A FUNCTIONAL LINK NEURAL NETWORK WITH MODIFIED CUCKOO SEARCH FOR PREDICTION TASKS

SITI ZULAIKHA BINTI ABU BAKAR

A thesis submitted in
fulfillment of the requirement for the award of the
Degree of Master of Information Technology

Faculty of Computer Science and Information Technology
Universiti Tun Hussein Onn Malaysia

AUGUST 2017

In the name of Allah; The Most Gracious, The Most Merciful.

All praises are due to Allah. May Allah send His peace and blessings upon the beloved Messenger (S.A.W) and upon his companions, his family, and all who follow his guidance until the Day of Judgment.

Special dedication to my beloved mother (*We*)
Pn. Hjh. Wan Siti Normah Binti Wan Ishak

My supportive husband
En. Mohd Syazlan Bin Abdullah

and my siblings.
Thank you for your love, encouragements, prayers and everything
since this journey begins
as days passed by, weeks went by, and years gone by,
until the final stages.

You guys are the main reason for me to always strive to do the best.
This thesis is dedicated to all of you.

ACKNOWLEDGEMENT

Alhamdulillah, all praises to Allah for the strengths and His blessings in completing this thesis. At this moment of accomplishment, first of all, I would like to express my special appreciation to:

i) My determined supervisor, Assoc. Prof. Dr. Rozaida Binti Ghazali for her guidance and endless supports from the initial to the final level, for her patience, motivation, enthusiasm, and immense knowledge. Her invaluable helps of constructive comments and suggestions throughout the experimental and thesis work have contributed to the success of this research.

ii) I sincerely would like to thank and acknowledge the Universiti Tun Hussein Onn Malaysia (UTHM) for providing financial assistance under the Fundamental Research Grant Scheme (FRGS) which supported me to perform my work comfortably.

iii) I also want to express my thankfulness to the Centre for Graduate Studies (CGS) and the Research, Innovation, Commercialization and Consultancy Office (ORICC) for their hospitality and support towards my postgraduate affairs.

iv) Last but not least, I would like to express my gratefulness to my beloved families, for their endless loves, prayers and encouragements. To my dear friends especially postgraduate and PKINK members for the encouragements and moral supports during my study, thanks for the friendship and memories. It is a pleasure to thank all those who have helped either directly or indirectly. I would not have accomplished this work without the help and supports from so many people in various ways. Thank you very much. May all of us will be blessed. Ameen.

ABSTRACT

The impact of temperature, relative humidity and ozone changes bring a sharp warming climate. These changes can cause extreme consequences such as floods, hurricanes, heat waves and droughts. Therefore, prediction of temperature and relative humidity is an important factor to measure the environmental changes. Neural network, especially the Multi-Layer Perceptron (MLP) which uses Back Propagation algorithm (BP) as a supervised learning method, has been successfully applied in various problems for meteorological prediction tasks. However, this architecture has still been facing problems which the convergence rate is very low due to the multi layering topology of the network. Thus, this research proposed an implementation of Functional Link Neural Network (FLNN) which composed of a single layer of tunable weight trained with the Modified Cuckoo Search algorithm (MCS). The proposed approach was used to predict the daily temperatures, relative humidity and ozone data. Extensive simulation results have been compared with standard MLP trained with the BP, FLNN with BP and FLNN with CS. Promising results have shown that the proposed model has successfully out performed 14% percentage compared to other network models with reduced prediction error and fast convergence rate.

