UNIVERSITI PUTRA MALAYSIA

# VEHICLE CLASSIFICATION USING NEURAL NETWORK IN FORWARD SCATTERING RADAR

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# VEHICLE CLASSIFICATION USING NEURAL NETWORK IN FORWARD SCATTERING RADAR

**By**

**NOR KHAIRIAH BINTI IBRAHIM**

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**April 2009**

**Chairman: Y.M Raja Syamsul Azmir B. Raja Abdullah, PhD**

**Faculty: Engineering**

This thesis unveils the potential and utilization of Neural Network (NN) in radar applications for target classification. The radar system under test is a special of its kind and known as Forward Scattering Radar (FSR). FSR is a special type of bistatic radar which the transmitted energy is scattered by a target and the target is so close to the transmitter-receiver baseline. Recent works had shown that FSR can be effectively used for classification, but the result can be further improved by using advance classification method. To proof this, result from FSR experiment were used. The target used for this experiment is a ground vehicle which is represented by typical public road transport.

New features from raw radar signal were determined and extracted manually prior to classification process using Neural Network (NN). Two types of features in the time and frequency domain signature were examined, namely time required for counting zero crossings, first main lobe width, second main lobe- width and the number of lobes. Multilayer perceptron (MLP) back-propagation neural network trained with back-propagation algorithm was implemented and analyzed. In NN classifier, the unknown target is sent to the network trained by the known targets to attain the accurate output.

Two tasks of classifications are analyzed. The first task is to recognize the exact type of vehicle, four vehicle types were selected: Vauxhall Astra, Renault Traffic, Vauxhall Combo and Honda Civic. The second task is to group vehicle into their categories: small, medium and large. The proposed NN provides high percentage of successful classification which is 90% and 98% of overall data was correctly classified in vehicle recognition and vehicle categorisation respectively. The result presented show that NN can be effectively employed in FSR system as a classification method.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**VEHICLE CLASSIFICATION USING NEURAL NETWORK IN FORWARD SCATTERING RADAR**

Oleh

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Tesis ini menyingkap potensi penggunaan rangkaian neural dalam aplikasi radar untuk klasifikasi sasaran. Sistem radar yang diuji adalah istimewa dalam kelasnya iaitu 'Forward Scattering Radar (FSR)'. FSR adalah dari jenis bistatik radar dimana tenaga yang dihantar diserakkan oleh sasaran sehingga ke garisan tapak antara penghantar dan penerima. Dalam beberapa kerja yang terbaru menunjukkan bahawa FSR boleh digunakan secara efektif untuk klasifikasi tetapi pencapaiannya boleh diperbaiki lagi dengan menggunakan cara klasifikasi yang lebih baik. Untuk pembuktian, keputusan daripada eksperimen FSR digunakan. Sasaran yang digunakan dalam eksperimen ini adalah kenderaan darat yang diwakili oleh pengangkutan awam yang tipikal di jalan raya.

Sifat baru daripada isyarat radar mentah telah ditentukan dan diekstrak secara manual untuk digunakan dalam proses klasifikasi menggunakan rangkaian neural. Beberapa sifat daripada isyarat domain masa dan frekuensi telah diperiksa dan dinamakan sebagai lebar cuping pertama dan kedua serta bilangan lebar cuping utama. 'Perceptron' berbilang

lapisan dengan algoritma aliran belakang telah dilaksanakan dan dianalisis. Dalam klasifikasi rangkaian neural, sasaran yang tidak diketahui dihantar kepada rangkaian yang telah di latih dengan sasaran yang dikenali untuk mencapai keluaran yang tepat.

Dua tugas klasifikasi telah dianalisis. Tugas pertama adalah untuk mengklasifikasi jenis kenderaan dan empat jenis kenderaan telah dipilih iaitu Vauxhall Astra, Renault Traffic, Vauxhall Combo dan Honda Civic. Tugas kedua adalah untuk mengklasifikasi kenderaan kepada tiga jenis kumpulan iaitu kecil, sederhana dan besar. Rangkaian neural yang dicadangkan memberikan peratusan klasifikasi yang tinggi iaitu sebanyak 90% dari kesuluruhan data telah diklasifikasikan dengan tepat bagi pengelasan mengikut jenis kenderaan manakala 98% untuk klasifikasi mengikut kumpulan kenderaan. Keputusan yang diperolehi menunjukkan bahawa rangkaian neural boleh digunakan secara efektif untuk klasifikasi dalam sistem FSR.

