UNIVERSITI PUTRA MALAYSIA

WAVELET DECOMPOSITION-NNARX MODEL FOR FLOOD PREDICTION OF KELANTAN RIVER, MALAYSIA

MOHD AZROL SYAFIEE BIN ANUAR

WAVELET DECOMPOSITION-NNARX MODEL FOR FLOOD PREDICTION OF KELANTAN RIVER, MALAYSIA

By

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

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

WAVELET DECOMPOSITION-NNARX MODEL FOR FLOOD PREDICTION OF KELANTAN RIVER, MALAYSIA

By

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December 2018

Chair: Ribhan Zafira binti Abdul Rahman, PhD
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Flood is a major disaster that happens around the world. It has caused the loss of many precious lives and massive destruction of property. The possibility of flood can be determined depends on many factors that consist of rainfall, structure of the river, flow rate of the river etc. One of the research challenges is to develop accurate prediction models and what improvement can be made to the forecasting model. The objective of this thesis is to improve the performance of the neural network model to predict the flood on the Kelantan River, Malaysia. A technique for modelling of nonlinear data of flood forecasting using wavelet decomposition-neural network autoregressive exogenous input (NNARX) approach is proposed.

This thesis discusses the identification of parameters that involved in the forecasting field as rainfall value, flow rate of the river and the river water level. With the original data acquired, the data had been processing through to wavelet decomposition and filtered to generate a new set of input data for NNARX prediction model. This proposed technique has been compared with the non-wavelet NNARX.

The experimental result show that the proposed approach provides better testing performance compared to its counterpart, which the mean square error obtained is $2.0491e^{-4}$ while the normal NNARX is $6.1642e^{-4}$.

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

MODEL GELOMBANG DEKOMPOSISI-NNARX BAGI RAMALAN BANJIR DI SUNGAI KELANTAN, MALAYSIA

Oleh

MOHD AZROL SYAFIEE BIN ANUAR

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Banjir adalah bencana besar yang berlaku di seluruh dunia. Ia telah menyebabkan kehilangan nyawa dan kemusnahan harta benda. Kemungkinan banjir dapat ditentukan dengan bergantung kepada banyak faktor yang terdiri daripada hujan, struktur sungai, aliran sungai dan lain-lain. Salah satu cabaran penyelidikan ini adalah untuk membangunkan model ramalan yang tepat dan penambahbaikkan yang boleh dilaksanakan pada model ramalan. Objektif tesis ini adalah untuk meningkatkan prestasi model rangkaian neural dalam meramal banjir di Sungai Kelantan, Malaysia. Teknik pemodelan data ramalan banjir ini menggunakan penguraian gelombang kecil – rangkaian neural pendekatan input eksogen autoregressif (NNARX) adalah dicadangkan.

Tesis ini membincangkan pengenalpastian parameter yang terlibat dalam bidang ramalan seperti nilai hujan, kadar aliran sungai dan paras air sungai. Dengan data asal yang diperoleh, data telah melalui penguraian dan penapis gelombang kecil dalam menghasilkan set data input baru untuk model ramalan NNARX. Teknik yang dicadangkan ini telah dibandingkan dengan NNARX bukan gelombang kecil.

Keputusan eksperimen menunjukkan bahawa pendekatan yang dicadangkan memberikan prestasi ujian yang lebih baik berbanding dengan teknik NNARX yang biasa, yang mana ralat punca kuasa setara diperoleh adalah $2.0491e^{-4}$ manakala NNARX biasa ialah $6.1642e^{-4}$.

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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 the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ANN	Artificial neural network
BPNN	Backpropagation neural network
NNARX	Nonlinear autoregressive exogenous input neural network
ARX	Autoregressive exogenous input
RNN	Recurrent Neural Network
MA	Moving Average
AI	Artificial intelligence
ARIMA	Autoregressive integrated moving average
ARMA	Autoregressive moving average
SVM	Support vector machine
RMSE	Root mean square error
MSE	Mean square error
ANFIS	Neuro fuzzy inference system
MARE	Mean absolute relative error
DNN	Deep Neural Network
R	Regression