ABSTRAK

Kesan peningkatan suhu, kelembapan relatif dan perubahan ozon akan membawa perubahan iklim yang tinggi. Perubahan ini boleh menyebabkan terjadinya banjir yang melampau, ribut taufan yang besar, gelombang haba dan kemarau yang berpanjangan. Oleh yang demikian, kajian terhadap ramalan suhu dan kelembapan relatif perubahan ozon adalah faktor penting bagi mengukur perubahan persekitaran. Rangkaian Neural (NN), terutama Multi-Layer Perceptron (MLP) yang menggunakan algoritma Penyebaran Kembali (BP) sebagai kaedah suap balik, telah berjaya digunakan dalam menyelesaikan pelbagai masalah bagi tujuan ramalan oleh pihak meteorologi, kaedah ini masih menghadapi masalah yang mana kadar penumpuan yang dikeluarkan adalah sangat rendah kerana topologi rangkaian berlapis-lapis. Oleh itu, kajian ini mencadangkan untuk mengguna pakai Function Link Neural Network (FLNN) yang mempunyai satu lapisan sahaja dan dilatih dengan algoritma Modified Cuckoo Search (MCS). Sehubungan itu, FLNN digunakan untuk meramalkan suhu harian, kelembapan relatif dan kadar ozon. Keputusan simulasi yang meluas telah dibandingkan dengan piawaian MLP yang dilatih dengan BP, FLNN dan juga FLNN yang dilatih dengan CS. Kejayaan awal telah menunjukkan bahawa FLNN yang dilatih dengan MCS telah berjaya mengatasi prestasi model lain sebanyak 14% peratus dengan ralat ramalan dikurangkan dan kadar penumpuan yang cepat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ALGORITHMS

LIST OF SYMBOLS AND ABBREVIATIONS

k	-	Current weights and biases
gk	-	Current gradient
$\propto k$	-	Learning rate
w	-	Vector of weights
x	-	Vector of inputs
b	-	Bias
φ	-	Activation function
$x(i)$	-	Functionally expanded
N	-	Number of expanded
d	-	Set of features in the dataset
Pa	-	Probability
$\alpha > 0$	-	Step size
$\oplus$	-	Entry-wise multiplications
$y_i(x_e)$	-	The output
$n1$	-	Dimension
x_e	-	Input vector
$\mathscr{h}_j(x_e)$	-	Expansion result
$\boldsymbol{w}_{ij}$	-	Weight on connection from unit
$\mathcal{M}$	-	Nodes
$\mathscr{f}_i$	-	Invertible non-linear function
ANN	-	Artificial Neural Network
BP	-	Back Propagation
MLP	-	Multi-Layer Perceptron
FLNN	-	Functional Link Neural Network
HONN	-	Higher Order Neural Network
CS	-	Cuckoo Search

MCS	-	Modified Cuckoo Search
MSE	-	Mean Squared Error
NMSE	-	Normalized Mean Squared Error
CPU	-	Central Processing Unit

LIST OF PUBLICATIONS

Proceedings:

(i) Siti Zulaikha Bt Abu Bakar, Rozaida Bt Ghazali, Lokman Hakim Bin Ismail (2013). "Implementation of Modified Cuckoo Search Algorithm on Functional Link Neural Network for Temperature and Relative Humidity Prediction." In Proceedings of the First International Conference on advanced Data and Information Engineering (DaEng-2013).

(ii) Siti Zulaikha Abu Bakar, Rozaida Ghazali, Lokman Hakim Ismail, Tutut Herawan, Ayodele Lasisi (2013) "Implementation of Modified Cuckoo Search Algorithm on Functional Link Neural Network for Climate Change Prediction via Temperature and Ozone Data" in Recent Advances on Soft Computing and Data Mining (2014).

(iii) Rozaida Ghazali, Zulaika Abu Bakar, Yana Mazwin Mohmad Hassim, Tutut Herawan, Noorhaniza Wahid (2014). "Functional Link Neural Network with Modified Cuckoo Search Training Algorithm for Physical Time Series Forecasting." Intelligent Computing Theory (2014).

CHAPTER 1

INTRODUCTION

1.1 Overview

Global warming is a very serious issue in today's world. The impact of global warming in different regions has created a sudden demand in the determination of the need for studies of climate change predictions for the future. As the study acknowledges, prediction of climate change is a subject that is hard to implement because it includes a variation of physical classification. Greatest forecasting is established on skilled judgment than objective measurable approaches. Furthermore, parameters for climate change are still poorly constrained given ranges that are inconsistent with the observed warming. Besides that, the existing models (Paras *et al*., 2007) were only concerned on the delicate balance among the relative strength of feedback and the diversity of parameters that brought unclear results. The existence of limited models for prediction tasks' accuracy due to the complex environment of the time series prototypes has made it less functioning for some application.