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I certify that an Examination Committee met on 9th April 2009 to conduct the final examination of Nor Khairiah Bt. Ibrahim on her Master of Science thesis entitled "Vehicle Classification Using Neural Network in Forward Scattering Radar" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the degree of Master of Science.

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# DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

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**NOR KHAIRIAH BINTI IBRAHIM**

Date: 7 August 2009

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| | | |
|---|---|---|
| 1-NN | - | One Nearest-Neighbor |
| ADC | - | Analog Digital Conversion |
| ANN | - | Artificial Neural Network |
| BFGS | - | Broyden-Fletcher-Goldfarb-Shanno |
| BPF | - | Band Pass Filter |
| CW | - | Continuous Wave |
| DPS | - | Differential Power Spectrum |
| EOG | - | Electrooculography |
| FANN | - | Fast Artificial Neural Network |
| FFT | - | Fast Fourier Transform |
| FSR | - | Forward Scattering Radar |
| HMMs | - | Hidden Markov Models |
| HPF | - | High Pass Filter |
| HRRP | - | High Range Resolution Profile |
| KNN | - | K-Nearest Neighbour |
| KUNDE | - | kernel Uncorrelated Neighbourhood Discriminative Embedding |
| LM | - | Levenverg Marquadt |
| LNA | - | Low Noise Amplifier |
| LPF | - | Low Pass Filter |
| ML | - | Maximum Likelihood |
| MLP | - | Multilayer Perceptron |

| | | |
|---|---|---|
| NN | - | Neural Network |
| PCA | - | Principal Component Analysis |
| PCs | - | Principal Component |
| RCS | - | Radar Cross section |
| RMS | - | Root Mean Square |
| RTE | - | Radar Target Echo |
| SAR | - | Synthetic Aperture Radar |
| SARPROP | - | Simulated Annealing Resilient Propagation |
| SCG | - | Scaled Conjugate Gradient |
| SISAR | - | Shadow Inverse Synthetic Aperture Radar |
| SNR | - | Signal to noise ratio |
| SSC | - | Statistical Signal Characterization |
| SVM | - | Support Vector Machine |

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

Radar is an acronym for Radio Detection and Ranging [1]. The term 'radio' refers to the use of electromagnetic waves for the signal transmission. The detection and ranging are accomplished by timing delay between transmission of a pulse of radio energy and its subsequent return. A basic radar system sends out pulses of electromagnetic energy which travel almost unconstrained through the air or space until they come across an object on their path. In Radar, objects of interest, such as aircraft are called target. The contact with the target involves some of the energy being reflected from the target, some being absorbed by the target and some being transmitted through the target [1]. The proportion of the incident energy that is reflected is dependent on the wavelength of the radar signal and the size, shape and material composition of the target. The reflected energy can potentially be scattered in any direction, so the energy reflected back to the radar is very small and is detected using a specially designed receiver.

If the transmitter and receiver are collocated, this configuration is known as a monostatic radar system. In contrast, if the transmitter and receiver are separated by a distance comparable to that of the maximum range of the target, the system is known as a bistatic radar system. The monostatic and bistatic radar system configuration is illustrated in Figure 1.1 (a) and (b) respectively.