CHAPTER 1

INTRODUCTION

1.1 Overview

Flood is a common natural disaster that affecting lots of countries around the world. Flood have posed a great threat up to the extent of causing massive destruction on public facilities, residential homes and even worse, death. Malaysia is one of the countries that have endure and encounter this natural disaster. Flash flood is the types of flood that usually occur in the urban area meanwhile where the monsoon flood is in the east coast of Malaysia which consist of three states that is Kelantan, Pahang and Terengganu. The east coast flood dependent on the monsoon where it is due to the result of wind carrying large amount of rain. The monsoon season can be divided into two, which is northeast monsoon and southwest monsoon. Normally, east coast monsoon floods occur from October to February and bring heavy rainfall to Malaysia, especially East Peninsular Malaysia, Sabah and Sarawak, while west coast monsoon floods happen from May to August and bring little amount of rainfall to the west coast of the peninsula, including Kuala Lumpur, Selangor, Melaka, Johor, Perak, and Penang [1]. The monsoons contribute about 86% of the annual rainfall in the east coast region [2].

Water flow rate, rainfall and water levels among the parameters that contribute to flood events. Thus, in this modern era monitoring or prediction system rely on fuzzy logic or neural network have become common [3]. Though every intelligent system such as fuzzy logic and neural network are best suit to be implemented for forecasting compare to its linear model counterparts, each of this intelligent do have its own advantages and disadvantages need to be considered. Through several literature study shown that the neural network has certain advantages when dealing environmental data. Thus, neural network was used in this research to analyse the flood pattern that occurs in Kelantan.
The concept of the artificial neural network can be described as a computer model assumption of the biological brain. It consists of a set of interconnected simple processing units which combine to output a signal to solve a certain problem based on the input signals it received. In neural network, there many different types of model that can be applied to any certain applications and one of it is Neural Network Autoregressive with Exogenous Input (NNARX) which is based on linear Autoregressive Model with Exogenous Input (ARX) which is have become widely applied method in many prediction researches. ARX, and other model can be trained as neural network thus neural network also can be developed for system identification [4]. NNARX is a class of Recurrent Neural Network (RNN) that takes past input and output values to compute the current output.

Despite of the capabilities of the neural network in prediction, the model can still be improved from time to time by optimizing the system and combining with other technique or method that has been discussed in the literature review chapter. Wavelet decomposition is one of mathematical technique that transforms signal to spectral data in time and frequency [5]. The signal decomposes into approximation and detail, with passing previous coefficient through high and low pass filters. As such, in this research is to discover how this wavelet combination with neural network or in other term is called neuro-wavelet could be approached and be implemented in the forecasting field and especially for this river water level prediction.

1.2 Problem statement

In the river forecasting application, many parameters must be involved in order to deliver an accurate reading of the flood situation. Therefore, many methods have been introduced as to overcome such inaccuracy in predicting, where certain method tends to have advantages over others. The flood forecasting models involved with non-linear data such as rainfall, flow rate etc. Artificial intelligence (AI) application has shown rising interest throughout the year in solving forecasting problem. Backpropagation neural network (BPNN) model are among used technique in prediction due to its simplicity and easy to understand but neural network has other technique that can improve the accuracy when handling time-series forecasting as such NNARX. There are researches of that used NNARX as the predictor whether in the flash flood forecasting and monsoon flood. Different from flash flood, NNARX that applied in this type of field able to achieve a higher performance compared to monsoon flood. Monsoon flood can also be dividing into short-term and long-term forecasting with each have different set of data. With lower performance obtained through a long time period, does NNARX will also affect a shorter time period on monsoon flood. This leads us to uncover the capabilities and its limitation of the NNARX model in time series forecasting. Wavelet decomposition was discovered that could help improve the performance of AI such as support vector machine, adaptive neuro fuzzy inference system (ANFIS) etc. With this discovery of the wavelet advantages, this will help the NNARX to improve its performance and achieve a better accuracy.

1.3 Objectives

The aim of this project is to develop a prediction system through NNARX with Wavelet decomposition system. To achieve this aim, the following objectives are set:

- To identify the data from the related rivers and rainfall that causes the flood in the downstream of Kelantan River at Guillemard Bridge.
- To develop NNARX that have better accuracy compared to Backpropagation Neural Network.
- To combine NNARX with Wavelet decomposition method to improve the accuracy in flood prediction.