Therefore this research focused on neural network in order to investigate and stimulate the prediction of daily temperatures, relative humidity and ozone for climate change scenarios over certain areas. For this part, neural network especially Multi-Layer Perceptron (MLP) that has been using Back Propagation algorithm as supervised learning method, is effectively practical in many problems for meteorological forecast tasks (Husaini *et al*., 2011; Hayati & Mohebi, 2007; Kazeminejad *et al*., 2006). In conjunction with that, MLP which uses computationally intensive training algorithms will result a stuck in local minima. As for the better result, a Functional Link Neural Network which is a single layer, without hidden layer has been used for prediction of daily temperatures, relative humidity, and ozone for prediction tasks. Unfortunately, the problem of high convergence rate is still occurs even when using single layer of trainable weight. To overcome this problem, the function of supervised learning, BP that has been used before, was replaced by using Modified Cuckoo Search algorithm to get a better prediction performance.

1.2 Problem Statement

The increase in temperatures, relative humidity, and ozone of the world at current obviously shows a harsh warming climate. This has been further supported by studies made by the Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), which the temperature increment of 0.74 C was recorded for the past 100 years based upon past IPCC assessment and the latest findings were reported in six years duration last year (Solomon *et al*., 2007). The impact of exchange in worldwide temperature can also lead to other changes such as the increment of sea level. The cause of this change can happen in dangerous climates such as droughts, storms, and heat waves. Noticeably the impact of increase in temperature is the most accurate parameter for the main reason of global warming.

By referring to Malaysian Meteorological Department scientific report (Meteorological Department, 2009), regional climatic trends were in line with the increase in average temperature observed for Malaysia. The effect of environmental changes was the increasing temperature in the highlands like Cameron Highlands, Malaysia. Besides that, abnormal weather triggered floods or drought, haze, increased ocean levels and reduced water resources. Climate change prediction undoubtedly is a very tough mission that has been applied in the process of climate. The ability for temperature forecasting simulation is very important. Conventional methods for temperature forecasting are sophisticated and extremely complex. Besides that, the effectiveness driven data methods deliver an efficiency contrast with conventional process-based modeling. Structure models established via driven data methods are computationally quicker and requisite fewer input parameters compared with process-based models (Paras *et al*., 2007). Topmost between them are Neural Network (NN).

Character of Neural Network may be declared via its structure, which is signified using the network architecture and the design of relations among the nodes, its technique of defining the joining weights, and the activation functions that it employs. Multi- Layer Perceptrons (MLPs), which create probably the most commonly used network structure, are composed of a hierarchy of processing unit structures in a series of two or more jointly exclusive sets of neurons or layers. The movement of the data in the network is controlled by, layer to layer, from input to output, hence also be called Feed-Forward Network. Nevertheless, in time-based complications, measurements from physical systems are no longer an independent set of input samples, but rely on functions of time. Moreover, when the numbers of input and number of training examples become tremendously huge, the training process for a regular neural network structure becomes sluggish and excessively dull. The BP learning algorithm is gradient descent local optimization method which includes backward error correction of network weights, it still has some foremost complications required to be fixed. Therefore, the convergence rate of BP becomes sluggish and inappropriate to resolve huge matters.

To overcome such time-consuming activities, this study work concentrated on applying Functional Link Neural Network (FLNN) (Giles *et al*., 1987), a network in Higher Order Neural Networks category which has been using a single layer of learnable weights, hence decreases the complexity of networks, lowers the error rate and raises the convergence rate. However, the convergence performance of BP algorithm is extremely relies on the preliminary value election of joining weights and other parameters applied in the algorithm, that has created unbalanced platform for resolving huge problematic function. So the MCS has been proposed to replace the BP function, to unravel the issue and speed up the convergence rate.

1.3 Research Aim

The aim of this research was to propose an improved Functional Link Neural Network trained with Modified Cuckoo Search algorithm (MCS) for prediction of daily temperatures, relative humidity and ozone.

1.4 Research Objectives

In order to achieve the research aim above, few objectives have been set. They are:

(i) To simulate a Functional Link Neural Network for prediction tasks.

(ii) To propose a Modified Cuckoo Search algorithm (MCS) for training (i) in order to reduce the prediction error and speed up the convergence time.