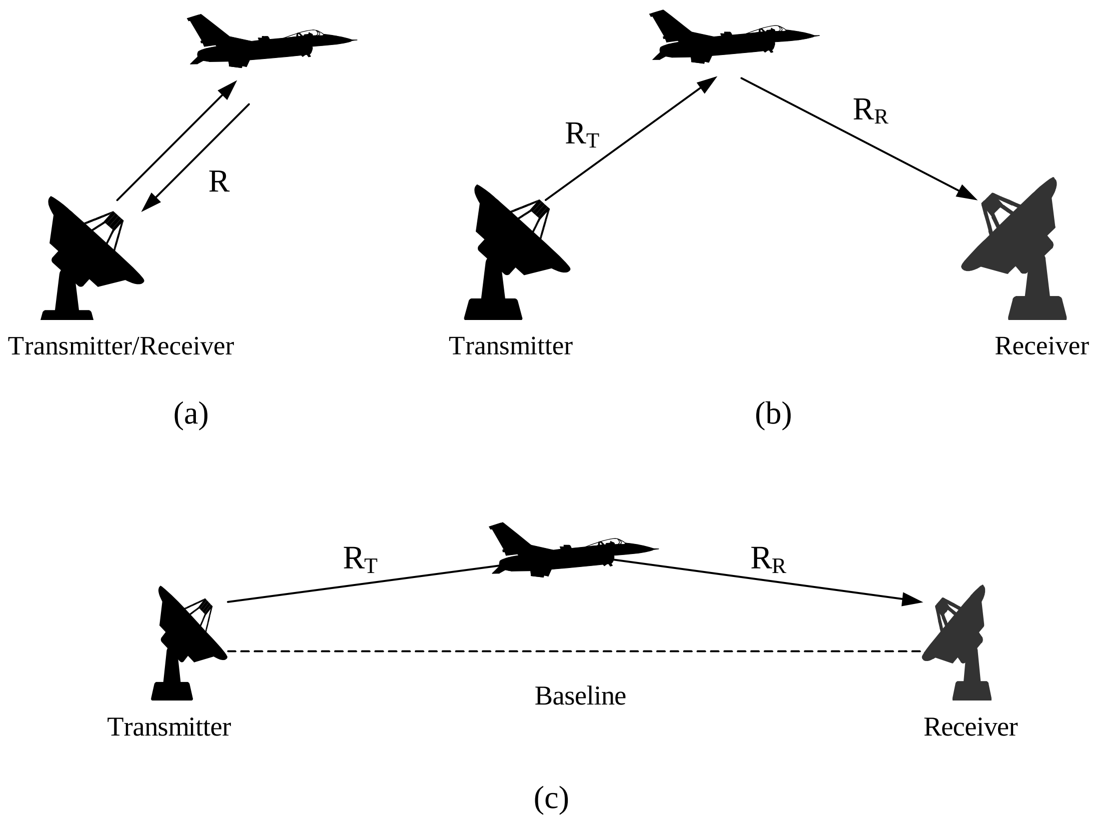



**Figure 1.1: (a) Monostatic radar (b) Bistatic radar and (c) Forward scattering radar**

Forward scattering radar (FSR) is a special type of bistatic radar [2], where the target is close to the transmitter-receiver baseline as shown in Figure 1.1(c). FSR presents a conservative class of systems that have a number of fundamental limitations, including the absence of range resolution and operation within narrow angles, and therefore require the target to be very close to the transmitter-receiver baseline. The bistatic radar technology has been used for several years and it is in military and civil applications.

The FSR offers a number of peculiarities that make it more attractive. The most attractive feature is the steep rise in the target radar cross section (RCS), which improves the understanding of radar system [2]. This feature makes FSR robust to 'Stealth' technology [2] and by using inverse synthetic aperture algorithms, FSR can be used as target classification [3]. Modern radar is no longer limited to detection and ranging, but also used for target classification and identification. The need for classifying a target has led to the development of many classification methods to be cooperated within the radar system. Thus, this thesis also proposes an alternative classification method which is based on the Neural Network for target classification to be used in an immature FSR system.

Neural Network (NN) approach becomes the most popular classification tool after the successful of this approach in solving problems especially in classification problem [4-6] and applications such as in medical [4], machining [5], power and control [6]. So, in this thesis, the application of neural network is proposed in order to give better performance in classifying the radar signature and the first of it kinds in FSR system. In addition to that, this research concentrates on developing an automatic classification system to classify target in FSR by exploiting the capability of NN. An NN can determine its conditions and adjust itself to provide different responses by using inputs and desired outputs. The most important thing about an NN is that it works as an expert system, which will eventually help the system in the decision making process. The targets that need to be classified in this work are the ground target (car, lorry and etc) collected from the experiment with total of 850 sample data.

