NEURAL NETWORK IN BIOMETRICS: A SURVEY IN FINGERPRINT CLASSIFICATION

SARAH NAZUHA MOHAMAD NASIR

UNIVERSITI UTARA MALAYSIA
2003

NEURAL NETWORK IN BIOMETRICS: A SURVEY IN FINGERPRINT CLASSIFICATION

A thesis submitted to the Graduate School in partial fulfillment of the requirements for the degree Master of Science (IKBS), Universiti Utara Malaysia

by

Sarah Nazuha Mohamad Nasir

© Sarah Nazuha Mohamad Nasir, July 2003. All rights reserved

Sekolah Siswazah
(Graduate School)
Universiti Utara Malaysia

PERAKUAN KERJA KERTAS PROJEK
(Certification of Project Paper)

Saya, yang bertandatangan, memperakukan bahawa
(I, the undersigned, certify that)

SARAH NAZUHA BT. MOHAMAD NASIR

calon untuk Ijazah Master of Science (IKBS)
(candidate for the degree of)

telah mengemukakan kertas projek yang bertajuk
(has presented his/her project paper of the following title)

NUERAL NETWORK IN BIOMETRICS : A SURVEY IN FINGERPRINT CLASSIFICATION

seperti yang tercatat di muka surat tajuk dan kulit kertas projek
(as it appears on the title page and front cover of project paper)

bahawa kertas projek tersebut boleh diterima dari segi bentuk serta kandungan dan meliputi bidang ilmu dengan memuaskan.
(that the project paper acceptable in form and content and that a satisfactory knowledge of the field is covered by the project paper).

Nama Penyelia : Cik Noraziah Che Pa
(Name of Supervisor)

Tandatangan :
(Signature)

Tarikh : 29.07.2003
(Date)

PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a post graduate degree from Universiti Utara Malaysia, I agree that the University Library may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by my supervisor (s) or, in their absence, by the Dean of the Graduate School. It is understood that any copying or publication, or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to Universiti Utara Malaysia for any scholarly use which may be made of any material from my thesis.

Requests for permission to copy or to make other use of material in this thesis in whole or in part should be addressed to:

Dean of Graduate School

Universiti Utara Malaysia

06010 UUM Sintok

Kedah Darul Aman

ABSTR4c.T

(Bahasa Malaysia)

Pengkelasan cap jari telah menjadi satu tajuk kajian yang terkenal kerana kesesuaiannya untuk tujuan pengesahan dan pengecaman. Terdapat beberapa pendekatan yang digunakan di dalam system pengkelasan cap jari iaitu berstruktur, bentuk susunan kata, statistic dan rangkaian neural. Tujuan pengkelasan cap jari adalah untuk mengkategorikan satu cap jari ke dalam kategori tertentu berdasarkan kepada konfigurasi bentuk keseluruhannya. Analisis perbandingan di antara pendekatan rangkaian neural dan bukan rangkaian neural telah menunjukkan kelebihan-kelebihan menggunakan rangkaian neural di dalam pengkelasan cap jari. Keputusan menunjukkan bahawa kombinasi rangkaian neural dan pendekatan pembelajaran mesin mengatasi penggunaan pendekatan rangkaian neural semata-mata dalam konteks ketepatan pengkelasan. Oleh itu kombinasi rangkaian neural dan pendekatan pembelajaran mesin adalah dicadangkan. Kelebihan-kelebihan yang jelas telah ditunjukkan oleh pembelajaran berpandu dan tidak berpandu dalam rangkaian neural untuk tujuan pengkelasan cap jari. Model rangkaian neural yang digabungkan dengan pembelajaran mesin (SOM-LVQ dan MLP) telah dicadangkan di akhir kajian. SOM-LVQ digunakan untuk pra-pengkelasan dan pengkelas MLP digunakan untuk pengkelasan.

ABSTRACT

(English)

Fingerprint classification has become a popular research topic due to its applicability in authentication and identification. There are several approaches in fingerprint classification systems which are structural, syntactic, statistical and neural networks. The purpose of fingerprint classification is to categorize a fingerprint into certain category based on its global pattern configuration. The analysis of comparisons between neural-network and non-neural network approaches have pointed out the advantages of using neural network in fingerprint classification. The results show that the combination of neural networks with other machine learning approach outperforms the neural networks based alone in terms of classification accuracy. Therefore a combination of neural networks and machine learning approach is suggested in this paper. The clear advantages of supervised and unsupervised learning in neural networks methods support the objective of this study that to suggest the neural network approach for fingerprint classification. A model of neural network combined with machine learning approach (SOM-LVQ and MLP) is proposed at the end of this study. SOM-LVQ is used for pre-classification and MLP classifier is used for classification.