(iii) To compare the out of sample performance of (ii) with the ordinary FLNN and Multi-Layer Perceptron trained with the standard BP Algorithm and FLNN trained with Cuckoo Search Algorithm in terms of the prediction error and convergence rate.

1.5 Research Scope

This research only focused on the usage of a Functional Link Neural Network with MCS to forecast the daily data obtained for better performances ranged from 1999 to 2005 and ozone data from UCSI datasets. All the data has been tested and compared to the Multi-Layer Perceptron that covered three regions of Malaysia. Prediction performance of FLNN-MCS was compared with MLP-BP, FLNN-BP and FLNN-CS by using prediction error and convergence time.

1.6 Research Significance

FLNN with Modified Cuckoo Search algorithm has been used for this research on prediction task. This research could support in alternative approach for training the FLNN network that provide better result in performances of error and CPU time. Results from the experiments were applied to develop a vigorous and consistent prediction design structure that can defeat both MLP-BP and FLNN-BP, and FLNN-CS in terms of producing less error and time.

1.7 Organization of Thesis

This thesis was structured in five chapters. Chapter 1, explained the overview, problem statements, research aim, research objectives, research scope, research significance and organization of thesis. While Chapter 2 discussed about the approach and technique in Artificial Neural Network and Modified Cuckoo Search algorithm. Besides that the thesis showed the comprehensive review of past researches on the topics. Chapter 3 explained the design of proposed model to accomplish the research objectives including the framework, data sources and the procedure of the data flow. Chapter 4 elaborated the experimental results from the comparative model with the proposed model. The last chapter; Chapter 5 highlighted the novelty, research contribution and proposed issues for upcoming research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Climate change is a long-term change in environment starting during the era of time from decades to millions of years. The changes have caused average climatic conditions, extreme possibilities, or some portions of the climate. Moreover it comprises long-term changes in the pattern of cyclic temperature, rainfall, humidity, wind and seasons. Climate change is able to occur in a certain area, or the entire world. This transformation produces vigorous processes on Earth, which is an outside power containing variation in the heat of the sun, and recently also human doings. In current practice, specifically in the perspective of environmental policy, the term "climate change" is frequently mentioned to the existing climate change.

2.2 Artificial Neural Networks (ANNs)

Artificial Neural Networks (ANNs) turn out to be an influential method for a lot of complex applications like function approximation, optimization, prediction, non-linear system identification, and pattern recognition. This is regarding to the information that they are able to adapt from samples and to perform non-linear mappings (Spanglar, 1994).

An artificial neuron is a computational architecture stimulated in the normal neurons. Normal neurons accept the indicators via synapses placed on the dendrites or membrane of the neuron. When the signals received are strong enough, they will exceed a certain threshold thus automatically activate the neuron and produce a signal though the axon. This signal might be referred to another synapse, and force to trigger other neurons.

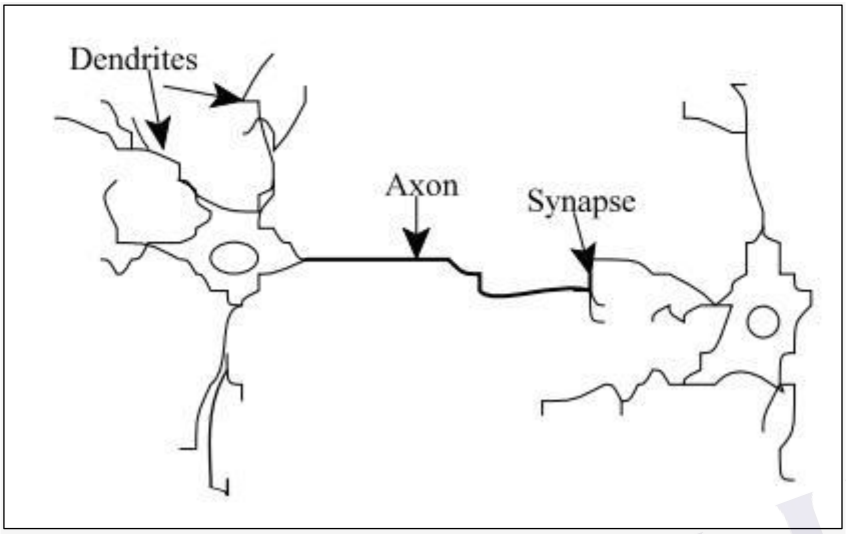

Figure 2.1: Natural neurons (Stergiou,and Sigano, 2004)

The difficulty of actual neurons is extremely abstracted when forming artificial neurons. Mostly, these neurons contain inputs such as synapse (Figure 2.1), which increase trough weights power of the corresponding signals, and are figured using mathematical function which defines the activation of the neuron. Alternative function which may be the identity computes the output of the artificial neuron, sometimes in dependence of a certain threshold. ANN syndicates artificial neurons in order to process data as shown as Figure 2.2.