1.4 Scope of Study

The main concern of this project is classifying the river water level. For classifying water level, the required parameters are the water level of Kelantan River, Rainfall of surrounding area and Lebir river flow rate. The data of rainfall, flow rate, water level was obtained from the Department of Irrigation and Drainage Malaysia [6]. As status river water level is normal, the data for other two classes which is caution (moderate) and danger is based on the millimetre of rain dropping, and water flow cubic metre per seconds result in the water level changes. The data used in this research are hourly data of November until December for 2012, 2013 and 2014. Figure 1.1 is the representing the area of study for this project that is in Kelantan.

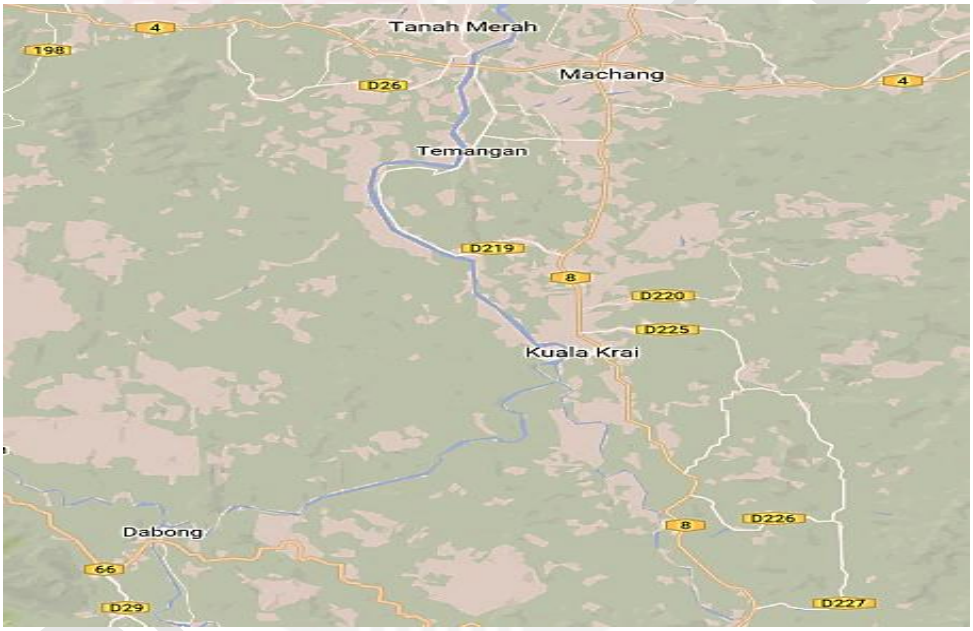

Figure 1.1: Area of Study (Kelantan)

1. 5 List of contributions

This is list of contribution that obtained and discovered throughout this research:

- The wavelet decomposition helps NNARX model to achieve better testing accuracy compared to its normal NNARX counterparts.
- Wavelet-BPNN model achieved higher accuracy compared to normal BPNN with increase both in training and testing phase.
- Discover the NNARX model to be able to predict in both short- and long-term period, although long term forecasting does not obtain a good performance as compared to shorter study time period.

REFERENCES

[1] Ang Kean Hua. (2014), Monsoon Flood Disaster in Kota Bharu, Kelantan Case Study: A Comprehensive Review, *International Journal of Scientific Engineering and Research (IJSER)*, Vol. 3, no. 5, pg. 79-81.

[2] C. L. Wong et al. (2009). Variability of rainfall in Peninsular Malaysia. *Hydrology and Earth System Science Discussions*, Volume 6, pg 5471–5503.

[3] Anil Kumar Lohani, N.K. Goel and K.K.S. Bhatia. (2005). Development of fuzzy logic based real time flood forecasting system for river Narmada in central India. *Journal of Classification*, Volume 33, pg. 17-19

[4] F. A. Ruslan, A. M. Samad, Z. Zain, and R. Adnan. (2014). Flood Water Level Modeling and Prediction Using NARX Neural Network : Case Study at Kelang River. *International Colloqium on Signal Processing & Its Application (CSPA)* , Issue. 1, pg. 7–9.