ACKNOWLEDGEMENTS

The author would like to thank the entire people who are involved in this study. First and foremost to my supervisor, Cik Noraziah Che Pa, thank you for guiding me throughout the study also for your valuable assistance for me to complete this study.

A special thanks to my friends Nor Fadilah Tahar, Rafikha Aliana A Raof and Chuah Minh Hooi. Thank you for all you supports.

My deepest appreciation goes to my beloved family who has been very supportive, patient and understanding all the time.

CONTENTS

Permission To Use i

Abstract (Bahasa Malaysia)..... ii

Abstract (English)..... iii

Acknowledgements..... iv

Table of Contents..... v

List of Tables..... viii

List of Figures..... ix

Chapter 1: Introduction

1.1 Overview of the study..... 1

1.2 Context of the study..... 2

1.3 Problem statements..... 3

1.4 Objectives of the study..... 3

1.5 Significance of the study..... 3

1.6 Scopes, Assumptions and Limitations..... 4

Chapter 2: Literature Review

2.1 Overview..... 5

2.2 A brief introduction of biometric..... 5

2.2.1 Fingerprints identification in biometric..... 5

2.3 Fingerprint Classification..... 7

2.4 Pattern recognition in fingerprint classification..... 8

2.4.1 Feature Extraction..... 9

2.5 Fingerprint Classification System..... 11
2.6 Approaches in fingerprint classification..... 12

Chapter 3: Methodology

3.1 Introduction..... 17
3.2 Study of the problem..... 18
3.2.1 Problems in fingerprint classification..... 18
3.2.2 Classifiers in fingerprint classification..... 19
3.2.3 Architecture and system components..... 20
3.2.4 Region of interest (ROI) detection for fingerprint classification 20
3.2.5 Measuring the performance of fingerprint classification accuracy..... 21
3.2.6 Why neural network?..... 21
3.2.7 Concept formation by combining neural networks and machine learning..... 22
3.2.8 Interpretation of neural network for classification tasks..... 23
3.2.9 Using neural network to minimize error in classification..... 23
3.3 Analysis of the models..... 24
3.3.1 Analysis of Advantages and disadvantages of the models..... 47
3.4 Design proposed model..... 48

Chapter 4: Results

4.1 Introduction..... 50
4.2 Proposed model for fingerprint classification..... 50
4.3 Description of the model..... 51
4.4 Justification of the model..... 52

Chapter 5: Conclusion and Recommendations

5.1 Advantages of neural networks for fingerprint classification..... 54
5.2 Combination of neural networks with machine learning approach..... 54

5.3 Limitations..... 55
5.4 Recommendations..... 55

References..... 56

Appendix : Fingerprint minutiae and codes in the database from NIST Special Database 27
Appendix A : Fingerprint position codes and distribution in database..... 61
Appendix B : Pattern classification and codes..... 61
Appendix C : Distribution of pattern classification..... 61
Appendix D : Orientation in fingerprint..... 62
Appendix E : Minutiae file format in the database (Type-9: minutiae attributes) 62
: Type-13 (Fingerprint image distribution) 63
Appendix F : Data directory hierarchy (distribution in NIST special database 27)63

LIST OF TABLES

Table 3.1: An analysis of Fingerprint Classification by Jain and Karu (1996) 25

Table 3.2: An analysis of Hierarchical Kernel Fitting
For Fingerprint Classification and Alignment by Anil Jain (1999) 27

Table 3.3: The example of result from the experiment 29

Table 3.4: An analysis of Comparison of FFT Filtering Methods
For Neural Network Classification by Watson *et al* (1994) 31

Table 3.5: An analysis of Neural Network Performance for Character
and Fingerprint Classification by Altering Network
Dynamics by Wilson *et al* (1995) 33

Table 3.6: An analysis of Neural Network Based Minutiae filtering in
Fingerprints by Maio and Maltoni (1998) 36

Table 3.7: An analysis of Industrial Applications of HNN: Character
Recognition and Fingerprint Classification by Halici *et al* (1999) 38

Table 3.8: An analysis of Automatic Fingerprint Verification Using
Neural Network by Ceguerra and Koprinska (2001) 41

Table 3.9: An analysis of A New Machine Learning Approach
to Fingerprint Classification by Yao *et al* (2001) 44

Table 3.10: An analysis of Fingerprint Classification by
Combination of Flat and Structural Approaches by
Marcialis *et al* (2001) 46

LIST OF FIGURES

Figure 2.1(a): Tented Arch, (b): Left Loop, (c): Whorl (d): Right Loop 7

Figure 2.2: Ridge ending (square) and ridge bifurcation (circle) 10

Figure 3.1: Components in fingerprint classification system 19

Figure 3.2: The Flow of a Complete Fingerprint Classification System 20

Figure 3.3: Structural Approach in fingerprint classification 26

Figure 3.4: The example of flow chart of fingerprint classification using syntactic approach 29