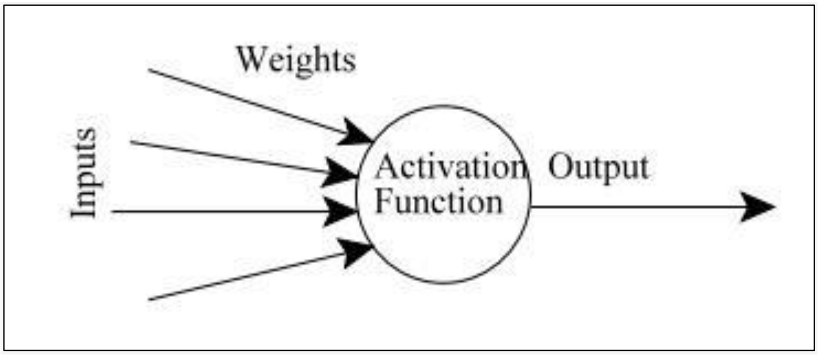

Figure 2.2: An artificial neuron (McCulloch and Pitts, 1943)

2.3 Back Propagation Algorithm

Basically, a feed-forward propagates activation to generate an output and its backward propagates error to specify weight changes (as shown in Figure 2.3). The weights on the continuance between neurons pass through the values in both ways. Back Propagation is a common technique for training feed forward propagation which decreases the value of the continuous objective function on subsequent test of the input .This model is used to study the weights of a multi-layer neural network, through a static architecture. It executes gradient descent to try to lowering the sum squared error between the network's output values and the given target values.

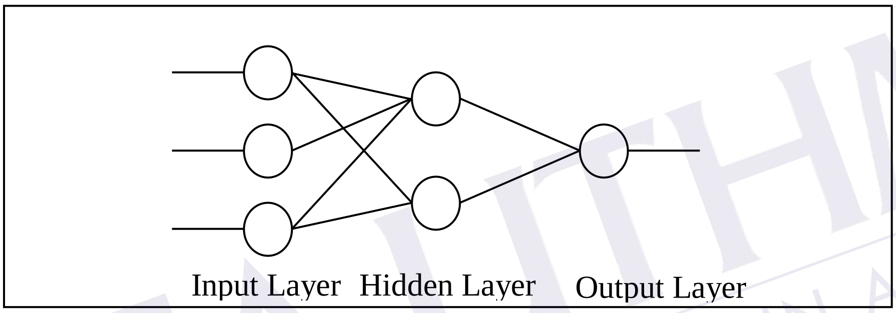

Figure 2.3: Feed forward activation

There are many variants of the Back Propagation model. Some of the explanations are defined in this division. The modest execution of Back Propagation learning updates the network weights and biases in the direction which the performance function quickly reduce the negative of the gradient. One of the formulas of this model can be expressed as below;

$$xk + 1 = xk - \propto kgk \tag{2.1}$$

where;

xk : Vector of existing weights and biases.

gk : The present gradient

$\propto k$: Learning rate

There are two dissimilar methods in this slope descent algorithm which can be applied using additional approach and group approach. In additional approach technique, the slope is figured and the weights are updated when each input is practical to the system. While in group approach, all the inputs are prior applied to the network and the weights will be updated. The BP algorithm can be exemplified via adjusting the connection weights to small random values. The weights can be considered as a real number. Normally, the algorithm of BP can be explained through steps mentioned above:

