UNIVERSITI PUTRA MALAYSIA

HYBRID PRE-CLASSIFICATION TECHNIQUE – ARTIFICIAL NEURAL NETWORK FOR LIGHTNING SEVERITY CLASSIFICATION

MUHAMMAD AZHAR OMAR

HYBRID PRE-CLASSIFICATION TECHNIQUE – ARTIFICIAL NEURAL NETWORK FOR LIGHTNING SEVERITY CLASSIFICATION

By

MUHAMMAD AZHAR OMAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the requirements for the Degree of Master Science

August 2014

COPYRIGHT

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Master of Science

HYBRID PRE-CLASSIFICATION TECHNIQUE – ARTIFICIAL NEURAL NETWORK FOR LIGHTNING SEVERITY CLASSIFICATION

By

MUHAMMAD AZHAR OMAR

August 2014

Chairman : Mohd Khair Hassan, PhD
Faculty : Engineering

This thesis is presents the classification of lightning severity from meteorology characteristic using the computational intelligence; the Artificial Neural Network (ANN). The meteorology parameters used are very basic and economical as it is designed for public. The targeted user group is for those who have a higher risk to be strike by lightning and also for those users without any meteorology background. Examples of these targeted user groups are recognized as those who enjoys outdoor activities, the event organizer, building maintenance workers, and skyscraper crane operator. This group of user is prone to lightning strikes since their working environments are constantly exposed to the lightning strikes possibility.

The weather forecast broadcasted on mass media does not fully describe the condition of the daily weather qualitatively. Hence, the qualitative interpretation given to the public usually too general and does not provide sufficient information needed, in this case the lightning severity information. Therefore, by analyzing the meteorology parameters quantitatively, the severity of lightning can be determined, thus revealing the risk of lightning strikes on that particular day. This piece of information may benefits user in order to avoid the risk of casualties and property losses due to lightning.

During the study, three objectives are listed. First objective is to establish a practical scale; the Daily Lightning Severity Scale (DLSS). Second, the application of ANN in

classifies the severity of the lightning. And third, to propose and test a new technique of separating data for ANN Training, Validation and Testing (TVT) datasets, known as PreClass Test (PrCT) technique.

The study outcome revealed that the proposed scale of DLSS is practical to be used for the study area. The DLSS listed out four levels of lightning severity denoted as Safe, Normal, Frequent, and Very Frequent. While developing ANN, two networks were prepared for this study based on two datasets, known as *RandSet* and *PrCTSet*. The *RandSet* utilize common method of separating the TVT dataset using random separation ratio whilst the *PrCTSet* applied the new proposed technique for TVT separation. The result indicates the PrCT techniques have faster training result at approximately 50% reduction of number of epochs required and shortening almost 50% of training time compared to random separation method. It was observed that networks developed from both datasets yields good performance. *PrCTSet* score 92.9% of accuracy, while the *RandSet* network scores similar accuracy at 92.9%. It is suggested that the PrCT method is suitable for ANN application which requires faster training time and at minimal computational effort.

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

TEKNIK HIBRID PRA-PENGELASAN-JARINGAN NEURAL BUATAN BAGI PENGELASAN KESERIUSAN KILAT

Oleh

MUHAMMAD AZHAR OMAR

Ogos 2014

Pengerusi : Mohd Khair Hassan, PhD
Fakulti : Kejuruteraan

Kajian tesis ini membentangkan pengelasan keseriusan kilat dari sudut meteorologi menggunakan kepintaran pengkomputeran; rangkaian neural buatan (ANN). Parameter metereologi yang digunakan adalah amat mudah/asas dan berekonomi kerana ia direkabentuk untuk kegunaan awam. Kumpulan pengguna sasaran adalah pengguna yang berisiko tinggi akan bahaya panahan petir dan juga kepada pengguna yang tidak mempunyai latar belakang pengetahuan metereologi. Contoh kumpulan sasaran yang dikenalpasti adalah mereka yang melakukan aktiviti luar, pengurus acara program luar, penyenggara bangunan, dan operator kren bangunan pencakar langit. Kumpulan sasaran ini berisiko tinggi lantaran keadaan tempat bekerja yang seringkali terdedah kepada kemungkinan bahaya panahan petir.

