DESIGNING A NEURAL NETWORK BASED AUDIO CLASSIFICATION SYSTEM

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DESIGNING A NEURAL NETWORK BASED AUDIO CLASSIFICATION SYSTEM

A thesis submitted to the Graduate School in partial fulfillment of the requirement for the degree Master of Science (Intelligent System),

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(Northern University of Malaysia)

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ABSTRACT

Artificial neural networks have found profound success in the area of

pattern recognition. The collections of digital music have become

increasingly common over the recent years. As the amount of data

increases, digital content classification is becoming more important.

In this thesis, we are studying content-based classification of digital

musical signals according to their musical genre (e.g., jazz, rock, pop

and blues) and the features used. The purpose of this thesis is to

propose of designing a neural network based audio classification

system "Model", and analyze the requirements that needed to

classifying it. This thesis covers a literature review on human

musical genre recognition, neural network technique, signal

processing, and related works of research. In addition, the

methodology that used in designing audio classification model using

neural network is introduced. The method was follow in this thesis is

content analysis, and the designing of the model has through several

phases: requirements analysis, knowledge representation and model

designing. The theory behind the used features is reviewed and the

fining from the proposed designing is presented.

Keywords: Neural Network: Digital Audio; Classification System.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Classification of digital audio "signals" according to their contents has been a major concern in recent years. There have been many studies on Audio Content Analysis (ACA), using different features and different methods. It is a well-known fact that audio signals are baseband, one-dimensional signals (Aksoy, 2002). General audio consists of a wide range of sound phenomena such as music, sound effects, environmental sounds, and speech and non-speech signals.

With the development of multimedia technology, classification is increasingly used in audio applications (Wold, 1996). In general, many research efforts high accuracy audio classification is only achieved for the simple cases such as speech, music discrimination. Pfeiffer (1996) have presented, a theoretical framework and application of automatic audio content analysis using some perceptual features. Saunders (1996), presented a speech music classifier based on simple features such as *Zero Crossing Rate* (ZCR) and short time energy for radio broadcast.

A *Neural Network* (NN) classifier is an artificial intelligent network with parallel processing units working together. The most common neural network model is the *Multilayer Perceptron* (MLP). This type of neural network is known as a supervised network (Haykin, 1999), because it requires a desired output in order to learning. The goal of this type of network is to create a model that correctly maps the input to the

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References

Aksoy, M., Ayaz, H. & Konukoglu, E. (2002). Content-based Classification of Musical Instrument Sounds Using Gaussian Methods. EE 473 DIGITAL SIGNAL PROCESSING.

Aucouturier, J. & Pachet, F. (2003). Representing Musical Genre: A State of the Art. Journal of New Music Research, vol. 32, no. 1, pages 83-93.

Batlle, E. & Cano, P. (2001). Automatic Segmentation for Music Classification using Competitive Hidden Markov Models. Audiovisual Institute. University Pompeu Fabra Rambla 31, 08002 Barcelona Catalunya – Spain.

Becchetti, C. & Ricotti, P. L. (1999). Speech Recognition, Theory and C++ Implementation. John Wiley & Sons.

Breure, L. (2001). Development of the genre concept. New Music Journal. Retrieved April 4th, 2004, form: http://www.cs.uu.nl/people/leen/GenreDev/GenreDevelopment.htm.

Burred, J. & Lerch, A. (2003). A Hierarchical Approach to Automatic Musical Genre Classification. Communication Systems Group Technical University Berlin, Germany. Proc. of the 6th Int. Conference on Digital Audio Effects (DAFx-03), London, UK. September 8-11.

Daniel, K. (1998). Artificial Neural Networks. An individual project within MISB-420-0. Saint Louis University. St. Louis November. Retrieved March 22nd, 2004, from: http://hem.hj.se/~de96klda/NeuralNetworks.htm

Erickson. T. (1999). Rhyme and punishment: The creation and enforcement of conventions in an on-line participatory limerick genre.

Eronen, A. (2003). Musical instrument recognition using ICA-based transform of features and discriminatively trained HMMs. vol. 2, pages 133-136. Seventh International Symposium on Signal Processing and Its Applications.

Foote, J. α (1999). An Overview of Audio Information Retrieval. Multimedia Systems, 7(1): 2–10.

Foote, J. b (1997). A Similarity Measure for Automatic Audio Classification. In Proc. AAAI Symposium on Intelligent Integration and Use of Text, Image, Video, and Audio Corpora.

Grimaldi, M., Cunningham, P. & Kokaram, A. (2001). An Evaluation of Alternative Feature Selection Strategies and Ensemble Techniques for Classifying Music. Computer Science Department, Trinity College Dublin, Ireland and Electronic Engineering Department, Trinity College Dublin, Ireland.