(i) Feed forward computation

(ii) Back Propagation to the output layer

(iii) Back Propagation to the hidden layer

(iv) Weight updates

2.4 Multi-Layer Perceptron (MLP)

MLP is the architecture of modest *neurons* called *perceptron*. Rosenblantt was the person who introduced the earlier theory of a single perceptron in 1958. The perceptron figures a single *output* from numerous actual-valued *inputs* by producing a linear merging following to its input *weights* and then possibly placing the output via some nonlinear activation function. Precisely this iteration can be stated as below;

$$y = \varphi(\textstyle\sum_{i=1}^{n} w_i x_i + b) = \varphi\,(w^T x + b) \qquad (2.2)$$

where,

w : Vector of weights,

x : Vector of inputs

b : The bias

φ : The activation function

This function is mathematically suitable and nearly close to linear origin while saturating rather quickly when getting away from the origin. This allows MLP structure to model well both strongly and slightly nonlinear mappings.

A typical Multi-Layer Perceptron (MLP) network contains a group of source nodes establishing the input layer, one or more hidden layers of computation nodes, and an output layer of nodes. The input signal will be transmitted via the layer to the other layers .The network with multi hidden layers such as the signal-flow is shown in Figure 2.4.

The calculations accomplished using a feed forward architecture with a flat network through nonlinear activation functions and a linear output layer can be iterate as below;

$$x = f(s) = B\varphi\,(As + a) + b \qquad (2.3)$$

where,

s : Vector of inputs

x : Vector of outputs.

A : The matrix of weights of the first layer

a : The bias vector of the first layer

B : Respectively the weight matrix

b : The bias vector of the second layer

φ : The activation function

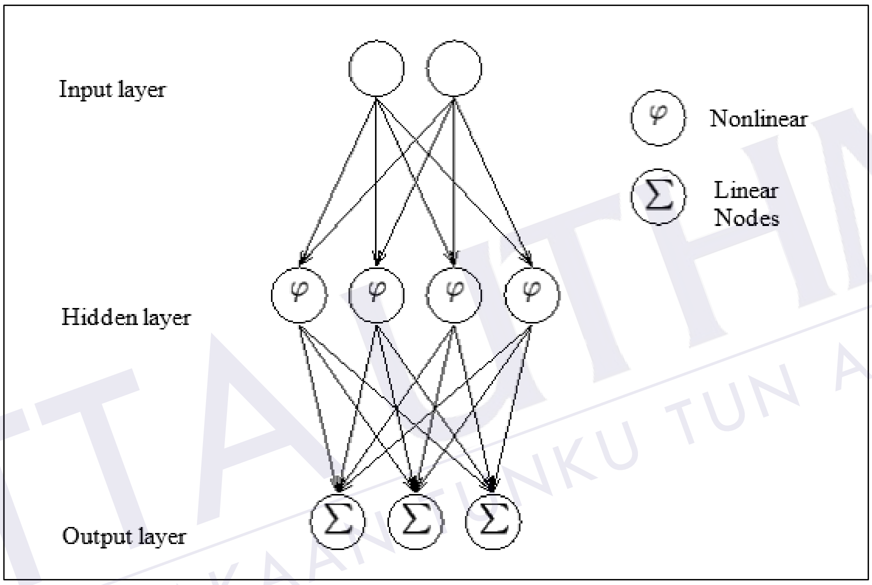

Figure 2.4: MLP (Hochreiter & Schmidhuber, 1999)

The problem of the supervised learning method of MLP can be fixed using Back Propagation algorithm. This network also can be applied for unsupervised learning via the auto-associative structure. This can be completed by setting the equal values for the inputs and the outputs of the network. The removed sources appear from the values of the hidden neurons (Hochreiter & Schmidhuber, 1999). This method is computationally quite concentrated. The MLP model needs to have at least three hidden layers for any rational representation and training as a network is a time unbearable method.

MLP is the most popular normal type of architecture applied, and its capability to execute complex non-linear mappings and acceptance to noise data is well recognized (Haykin, 1999). Nevertheless, the problematic of MLP will produce a suffering long training period and frequently extend local optima. Besides that, bigger

REFERENCES

Bratton D, Kennedy J. Defining a standard for particle swarm optimization, Proceedings of the 2007 IEEE Swarm Intelligence Symposium, 2007.