Penyiaran laporan ramalan cuaca yang disiarkan oleh media massa tidak menggambarkan sepenuhnya tentang keadaan cuaca harian secara kualitatif. Bahkan, interpretasi kualitatif yang disiarkan kepada orang awam selalunya terlalu umum dan tidak memberi maklumat yang diperlukan secara mencukupi, dalam konteks hal ini ia berkenaan maklumat darjah keseriusan kilat. Oleh yang demikian, dengan menganalisis parameter metereologi secara kuantitatif, darjah keseriusan kilat dapat diketahui, seterusnya mengenalpasti tahap risiko petir pada hari berkenaan. Maklumat ini mungkin dapat memberi manfaat kepada pengguna supaya mereka boleh mengelakkan diri daripada situasi yang berisiko serta kerugian harta benda yang berpunca daripada panahan petir.

Ketika kajian dijalankan, tiga objektif telah digariskan. Objektif pertama kajian adalah untuk membentuk satu skala yang praktikal iaitu Skala Keseriusan Kilat Harian (DLSS). Kedua, applikasi ANN didalam mengelaskan keseriusan kilat dalam sehari. Dan yang ketiga, mencadang dan menguji kaedah baru dalam mengasingkan data latihan, pengesahan dan ujian yang dikenali sebagai kaedah ujian pengelasan awal, (PrCT).

Hasil kajian menunjukkan bahawa piawaian/standard yang dicadangkan DLSS adalah praktikal untuk digunakan di kawasan kajian. DLSS menyenaraikan empat darjah keseriusan kilat yang ditanda/dilabel sebagai "Selamat", "Normal", "Kerap" dan "Sangat Kerap". Ketika dalam proses membangunkan ANN, dua rangkaian untuk kajian ini telah disediakan berdasarkan dua set data yang dikenali sebagai *RandSet* dan *PrCTSet*. *RandSet* melalui kaedah biasa memisahkan data set TVT menggunakan nisbah pengasingan rawak, manakala *PrCTSet* pula diaplikasi menggunakan teknik baru yang dicadangkan untuk memisahkan TVT. Hasil dapatan kajian menunjukkan bahawa teknik PrCT mempunyai keputusan latihan pantas dengan hampir 50% pengurangan dalam nombor epok yang diperlukan serta hampir 50% masa latihan dipendekkan apakala dibandingkan dengan teknik pengasingan rawak. Pemerhatian ini menunjukkan bahawa rangkaian yang dibangunkan melalui kedua-dua set data menghasilkan penilaian yang baik. *PrCTSet* mencatatkan skor ketepatan sebanyak 92.9%, manakala rangkaian *RandSet* juga mencatatkan skor ketepatan yang sama sebanyak 92.9%. Kaedah PrCT yang dicadangkan adalah bersesuaian untuk kegunaan ANN yang memerlukan masa latihan yang pantas serta penggunaan pengkomputeran yang minimal.

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest gratitude to my supervisor Dr Mohd Khair Hassan for his encouragement and invaluable supervision throughout the progress of this research. I am so fortunate to have such a great supervisor who has always been supportive and provided me the necessary facilities.

The gratitude also dedicated to co-supervisors Dr Azura Che Soh and Prof. Dr Mohd Zainal Abidin Ab Kadir, for their encouragement and ideas in shaping my research work and helped me tremendously at every step forward. Their valuable time and suggestions are highly appreciated.

Thank you to School of Graduate Studies, UPM for being involved in organizing the research supplemental courses throughout Putra Sarjana. Their courses had benefits me a lot in a way of doing research, especially in writing and presenting my works during conference and research progress presentation.