Hartmann, W., Pitch, P. & Auditory O. (1996). Journal of the Acoustical Society of America, vol. 100, no. 6, pages 3491-3502.

Haykin. S. (1999). Neural networks: a comprehensive foundation. 2nd edition, Prentice-Hall.

Houtsma, A. J. M. (1997). Pitch & Timbre: Definition, Meaning and Use. Journal of New Music Research, vol. 26, no. 2, pages 104-115, 1997.

Houtsma, A. J. M. (1995). Hearing, handbook of perception and cognition, chapter 8: Pitch Perception, pages 267-296. Academic Press Inc., San Diego, CA, USA, 2nd edition.

Hussey, J. & Hussey, R. (1997). Business Research: A Practical Guide for Undergraduate and Postgraduate Students, Ist ed. MACMILLAN PRESS LTD.

Li, D., Sethi, I., Dimitrova, N. & McGee, T. (2001). Classification of general audio data for content-based retrieval. Pattern Recognition Letters, vol. 22, no. 5, pages 533-544.

Liu, Z., Wang, Y. & Chen, T. (1998). Audio Feature Extraction and Analysis for Scene Segmentation and Classification. Journal of VLSI Signal Processing System, 20: 61–79.

Logan, B. (2000). Mel Frequency Cepstral Coefficients for music modeling. International Symposium on Music Information Retrieval.

Oravec, M. (2001). Multilayer Perceptron in Face Recognition. Faculty of Electrical Engineering and Information Technology, Bratislava.

Pachet, F. & Cazaly, D. (2000). Taxonomy of Musical Genres. Paris, France. Content-Based Multimedia Information Access Conference (RIAO).

Perelmuter, G., Enrique, V., Vellasco, M. & Pacheco, M. (2000). Recognition of Industrial Parts Using Artificial Neural Networks. Department of engineering, PUC Rio, Brazil.

Pfeiffer, S., Fischer, S. & Effelsberg, W. (1996). Automatic Audio Content Analysis. Proceedings of the fourth ACM international conference on Multimedia, pp. 21-30.

Rabiner, L. and Juang, B. H. (1993). Fundamentals of Speech Recognition. PTR Prentice-Hall Inc., New Jersey.

Reynolds, D. & Rose, R. (1995). Robust Text-Independent Speaker Identification Using Gaussian Mixture Speaker Models. IEEE Transactions on Speech and Audio Processing, vol. 3, no. 1, pages 72-83.

Robert, S. T. (2001). Digital Audio Technology. Center for Audio Recording Arts (CARA). MI 313. Retrieved March 25th, 2004, from: http://cara.gsu.edu/courses/MI 313/digi2.htm

Sadie, S. editor. (2001). The New Grove Dictionary of Music and Musicians. MacMillan Publishing Company.

Saunders, J. (1996). Real-time Discrimination of Broadcast Speech/ Music. Proc. ICASSP96, vol.II, pp.993-996, Atlanta.

Saunders, J. (1996). Real-time Discrimination of Broadcast Speech/Music, vol. 2, pages 993-996. Atlanta, GA. IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP).

Scheirer, E. (1998). Tempo and beat analysis of acoustic musical signals. Journal of the Acoustical Society of America, vol. 103, no. 1, pages 558-601.

Scheirer, E. & Slaney, M. (1997). Construction and Evaluation of a Robust Multifeature Speech/Music Discriminator, vol. 2, pages 1331-1334. IEEE International Acoustics, Speech, and Signal Processing (ICASSP).

Silvia, P., Stephan, F. & Wolfgang, E. (1996). Automatic Audio Content Analysis. In ACM Multimedia 96, pages 21–30, Boston.

Scott, P. (2001). Music Classification Using Neural Network. EE373B Project.

Wold, E., Blum, T. & Wheaton, J. (1996). Content-based Classification, Search and Retrieval of Audio. IEEE Multimedia, 3(3), pp.27-36.

Zhang, T. & Kuo, C. (1998). Content-based Classification and Retrieval of Audio. In SPIE's 43rd Annual Meeting - Conference on Advanced Signa! Processing Algorithms, Architectures, and Implementations VIII. San Diego.

Zhang, T. & Kuo, J. (1999). Content-based Audio Classification and Retrieval. University of Southern California. Retrieved March 25th, 2004, from: http://viola.usc.edu/extranet/Projects/database-audio/

Zhang, T. & Kuo, C. (2001). Audio Content Analysis for Online Audio Visual Data Segmentation and Classification. IEEE Transactions on Speech and Audio Processing, vol. 9, no. 4, pages 441-457.