Cass, R. and Radl, B. (1996) Adaptive Process Optimization Using Functional-Link Networks and Evolutionary Algorithm. *Control Eng. Practice*, Vol. 4, No. 11, pp. 1579-1584.

Climate change scenarios for Malaysia: 2001-2099. Malaysian Meteorological department scientific report, January 2009.

Durbin, R. & Rumelhart, D. (1989). Product units: A computationally powerful and biologically plausible extension to backpropagation networks. Neural Computation, 1, 133- 142.

Ehrhardt & Christian (July, 2010). "CPU time accounting". IBM. Retrieved 2014-08-05.

Fallahnezhad, M., Moradi, M. H., & Zaferanlouei, S. (2011). A Hybrid Higher Order Neural Classifier for Handling Classification Problems. *Expert Systems with Applications*, *38 (1)*, pp. 386-393.

Ghazali, R., & Al-Jumeily, D. (2009). Application of Pi-Sigma Neural Networks and Ridge Polynomial Neural Networks to Financial Time Series Prediction. In M. Zhang (Ed.). *Artificial Higher Order Neural Networks for Economics and Business*. Hershey, New York: IGI Global. pp. 271-293.

Giles, C. L. and Maxwell, T. (1987) Learning, invariance and generalization in high-order neural networks. *In Applied Optics*, vol. 26, no. 23, Optical Society of America, Washington D. C., pp.4972-4978.

Güldal, V., & Tongal, H. (2010). Comparison of Recurrent Neural Network, Adaptive Neuro-Fuzzy Inference System and Stochastic Models in Eğirdir Lake Level Forecasting. *Water Resources Management, 24 (1)*, pp. 105-128.

Hayati,M.,Mohebi,Z. 2007.Temperature Forecasting Based on Neural Network Approach in World Applied Sciences Journal 2 (6):613-620,2007.IBSN:1818-4952.IDOSI Publications 2007

Haykin, S., “Neural Networks, A Comprehensive Faoundation” 2nd ed. Prentice-Hall, New Jersey, USA, 1999. ISBN: 0-13-273350-1

Hochreiter, S.; Schmidhuber, J. (1999). "Feature Extraction Through LOCOCODE". Neural Computation 11 (3): 679–714. doi:10.1162/089976699300016629. ISSN 0899-7667.

Huang, B. Q., Rashid, R., & Kechadi, M.-T. (2007). Multi-Context Recurrent Neural Network for Time Series Applications. *International Journal of Computer Intelligence, 3 (1)*, pp. 45-54.

Husaini,N.A.,Ghazali,R., Ismail,L.H.(2011). An Application of Pi-Sigma Neural Network for The Prediction of Flood Disaster.University Tun Hussein Onn Malaysia.

Jayalakshmi, T., Santhakumaran, A., "Statistical Normalization and Back Propagation for Classification," *International Journal of Computer Theory and Engineering* vol. 3, no. 1, pp. 89-93, 2011.

Kaita, T., Tomita, S. and Yamanaka, J. (2002) On a Higher-order Neural Network for Distortion Invariant Pattern Recognition. *Pattern Recognition Letters 23*, pp 977-984.

Kazemijad,M.,Deghan,M.,Motamadinejad,M.B.,Rastegar,H.,2006. A New Short Term Load Forecasting Using Multilayer Perceptron in ICIA.

Klasser, M. S., & Pao, Y. H. (1988). Characteristics ofthe functionalink net: a higher order net.ln IEEE Proceedings of2nd Annual Inlemalional Conference on Neural Networks,San Diego,CA,I, 507-513

Knowles, A., Hussain, A., Deredy, W. E., Lisboa, P. G. J., & Dunis, C. (2005). higher-order neural network with Bayesian confidence measure for prediction of EUR/USD exchange rate. Forecasting Financial Markets Conference, 1-3 June, 2005, Marseilles, France.

McCulloch, W. and Pitts, W., (1943). A Logical Calculus of the Ideas Immanent in Nervous Activity. *Bulletin of Mathematical Biophysics*, Vol. 5, pp. 115-133.