Not forgotten to Ms. Amalina Awang, Ms. Jelaine Ferrer Segundo, and Ms. Noraziana Ali Teh who had contributed to grammar correction of the thesis. Also, thanks to my beloved family who always is there throughout my thick and thin time.

APPROVAL

I certify that a Thesis Examination Committee has met on August 25th 2014 to conduct the final examination of Muhammad Azhar Omar on his thesis entitled "HYBRID PRE CLASSIFICATION TECHNIQUE-ARTIFICIAL NEURAL NETWORK FOR LIGHTNING SEVERITY CLASSIFICATION" in accordance with the Universities and University Collages Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1988. The committee recommends that the student be awarded the Master of Science.

Members of Thesis Examination Committee were as follows:

……
Dr. Siti Anom Binti Ahmad
Dept. of Electrical/Electronic Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

……..
Assoc. Prof. Dr. M. Iqbal Bin Saripan
Dept. of Computer System & Communication Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner 1)

……
Dr. Noor Izzri Bin Abdul Wahab
Dept. of Electrical/Electronic Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner 2)

……
Assoc. Prof. Dr. Ismail Musirin
Dept. Electrical Power Engineering
Faculty of Electrical Engineering
Universiti Teknologi Mara
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of Supervisory Committee were as follows:

Mohd Khair Hassan, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd. Zainal Abidin Abd Kadir, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Azura Che Soh, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by Graduate Student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of
Chairman of
Supervisory
Committee: _____

Signature: _____

Name of
Member of
Supervisory
Committee: _____

Signature: _____

Name of
Member of
Supervisory
Committee: _____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADSC	Average Daily Strike Count
ANN	Artificial Neural Network
DLSS	Daily Lightning Severity Scale
DSC	Daily Strike Count
FPR	False Positive Rate
GLN	Global Lightning Network
GPS	Global Positioning Service
LB	Lower Boundary
lr	Learning Rate
MaxH	Maximum Humidity
MaxT	Maximum Temperature
mc	momentum constant
MinH	Minimum Humidity
MinT	Minimum Temperature
MMD	Malaysia Meteorological Department
MSC	Monthly Strike Count
MSE	Mean Square Error
NAPLN	North American Precision Lightning Network
nhl	Number of neuron in hidden layer
NOAA	National Oceanographic and Atmosphere Administration
PrCT	PreClass Test (a technique)
RMSE	Root Mean Square Error
ROC	Receiver Operating Characteristic
SSE	Sum Square Error
TN	True Negative
TNG	Training Data
TOA	Time of Arrival
TP	True Positive
TPR	True Positive Rate
TST	Testing Data
TVD	Validation Data
TVT	Training-Validation-Testing Data
UB	Upper Boundary
USPLN	United State Precision Lightning Network
WSI	Weather Service International

CHAPTER 1

INTRODUCTION

1.1 Research Background

Lightning is known as the released energy resulted from collision of clouds (Ahmad, 2001). The energy is released in the form of light and sound by making channels toward multiple directions. If any of the channel has reached the earth, it transfers huge amount of charges at thousands Ampere. The transferring energy at this rate is potentially harmful and potentially causes property losses, equipment burned-out, and even casualty.

Globally, there were approximately 25,000 victims of lightning strikes and caused one billion USD of losses per year (Ibrahim, 2012). In Florida, a statistic record in 1991 reveals that Florida has received 11 – 13 strikes per kilometre square in a year, putting the state at the top list for the most prone area to lightning strikes. Thus, upon worrying community safety, study of lightning has been advanced for better understand this natural disaster (Uman, 1986; Ab Kadir *et al*, 2012)

