes to dedicate this thesis to my mother.

Thanks for all she bestowed to me!