## 1.2 Problem Statement and Motivation

Most of the FSR research involved air target classification and it concentrates on target detection [7] and coordinate estimation [8] where only one research group dedicated to FSR for ground target detection and recognition [9–13]. In this research, vehicles represented by public road transports were used as the targets of interest. The benefit of using FSR for road vehicle classification is that it could be useful in many applications for example in security, civil applications and as the fundamental works for medical applications [14-16]. The special feature for example a steep rise in RCS compared to the traditional radar create 'come back' interest in FSR. In addition to that, the practical establishment of FSR is also still at the beginning stage, thus this system is still in a green field to be further explored.

In the previous FSR work [9], the objective was to study the feasibility of FSR system. Due to that, a simple automatic Principal Component Analysis (PCA) was used to extract feature from the received signals and also only the signal in Frequency domain was analysed as the possible features. For classification algorithm, K-Nearest Neighbour (KNN) method was used as the classifier. Even though the performance is acceptable, it is believed that the classification performance can be improved by using alternative classification method such as Artificial Neural Network. There are also still few characteristics and parameters from the raw received signal that have not been studied for classification. Until now, there is no published document on using the direct time domain signal and different kind of frequency domain signatures as features to be the input into the classification system.

The automatic feature extraction that is PCA used in [9] contains the discriminative information about the data. The large PCs attributed to noise present in the data and will decrease the valuable data information. The problems with the KNN as classifier are the difficulties in classifying the targets because of the errors that mainly occurred between neighbouring and the overlapping between the classes of target. KNN also needs large storage requirements and highly susceptible to the curse of dimensionality. Thus, in this study, the proposed ‘fixed’ features (theory and experiment) can reduce the problem of large PCs attribute to noise and will increase the valuable data. The suggested NN architecture with definite threshold will reduce the overlapping and neighbouring problem.

Until now only few radar systems use NN for classification as well as for other purposes [17-20]. So, we believe that the NN has not been fully tested in the Radar application. For example, Soleti et. al. [17] uses neural network for polarimetric radar target classification. This paper shows the adoption of two different type of feed-forward neural network in order to classify the target echo. The networks used have been tested on two types of simulated targets: a small tonnage ship with a low level of detail and medium tonnage ship with higher details. In [18-20], they show the applications of the NN in classifying radar target, which used the noisy spectral responses from different types of aircraft to train the network. Their performance is compared with the conventional minimum distance classifier for noisy systems and the NN is found to provide better performance in target classification as compared to a conventional scheme.

## 1.3 Aim and Objectives

The aim of this thesis is to:

Develop an automatic classification system that can be incorporated with the FSR system.