According to Cooper and Ab Kadir, South East Asia region has been estimated with the annual rate of 6 deaths per million in lightning casualties (Cooper and Ab Kadir, 2010). Malaysia is not exempted. Even, the country is estimated with 100 to 150 lightning death per year (Holle, 2008). The estimation is further supported by the research study from Forensic Pathology Units of University Malaya. There were 27 fatal cases of lightning strikes in year 1996 to 2005. Majority of the victims were construction workers (62.5%) are not survived. The highest number of cases (5 cases of 23) was in December 2004 most of the cases involving the lightning incidence occur in the evening (Murty *et al*, 2009). Casualties were also reported in 2011, in which the man was stroke by lightning after fishing prawns at Sungai Perak, followed by the case of land surveyor who died after the strike near an oil palm factory, and six Indonesian workers were stroke in separate incidents in Shah Alam and Hulu Selangor (Lean, 2011). As in August 2012, two kids were stricken and died during helping their father farming (Azam, 2012; Ahmad *et al*, 2014).

Some cases were reported regarding the damages caused by lightning strikes. For example, in 2006, a computerized highway supervision system in Ipoh has been burnt down. An oil storage tank at Port Dickson in year 2007 was ablaze due to the fire started by the lightning, and also caused the panicking situation when the strikes interrupted the power line and life support equipment in Putrajaya Hospital in 2009 (Lean, 2011). Building as an example of property may be protected by well-designed protection devices. However, occasions like sport event, national parade, building

maintenance, fishery, land-surveying or any outdoor activities, are supposed to be scheduled at a proper time to avoid the lightning strike accidents.

Abd Kadir expects that in future the data could be worse, since our world today suffering from climate change and global warming which may cause the weather to be hardly predictable (Lean, 2011). According to the Centre of Excellence of Lightning Protection (CELP) study, Subang, a town near to Kuala Lumpur received 362 days of lightning strikes in year 1987 (Johari *et al*, 2007). The increasing number of factories in Kuala Lumpur in recent decade may also affect the atmosphere of chemical composition, consequently affecting the pattern of lightning trend. Thus, there is a necessity to have a new perspective on lightning trends and specific meteorology pattern nowadays for Subang. Thus, by investigating and identifying lightning strike trend, it is hoped to give new information, as well as better guidance for society in protecting life and property.

1.2 Problem statement

It is compulsory to spread the awareness to society regarding the lightning severity (Murty *et al*, 2009; Holle, 2009; Cooper and Ab Kadir, 2010; Ibrahim, 2012; and Ab Kadir *et al*, 2012). The lightning study or also known as fulminology is not an easy subject to be taught to the community. In fact, the lightning study itself is not yet fully understood by the meteorologist or the fulminologist (McCall, 2003; Ackerman and Knox, 2007; Reynolds, 2007). It does require deep knowledge and time to study the theory and mechanism underlying the lightning strike.

Public citizen like fisherman, outdoor activist, maintenance manager and event organizer are those in needs for this information in their daily life. They are totally depending on their experience and guts to decide the best time to execute their activity. The closest technology to them is the daily forecast that has been freely available in mass media. However, the broadcasted info is practically too basic since it was generalized for wide area. Therefore, the accuracy of information obtained is compromised.

It is suggested that there is a practical reference or scale of lightning to be used for those who are worked on the field. The standard should be based on measurable parameters and easy to obtain. (Accuweather.com, 2011). The scale, or the Daily Lightning Severity Scale (DLSS), is proposed by applying computational intelligence algorithm based on historical data given since there are a lot of uncertainty persisted in fulminology. The DLSS is best developed by black box approach like the ANN.

Meanwhile, in applying supervised ANN, there is a necessity to separate the available data into three subsets, known as training set, validation set, and testing set.

The most important part is the training set. The training set will define the network behaviour and result. Thus, it is compulsory to ensure the training set is correctly selected and free from any outlier. The problem arises when selecting the outlier to be removed from training data. Therefore, a new method, called as PreClass Test, PrCT is suggested for this purpose (Gardner and Dorling, 1998).