Figure 3.5: The example of fingerprint classification using K-L transform for global recognition 32

Figure 3.6: Error reject graph for sigmoidal MLP, sinusoidal MLP and PNN for classification of fingerprint 35

Figure 3.7: Neural network classifier 37

Figure 3.8: UHNN (2 Layers PCA-MSOM) used for fingerprint classification 40

Figure 3.9: Generating the feature vector: a fingerprint with the reference axis (top), its shape signature (middle), its digitized shape signature (bottom), with the direction of each feature 43

Figure 3.10: The example of segmented fingerprint images for generating fingerprint vector 45

Figure 4: The proposed model for fingerprint classification 51

Chapter 1
Introduction

1.1 Overview of the study

The study of neural networks is an extremely interdisciplinary field, both in its development and its application (Fausett, 1994). There are various points of view as to the nature of neural networks. This paper will describe the area in which neural networks are being applied, the biometrics applications. The breadth of neural network applicability will be discovered in the survey on fingerprint classification. By doing the comparison between non-neural network and neural networks approach, this study will contribute to the use of neural network in fingerprint classification.

An artificial neural network is an information processing system that has certain performance characteristics in common with biological neural networks (Fausett, 1994). According to Fausett (1994), artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology.

The characteristics of neural networks make them a useful tool in processing reliable recognition or identification of complex patterns (Gallinari, 1998). Neural information processing has proven to be a very useful and robust technique in such pattern recognition tasks.

Pattern recognition can be defined as a process that leads to a decision. The quality of this decision can only be measured by statistics relating the number of good and bad classifications (Davalo & Naim, 1991).

The contents of the thesis is for internal user only

REFERENCES

1. Amengual, J.C., Juan, A., Perez, J.C., Prat, F., Saez, S., & Vilar, J.M. (1997). Real-time Minutiae Extraction in Fingerprint Image. *Journal Inst. Tecnology of Information (ITI)*, Spain.

2. Bazen, A.M., Otterlo, M.V., Gerez, S.H. & Poel, M. (2001). A Reinforcement Learning Agent for Minutiae Extraction from Fingerprints. http://www.cs.utwente.nl/~otterlo/downloads/ BNAIC2001CameraReady.pdf

3. Bernatzki, A., Eppler, W. & Gemmeke, H. (1996). Interpretation of Neural Networks for Classification Tasks. http://fuzzy.fzk.de/eppler/postscript/eufit.ps

4. Bishop, C.M. (1995). *Neural Networks for Pattern recognition*, Clarendon Press, Oxford.

5. Blue, J.L., Candela, G.T., Grother, P.J., Chellappa, R., & Wilson, C.L. (1994). Evaluation of pattern classifiers for fingerprint and OCR applications. *Pattern Recognition*, 27(4), 485-501.

6. Brouwer, R.K. (2002). A Discrete Fully Recurrent Network of Sigmoid Units for Associative Memory and Pattern Classification. *International Journal of Pattern Recognition.*

7. Candela, G.T. & Chellappa, R. (1993). Comparative Performance Of Classification Methods For Fingerprint. *US National Institute of Standards and Technology report NISTIR 5163.*

8. Ceguerra, A. & Koprinska, I. (2001). Automatic Fingerprint Verification Using Neural Networks, www.cs.usyd.edu.au/~irena/icann02.pdf.

9. Davalo, E., & Naim, P. (1991). *Neural Networks*, Macmillan Education Ltd

10. Fausett, L. (1994). *Fundamental Of Neural Networks: Architectures, Algorithms and Applications*. Prenticae Hall, Englewood Cliffs. New Jersey.

11. FBI. Advanced Latent Fingerprints. (1983) U.S. Department of Justice, Federal Bureau of Investigation.http://www.fbi.gov

12. Fu, K.S. (1985). *Syntactic Pattern Recognition.* Prentice Hall, Englewood Cliffs, New Jersey.

13. Gallinari, F. (1998). *Industrial Applications of Neural Networks.* World Scientific Co.Pte. Ltd., Singapore, New Jersey, London, Hong Kong.

14. Garris, M.D. & McCabe (2000). NIST Special Database 27, Fingerprint Minutiae From Latent And Matching Tenprint Images, National Institute of Standards and Technology.

15. Halici, U. & Ongun, G. (1996). Fingerprint Classification Through Self-Organizing Feature Map Modified to Treat Uncertainty , *In Proceedings of IEEE.* 84(10) 1479-1512.