Mil Milenkovic, S., Obradovic, Z., & Litovski, V. (1996). Annealing Based Dynamic Learning in SecondOrder Neural Networks, (Technical Report), Department of

Electronic Engineering, University of Nis, Yugoslavia.enkovic,.S, Obradovic,.Z ,Litovskil,.V (1996)

Mirea, L. and Marcu, T. (2002) System identification using Functional-Link Neural Networks with dynamic structure. *15th Triennial World Congress*, Barcelona, Spain.

Pao, Y.H., and Takefuji, Y., "Functional-link net computing: theory, system architecture, and functionalities," Computer, vol. 25, no. 5, pp. 76–79, 1992.

Pao, Y., " Adaptive Patten Recognition and Neural Networks." Addison-Wesley, USA, 1989. ISBN: 0 2010125846

Pau, Y.H, Phillips S.M (1995). The Functional Link Net and learning optimal control. *Neurocomputing* 9, pp 149-164.

Paras,Mathur,s.,Kumar,A. & Chandra,M., 2007. A Feature Based Neural Network Model for Weather Forecasting in World Academy of Science Engineering and Technology.

Patra, J.C., Bos, A.V.D. (2000). Modeling of an intelligent pressure sensor using functional link artificial neural networks. *ISA Transactions 39*, pp. 15-27.

Patra, J.C., Pal, R.N. (1995). A functional link artificial neural network for adaptive channel equalization. *Signal Processing 43*. pp. 181-195.

Payne, Robert B. (2005). The Cuckoos. Oxford University Press. ISBN 0-19-850213-3. Retrieved 2007-12-19.

Rehman, M. Z., & Nawi, N. M. (2011). The Effect of Adaptive Momentum in Improving the Accuracy of Gradient Descent Back Propagation Algorithm on Classification Problems. *Journal of Software Engineering and Computer Systems, 179 (6)*, pp. 380-390.

Schmidt W. A.C., & Davis, J.P., " Pattern Recognition Properties of Various Feature Spaces for Higher Order Neural Networks." In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 15, No.8, August 1993

Shrestha, R. R., Theobald, S., & Nestmann, F. (2005). Simulation of Flood Flow in a River System using Artificial Neural Networks. *Hydrology and Earth System Sciences, 9 (4)*, pp. 313-321.

SkyMark Corporation. (2012). Histograms. Retrieved on March 4, 2012, from http://www.skymark.com/resources/tools/histograms.asp.

Spangler,M.V.,1994.Uses of Process Insights at a Refractory Gold Plant,Pavilion Users Conference, October 17,1994, pp.1-7

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B.M.Tignor and H.L. Miller (eds.). 2007 a: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Stergiou, B and Sigano, D. (2004, August 17). Neural Networks. Retrieved from https://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/cs11/report.html

Walton, S., Hassan, O., Morgan, V., Brown, M.R., (2011). Modified cuckoo search: A new gradient free optimisation algorithm. Chaos, Solitons & Fractals 44,p.710–718

Yang X. S., and Deb, S., "Cuckoo search via Lévy flights," in World Congress on Nature & Biologically Inspired Computing, Coimbatore, India, pp. 210–214, 2009.

Yang, X.S., Deb, S., Cuckoo search via Lévy flights. Proceedings of World Congress on Nature & Biologically Inspired Computing (NaBIC 2009, India), IEEE Publications, USA 2009; p. 210–214.

Yang, S., and Deb, S., "Engineering optimization by cuckoo search", Int. J. of Mathematical Modeling and Numerical Optimisation, vol. 1, no. 4, pp. 330-343, 2010.

VITA

The author was born Jun, 1st 1986 in Kampung Kuala Nal. She went to Sekolah Menengah Ugama Arab Rahmaniah, Kuala Krai Kelantan during Lower Secondary School and continued her study at Sekolah Kebangsaan Agama Lati, Pasir Mas Kelantan for her Upper Secondary School. She furthered her study at Negeri Sembilan Matriculation College for matriculation program in 2005. She pursued her degree at Universiti Tun Hussein Onn Malaysia (UTHM), formerly known as Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO) and graduated with the Bachelor in Information Technology in 2010. Upon graduation, she was a Business Development and ICT Executive at Sinar Training and Consultant Sdn. Bhd. She then enrolled at the UTHM in 2011 where she continued the Master Degree in Information Technology. Now she works as an IT Officer at Perbadanan Kemajuan Iktisad Negeri Kelantan.