1.3 Research aim and objectives

The aim of this study is to classify the severity of lightning strikes based on basic meteorology parameters, and practical for laymen users. The specific objectives can be outlined as follows;

i. To establish a standard for Daily Lightning Severity Scale (DLSS) using quartile analysis for Subang area.
ii. To develop an Artificial Neural Network (ANN) for classifying the severity of lightning strike in terms of daily application.
iii. To propose and test a new technique of separating data for ANN Training-Validation-Training (TVT) datasets, called as PreClass Test, (PrCT) technique.

1.4 Scope of work

This thesis is concerned with the evaluation of lightning severity classification as according to the meteorological characteristic. The classification is done by using ANN with two methods of separation data technique; the Random Separation method, and the Pre-Class Test method. The Input and Output utilized in this study are assumed as;

i. The numbers of meteorological parameters data are kept as minimal as possible. Only temperature and humidity parameters are selected due to its measurability and retrievable for laymen user.
ii. Since the Global Lightning Network, GLN just operated since 2007, the three years data supplied are assumed accurate during the measurement and practical for this study.

1.5 Thesis outline

The thesis consists of five chapters; the first chapter describes the general idea of the study including the problem statement and the objectives. Chapter 2 is dedicated for discussing the literature review of lightning phenomena from meteorology perspective and also the application of ANN in meteorology. The review will discuss the theory of lightning, the ANN abilities, and the constructed hypothesis.

Meanwhile, Chapter 3 discussed the methodology of the thesis. The methodology divided into three parts which is the data acquisition stage, design stage and also the experiment stage. The data acquisition describes the sources of data and how it is

synched. The next design stage illustrates how the output class is determined and parameters are calculated. Besides, the construction of ANN also will be described in this chapter. At the end of this stage, two datasets; *PrCTSet* and *RandSet* are yielded and ready for ANN training Process.

The next Chapter 4 is briefly discussing the result of the experiment and concludes a comparison between two datasets prepared. The performance and validation of each set are well described. The advantages and disadvantages of the proposed technique also will be summarized in this chapter.

The thesis conclusion is presented in Chapter 5. The chapter highlights the major finding of the study. Besides, the contribution, and future recommendation will be stated in this chapter.

REFERENCES

Ab Kadir, M.Z.A., Misbah, N.R., Gomes, C., Jasni, J., Wan Ahmad W.F., and Hassan M.K. (2012). Recent Statistics on Lightning Fatalities in Malaysia. International Conference on Lightning Protection (ICLP) (pp. pg. 1-5). Vienna, Austria: IEEE.

Abdul Rahman R.Z., Che Soh A., and Adnan S.N.N. (2011). Neural Network Application for Lightning Characteristics & Mapping for Peninsular Malaysia. The Third International Conference on Computational Intelligence, Modelling and Simulation (CIMSiM) (pp. 7-13). Langkawi: IEEE.

Abdullah, N., Yahaya, M.P., Hudi, N.S., (2008). Implementation and Use of Lightning Detection Network in Malaysia. 2nd IEEE International Conference on Power and Energy (PECon08) (pp. pg. 383-386). Johor Baharu: IEEE.

Accuweather.com. (12 April, 2011). Should There Be A Ranking System for Thunderstorms? Retrieved 29 December, 2013, from accuweather.com: http://www.accuweather.com

Ackerman, S.A, and Knox, J.A.. (2007). Meteorology: Understanding The Atmosphere (Internation Student Edition (2nd Ed.) ed.). CA: Thomson Higher Education.

Ahmad, N.A., Abu Bakar N.N., Adzis, Z.. (2014). Study of Lightning Fatalities in Malaysia from 2004 to 2012. Jurnal Teknologi (Sciences and Engineering), Vol. 66(1), 9-13.

Ahmad, H. (2001). Kilat dan Perlindungan. Skudai, Malaysia: Universiti Teknologi Malaysia.

Ali A.F., Johari D., Nik Ismail N.F., Musirin I., and Hashim N.. (2011). Thunderstorm Forecasting by using Artificial Neural Network. The 5th International Power Engineering and Optimiziation Conference (PEOCO2011) (pp. pg. 369-374). Shah Alam, Malaysia: IEEE.