[5] Seo, Y., Kim, S., Kisi, O., & Singh, V. P. (2015). Daily water level forecasting using wavelet decomposition and artificial intelligence techniques. *Journal of Hydrology*, *520*, 224–243. https://doi.org/10.1016/j.jhydrol.2014.11.050

[6] Information Management Unit, Water Resources Management and Hydrology Division Department of Irrigation and Drainage, Malaysia. Retrieved from: https://www.water.gov.my/

[7] Zealand, C. M., Burn, D. H., & Simonovic, S. P. (1999). Short term streamflow forecasting using artificial neural networks, *214*(September 1997), 32–48.

[8] Besaw, L. E., Rizzo, D. M., Bierman, P. R., & Hackett, W. R. (2010). Advances in ungauged streamflow prediction using artificial neural networks. *Journal of Hydrology*, *386*(1–4), 27–37. https://doi.org/10.1016/j.jhydrol.2010.02.037

[9] Adsaffuan, (2015, June 30). Banjir Kelantan 2014 – Satu Muhasabah. Retrieved from: http://pks.kelantan.gov.my/?p=82

[10] Perera, E. D. P., & Lahat, L. (2015). Fuzzy logic-based flood forecasting model for the Kelantan River basin, Malaysia. *Journal of Hydro-Environment Research*, *9*(4), 542–553. https://doi.org/10.1016/j.jher.2014.12.001

[11] On-line Hydrological Data Retrived from: http://infobanjir.water.gov.my/real_time.cfm

[12] Jian, W., Jiang, X., Zhang, J., Xiang, Z., & Jian, Y. (2012). Comparison of SOC Estimation Performance with Different Training Functions Using Neural Network. *2012 UKSim 14th International Conference on Computer Modelling and Simulation*, 459–463. https://doi.org/10.1109/UKSim.2012.69

[13] Sharma, B., & Venugopalan, K. (2014). Comparison of Neural Network Training Functions for Hematoma Classification in Brain CT Images. *IOSR Journal of Computer Engineering Ver. II*, *16*(1), 31–35. https://doi.org/10.9790/0661-16123135

[14] Matlab Mathwork Documentation. Retrieved from: https://www.mathworks.com/help/deeplearning/ug/choose-a-multilayer-neural-network-training-function.html;jsessionid=d1298df2e41e8d8395d294f234c9

[15] Kamble, L. V., Pangavhane, D. R., & Singh, T. P. (2015). Neural network optimization by comparing the performances of the training functions - Prediction of heat transfer from horizontal tube immersed in gas-solid fluidized

bed. *International Journal of Heat and Mass Transfer*, *83*, 337–344. https://doi.org/10.1016/j.ijheatmasstransfer.2014.11.085

[16] Payal, A., Rai, C. S., & Reddy, B. V. R. (2013). Comparative Analysis of Bayesian Regularization and Levenberg-Marquardt Training Algorithm for Localization in Wireless Sensor Network, 191–194.

[17] Abdulkadir, S. J., & Yong, S.-P. (2014). Empirical analysis of parallel-NARX recurrent network for long-term chaotic financial forecasting. *2014 International Conference on Computer and Information Sciences (ICCOINS)*, (June), 1–6. https://doi.org/10.1109/ICCOINS.2014.6868354

[18] Rahimi, Z., Mohd Shafri, H. Z., & Norman, M. (2018). A GNSS-based weather forecasting approach using Nonlinear Auto Regressive Approach with Exogenous Input (NARX). *Journal of Atmospheric and Solar-Terrestrial Physics*, (June), 0–1. https://doi.org/10.1016/j.jastp.2018.06.011

[19] F.s. Panchal, M. Panchal, (2014). Review on Methods of Selecting Number of Hidden Nodes in Artificial Neural Network. IJCSMC, Volume 3, Issue 11, 455-464

[20] K. Gnana Sheela and S. N. Deepa (2013). Review on Methods to Fix Number of Hidden Neurons in Neural Networks. Mathematical Problems in Engineering, vol. 2013, Article ID 425740, 11 pages. https://doi.org/10.1155/2013/425740.