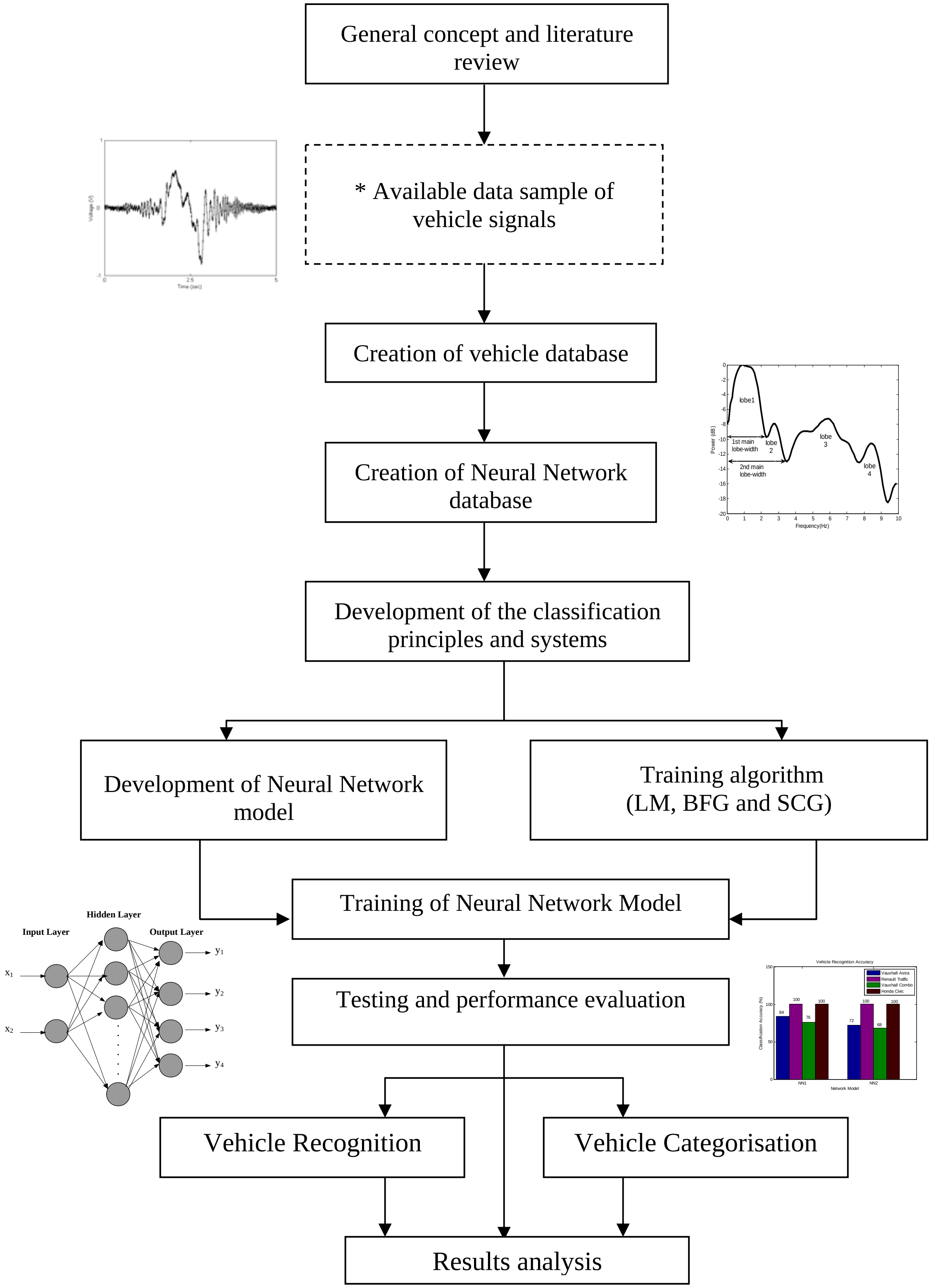
And the specific objectives are to:

1. Find the special characteristic from the vehicles signature to be used as inputs to neural network by feature extraction.
2. Find a good configuration for classification system such as the different features used as inputs to the network and the number of training datasets to train the network.
3. Develop neural network architecture. The network will classify the vehicles into their class ***(vehicle recognition)*** and into their categories ***(vehicle categorisation).***
4. Find the suitable parameters for the neural network architecture to form the classifier with high accuracy. The investigated parameters are the number of hidden neurons for the network and the training algorithms used to train the network.

We have developed an automatic classification algorithm to be incorporated with the FSR classification system. Figure 1.2 illustrates the methodology flowchart to achieve the above aim and objectives. The most important steps of the study includes the basic theoretical analysis and experimental investigation.

## 1.4 Thesis Outline

This thesis consists of five chapters. Chapter One introduces the thesis title and the objectives of this research. In Chapter Two, some basic background for radar system is discussed and the basic of FSR is described. The background of the proposed method also discussed and the review is made about other classification methods. Chapter Three describes the method used for data collection, as well as the classification system. This includes the description of our proposed classifier for vehicle classification. The inputs to neural network come from the feature extracted from the vehicle signatures. The neural network architecture is developed. Chapter Four presented the overall classification performance using the proposed method. Finally, in Chapter Five, the conclusions are summarized and the future work is discussed.




Note: *Data available from previous work [9].

**Figure 1.2: Methodology flowchart**