Andrews Shenouda, E. A. (2006). A Quantitative Comparison of Different MLP activation Functions in Classification. In Advances in Neural Networks (pp. 849-857). Springer Berlin Heidelberg.

Azam, N. (16 August, 2012). Negara: Dua Sepupu Maut Dipanah Petir. Kosmo! Online.

Bankert, R. L. (1994). Cloud Classification of A VHRR Imagery in Maritime Regions Using a Probabilistic Neural Network. Journal of Applied Meteorology, Vol. 33(Issue 8), pg. 909-918.

Byvatov E., F. U. (2003). Comparison of Support Vector Machine and Artificial Neural Network Systems for Drug/Nondrug Classification. *Journal of Chemical Information and Computer Sciences*, 1882-1889.

Che Soh, A., Abdul Rahman, R., Ab. Kadir, M., & Mohd Shif, N. (December, 2011). Development of the lightning Location Mapping System Using Fuzzy Logic Technique. International Review of Modelling and Simulations (IREMOS), 6, 3301-3308.

Chen W.H., H. S. (2005). Application of SVM and ANN for Intrusion Detection. *Computers & Operations Research, Vol 32*, 2617-2634

Cooper, M. A., & Ab Kadir, M.Z.A.. (2010). Lightning Injury Continues To Be A Public Health Threat Internationally. 21st International Lightning Detection Conference. Orlando, Florida.

Elizondo D., Hoogenboom G., and McClendon R.W.. (1994). Development of A Neural Network Model to Predict Daily Solar Radiation. Agricultural and Forest Meteorology, Vol. 71(Issue 1-2), pg. 115-132.

Elkamel, A., Abdul Wahab, S., Bouhamra, W., Alper, E.. (2001). Measurement and Prediction of Ozone Levels around a Heavily Industrialized area: A Neural Network Approach. Advances in Environmental Research, Vol. 5, pg. 47-59.

Fawcett, T. (2004). ROC Graphs: Notes and Practical Considerations for Researchers. Technical Report. Netherlands: Kluwer Academic Publishers.

FloridaDisaster.org. (9 September, 2013). Lightning Safety. Retrieved 2 February, 2014, from Manatee County,Florida: http://www.mymanatee.org/home/government/departments/public-safety

Freeman, J., & Skapura, D. (1992). Neural Networks: Algorithms, Applications and Programming Techniques. United State of America: Addison - Wesley Publishing Company.

Gardner, M., & Dorling, S. (1998). Artificial Neural Networks (The Multilayer Perceptron)-A Review of Applications in the Atmospheric Sciences. Atmospheric Environment, Vol. 32(No. 14), pg. 2627-2636.

Gurney, K. (1997). An Introduction to Neural Networks. London: UCL Press.

Hartono, Z., & Robiah, I. (2003). Thunderstorm Day and Ground Flash Density in Malaysia. National Power Engineering Conference, (PECon) (pp. 217-219). Bangi, Malaysia: IEEE.

Hartono, Z., & Robiah, I. (2011). Improvised Lightning Safety Awareness Program. 2011 7th Asia-Pasific International Conference on Lightning (pp. 874-877). Chengdu,China: IEEE.

Holle, R. (2008). Annual Rates of Lightning Fatalities By Country. 20th International Lightning Detection Conference. Tucson, Arizona, USA.

Holle, R. (2009). Lightning-Caused Deaths and Injuries in and near Dwellings and other Buildings. Fourth Conference on the Meteorological Applications of Ligthning Data.

Hsieh, W. W., & Tang, B. (1998). Applying Neural Network Models to Prediction and Data Analysis in Meteorology and Oceanography. Bulletin of the American Meteorological Society, Vol.79(Issue 9), pg. 1855-1870.

Ibrahim, M. L. (15 April, 2012). Jurnal Lampu Merah: Gas Kilang Punca Amukan Petir. Kosmo Ahad, p. 14.