[21] D. Brezak, T. Bacek, D. Majetic, J. Kasac and B. Novakovic, (2012) "A comparison of feed-forward and recurrent neural networks in time series forecasting," *2012 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr)*, New York, NY, pg. 1-6. doi: 10.1109/CIFEr.2012.6327793

[22] Soomlek, C., Kaewchainam, N., Simano, T., & So-In, C. (2016). Using backpropagation neural networks for flood forecasting in PhraNakhon Si Ayutthaya, Thailand. *ICSEC 2015 - 19th International Computer Science and Engineering Conference: Hybrid Cloud Computing: A New Approach for Big Data Era*. https://doi.org/10.1109/ICSEC.2015.7401424

[23] Lueangaram, S. (2016). Time Lagged Back Propagation Neural Network with Rainfall for Flood Forecasting. International Conference on Intelligent Engineering System (INES) Budapest, Hungary 63–68.

[24] Chen, C.-S., Chen, B. P.-T., Chou, F. N.-F., & Yang, C.-C. (2010). Development and application of a decision group Back-Propagation Neural Network for flood forecasting. *Journal of Hydrology*, *385*(1), 173–182. https://doi.org/10.1016/j.jhydrol.2010.02.019

[25] Jiang, C., & Song, F. (2011). Sunspot forecasting by using chaotic timeseries analysis and NARX network. *Journal of Computers*, *6*(7), 1424–1429. https://doi.org/10.4304/jcp.6.7.1424-1429

[26] Dengen, N. (2016). Comparison of SARIMA , NARX and BPNN Models in Forecasting Time Series Data of Network Traffic. International Conference on Science in Information Technology (June 2013), 264–269.

[27] Rohaimi, N. A., Ahmat, F., & Gqdq, R. (2016). 3 Hours Ahead of Time Flood Water Level Prediction Using NNARX Structure : Case Study Pahang, Control and System Graduate Research Colloqium(August), 98–103.

[28] Haviluddin, & Alfred, R. (2016). Performance of modeling time series using nonlinear autoregressive with eXogenous input (NARX) in the network traffic forecasting. *Proceedings - 2015 International Conference on Science in Information Technology: Big Data Spectrum for Future Information Economy, ICSITech 2015, 2013*(June 2013), 164–168.

https://doi.org/10.1109/ICSITech.2015.7407797
[29] Thakur, A., Tiwari, A., Kumar, S., Jain, A., & Singh, J. (2016). NARX based forecasting of petrol prices. *2016 5th International Conference on Reliability, Infocom Technologies and Optimization, ICRITO 2016: Trends and Future Directions*, *610*(1), 610–614. https://doi.org/10.1109/ICRITO.2016.7785027
[30] Ruslan, F. A., Samad, A. M., Tajjudin, M., & Adnan, R. (2016). 7 hours flood prediction modelling using NNARX structure: Case study Terengganu. *Proceeding - 2016 IEEE 12th International Colloquium on Signal Processing and Its Applications, CSPA 2016*, (November), 263–268. https://doi.org/10.1109/CSPA.2016.7515843
[31] Shakila, N., Zubir, A., Jaafar, K., Hezri, M., Rahiman, F., & Mara, U. T. (2016). Water Level Modeling for Kelantan River at Jeti Kastam Station Using Nonlinear Autoregressive with Exogenous Input Structure, (August), 142–147.
[32] Supratid, R. K. and S. (2016). Thailand tourism forecasting based on a hybrid of discrete wavelet decomposition and NARX neural network. https://doi.org/10.1108/IMDS-11-2015-0463
[33] Pandey, A. S., Singh, D., & Sinha, S. K. (2010). Intelligent hybrid wavelet models for short-term load forecasting. *IEEE Transactions on Power Systems*, *25*(3), 1266–1273. https://doi.org/10.1109/TPWRS.2010.2042471
[34] Zhang, S., Chen, J., She, L. H., & Bao, X. R. (2010). Use of optimal wavelet packet decomposition for the long-term prediction of variable-bit-rate video traffic. *Iet Communications*, *4*(11), 1277–1287. https://doi.org/10.1049/iet-com.2009.0405
[35] Khandelwal, I., Adhikari, R., & Verma, G. (2015). Time series forecasting using hybrid arima and ann models based on DWT Decomposition. *Procedia Computer Science*, *48*(C), 173–179. https://doi.org/10.1016/j.procs.2015.04.167
[36] Seo, Y., & Kim, S. (2016). River Stage Forecasting Using Wavelet Packet Decomposition and Data-driven Models. *Procedia Engineering*, *154*, 1225–1230. https://doi.org/10.1016/j.proeng.2016.07.439
[37] He, Z., Wen, X., Liu, H., & Du, J. (2014). A comparative study of artificial neural network , adaptive neuro fuzzy inference system and support vector machine for forecasting river flow in the semiarid mountain region. *Journal Of Hydrology*, *509*, 379–386. https://doi.org/10.1016/j.jhydrol.2013.11.054
[38] Chen, L., & Lai, X. (2011). Comparison between ARIMA and ANN models used in short-term wind speed forecasting. *Asia-Pacific Power and Energy Engineering Conference, APPEEC, (c)*. https://doi.org/10.1109/APPEEC.2011.5748446
[39] Valipour, M., Banihabib, M. E., & Behbahani, S. M. R. (2013). Comparison of the ARMA, ARIMA, and the autoregressive artificial neural network models in forecasting the monthly inflow of Dez dam reservoir. *Journal of Hydrology*, *476*, 433–441. https://doi.org/10.1016/j.jhydrol.2012.11.017
[40] Dhimish, M., Holmes, V., Mehrdadi, B., & Dales, M. (2018). Comparing Mamdani Sugeno fuzzy logic and RBF ANN network for PV fault detection. *Renewable Energy*, *117*, pg 257–274. https://doi.org/10.1016/j.renene.2017.10.066
[41] Biswajeet, P., & Saied, P. (2010). Comparison between prediction capabilities of neural netwotk and fuzzy logic technique for L and slide susceptibility mapping. Disaster Advances, Volume 3, pg 26-34.