16. Halici, U., Erol, A., & Ongun, G. (1999). Industrial Applications of Hierarchical Neural Network: Character Recognition and Fingerprint Classification. *International Series on Computational Intelligence,* 180-192.

17. Henry, E.R. (1999). *Classification and Uses of Fingerprints.* Routledge, London.

18. Hong, L., Jain, A. & Bolle, R. (1996). Fingerprint Enhancement. ftp.cps.msu.edu/pub/prip/hong/wacv.ps.gz

19. Hrechak, A.K., & McHugh, J.A. (1990). Automated Fingerprint Identification Using Structured Matching. *Pattern Recognition.*23, 893-904.

20. Isenor, P.K., & Zapy, S.A. (1985). Fingerprint identification using graph matching. *Pattern Recognition,*19:113-122.

21. Jain, A., Karu, K. (1996). Fingerprint Classification. *Pattern recognition,*29(3) 384-404.

22. Jain, A. (1999). Hierarchical Kernel Fitting for Fingerprint Classification and Alignment. *IEEE Trans. Of Pattern Recognition and Machine Intelligence,* 22(2).

23. Kinder, W. & Brauer, W. (1992). Classification of Trajectories- Extracting Invariants with a Neural Network. http://www.jessen.informatik.tumuenchen.de/ftp/Automated_Reasoning/Reports/FKI-Reports/fki-168-92.ps.gz

24. Lampinen, J., Smolander, S., & Korhonen, M. (1995). Wood Surface Inspection System Based on Generic Visual Features. *In Proceedings of ICANN 1995, Paris.* 35-42.

25. Maio, D., & Maltoni, D. (1998). Neural Network Based Minutiae Filtering in Fingerprints. *In Proceedings of 14th International Conference on Pattern Recognition.*

26. Marciallis, G., Roli, F., & Frasconi, P. (2001). Fingerprint Classification by Combination of Flat and Structural Approaches. *In Proceedings of AVBPA 2001,*241-246.

27. Mehtre, B.M., & Chatterjee, B. (1989). *Pattern Recognition,*381-385.

28. Moayer, B., & Fu, K.S. (1975). A syntactic approach to fingerprint pattern recognition. *Pattern Recognition,* 7, 1-23.

29. Ripley, B.D (1995). Pattern Recognition via Neural Networks. www.stats.ox.ac.uk/pub/neural/papers/PRNN.ps.Z

30. Rumelhart, D.E., Hinton, G.E., & Williams, R.J. (1986). Learning Representations By Backpropagating Errors. *Nature*, 332: 533-536.

31. Simula, O., & Vesanto, J. (1999). The Self-Organizing Map in Industry Analysis. *International Series on Computational Intelligence*, 89-112.

32. Smith, R.E. (2002). *Authentication Form Passwords to Public Keys.* Addison-Wesley.

33. Sparrow, M.K., & Sparrow P.J. (1985). A Topological Approach to the Matching of Single Fingerprints :*Technical Report Special Publication SW-124*, National Bureau of Standards, Washington, DC.

34. Tico, M., Immonen, E., Ramo, P., Kuosmanen, P., & Saarinen, J. (2001). Fingerprint Recognition Using Wavelet Features. *In Proc.ISCAS*, 21-24.

35. Trenkle, J.M. (1993). Region of Interest Detection for Fingerprint Classification. www.novodynamics.com/trenkle/papers/aipr93.ps.gz

36. Vapnik, V.N. (1998). *Statistical Learning Theory.* Wiley, New York.

37. Visa, A., Iivarinen, J., Valkealathi, K., & Simula, D. (1995). Neural Network based Cloud Classifier. *In Proceedings of ICANN 1995. Paris.* 303-309.

38. Watson, C.I., Candela, G.T., & Grother, P.J. (1994). Comparison of FFT Fingerprint Filtering Methods for Neural Network Classification. *Technical Report NISTIR.*

39. Wessels, T. & Omlin, C.W. (1998). A Hybrid System for Signature Verification. http://www.citeseer.com

40. Wilson, C.L., & Blue, J.L. (1995). Improving Neural Networks Performance for Character and Fingerprint Classification by Altering Networks Dynamics. *World Congress on Neural Networks Proceeding II* 151-158.

41. Xiao, Q. & Raafat, H. (1991), Pattern Recognition, 24(10), 985-992.

42. Yao, Y., Marciallis, G.L., Pontil, M., Frasconi, P., & Roli, F. (2001). A New Machine Learning Approach to Fingerprint Classification. *In Proceeding of AVBPA 2001*. 241-246.

43. Introduction To Pattern Analysis. Retrieved March 14, 2003. From: http://www.texasA&M.edu

44. Fingerprint Classification. Retrieved June, 27, 2003. From: http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/prints_ext.html