Johari D., Rahman T.K.A, Musirin, I., (2007). Artificial Neural Network Based Technique for Lightning Prediction. The 5th Student Conference on Research and Development - SCOReD 2007.

Lean, L. P. (27 August, 2011). NewsFocus: Climate Change Worsens Lightning Threat. New Straits Times, p. 13.

Mazurowski M.A., Habas P.A., Zurada J.M, Joseph Y.L, Baker J.A., and Tourassi G.D.. (2008). Training Neural Network Classifiers for Medical Decision Making: The Effects of Imbalanced Datasets on Classification Performance. Neural Networks, Vol. 21(2-3), pg. 427-436.

McCall, G. (2003). The Handbook of the Weather. London: Amber Books Ltd.

Murty O.P., Kiang C.K., Ari Husin M.H., Nanta Kumar R.K., and Mohammed Yusuf W.Y.W. (2009). Fatal Lightning Strikes in Malaysia: A Review of 27 Fatalities. American Journal of Forensic Medicine & Pathology, 30(3), 246-251.

Negnevitsky, M. (2005). Artificial Intelligence: A Guide to Intelligent Systems (Second ed.). Edinburgh Gate: Pearson Education Limited.

Nikulin, M. (7 February, 2011). Three-sigma rule. Retrieved 5 February, 2014, from encyclopediaofmath.org: http://www.encyclopediaofmath.org/index.php/Three-sigma_rule

NOAA. (2014). Tropical Atmosphere Ocean Project (TAO project). Retrieved 3 February, 2014, from Pacific Marine Environment Laboratory, National Oceanic and Atmospheric Administration: http://www.pmel.noaa.gov/tao

Ren, J. (2012). ANN vs. SVM: Which one performs better in classification of MCCs in mammogram imaging. *Knowledge-Based Systems, Volume 26*, 144-153.

Reynolds, R. (2007). Guide to Weather. London: Octopus Publishing Group Ltd.

Suparta W., Adnan J., and Mohd Ali M.A.. (2011). Detection of Ligthning Activity Using GPS PWV Measurements. 2011 International Conference on Environment Science and Engineering (pp. 115-120). Penang: IEEE.

TheAirlinePilots.com. (1 Oct, 2014). *TheAirlinePilots.* Retrieved from www.theairlinepilots.com:http://www.theairlinepilots.com/forum/viewtopic.php?p=436&sid=..

Uman, M. A. (1986). All About Lightning. New York: Dover Publication Inc.

Watrous, R. L. (1987). Learning Algorithms for Connectionist Networks: Applied Gradient Methods of Nonlinear Optimization. Proceedings of the IEEE first

International Conference on Neural Networks rm (pp. 619-627). San Diego, CA: IEEE.

Webmaster, T. (10 October, 2012). National Weather Service Weather Forecast Office, Tampa Bay Area, FL. Retrieved 6 January, 2014, from Tampa Bay Graphical Hazardous Weather Outlook: http://www.srh.noaa.gov/tbw

Weng, L.Y., Omar, J.B., Siah, Y.K., Ahmed, S.K., Zainal Abidin, I., Abdullah, N.. (2010). Lightning Forecasting using ANN-BP and Radiosonde. 2010 International Conference on Intelligent Computing and Cognitive Informative (pp. 152-155). Kuala Lumpur: IEEE.

Williams, R. (1986). The Logic of Activation Functions. In David, D. E. Rumelhart, & J. L. McClelland, Parallel Distributed Processing. Cambridge: The MIT Press.

Xiong, Y.J, Qie,X.S, Zhou Y.J, Yuan, T., Zhang T.L., (2006). Regional Responses of Lightning Activities to Relative Humidity of the Surface. Chinese Journal of Geophysics, 49(2), pg. 311-318.

Zhang Y., Ma M., Lu W., and Tao S., (2009). Review on Climate Characteristics of Lightning Activity. Acta Meteorologica Sinica, Vol. 24(2), 137-149.