[42] Amber, K. P., Ahmad, R., Aslam, M. W., Kousar, A., Usman, M., & Khan, M. S. (2018). Intelligent techniques for forecasting electricity consumption of buildings. *Energy*, *157*, 886–893. https://doi.org/10.1016/j.energy.2018.05.155

[43] Tung-Kuang Wu, Shian-Chang Huang and Ying-Ru Meng. (2006) "Identifying and Diagnosing Students with Learning Disabilities using ANN and SVM," *The 2006 IEEE International Joint Conference on Neural Network Proceedings*, Vancouver, BC, pg. 4387-4394. https://doi: 10.1109/IJCNN.2006.247038

[44] Z. M. Yaseen, A. El-shafie, O. Jaafar, H. A. Afan, and K. N. Sayl (2015) Artificial intelligence based models for stream-flow forecasting: 2000-2015," *Journal of Hydrology*, vol. 530, pg. 829–844,

[45] A. O. Pektaş and H. Kerem Cigizoglu. (2013). ANN hybrid model versus ARIMA and ARIMAX models of runoff coefficient. *Journal of Hydrology*, vol. 500, pg. 21–36.

[46] R. M. Adnan, "Streamflow forecasting of Astore River with Seasonal Autoregressive Integrated Moving Average model Ozgur Kisi," no. April, 2017.

[47] Alvisi, S., Mascellani, G., & Franchini, M. (2006). Water level forecasting through fuzzy logic and artificial neural network approaches, Volume 10, pg 1–17.

[48] Bernama (2015, Mac 14) Banjir Kelantan: Pembalakan masih aktif di Gua Musang. Astro Awani. Retrieved from http://www.astroawani.com/berita-malaysia/banjir-kelantan-pembalakan-masih-aktif-di-gua-musang-55597.

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After finished his degree studies, he continued his education with a master thesis in control system engineering. At the same time, he was awarded with Grant Research Fellowship (GRF) from 2017 till 2018. He also has taught tutorials and as lab demonstrator for 3 semester in basic electronic and control system.

PUBLICATIONS

Conference

M. A. S. Anuar, R. Z. A. Rahman, S. B. Mohd, A. C. Soh and Z. D. Zulkafli, 2017, Early prediction system using neural network in Kelantan River, Malaysia. *2017 IEEE 15th Student Conference on Research and Development (SCOReD)*, Putrajaya, pp.104-109. doi: 10.1109/SCORED.2017.8305412

Journals

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