INTERNET OF THINGS EARLY FLOOD WARNING SYSTEM WITH ETHOLOGY INPUT AND FUZZY LOGIC

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DEDICATION

This thesis is dedicated to my mother and father, who gave me endless love, trust, constant encouragement over the years, and for her prayers. It is also dedicated to my husband and kids, for their patience, support, love, and for enduring the ups and downs during the completion of this thesis.

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ABSTRACT

Flood is considered as a serious natural disaster in Asia. Flood has affected millions of people in Asia in the recent years including Malaysia and its neighboring countries. The severity of the problems resulted from flood has significantly affected the government in terms of economic and social. Information Communication Technology (ICT) can be utilized in addressing flood challenge by contributing in the aspects of early flood warning as well as alerting the affected community. Early flood warning systems face several challenges in terms of warning dissemination that is not timely, people centered, accessible and explainable. Thus, this study developed an Internet of Thing (IoT) early flood warning system (IEFWS) with ethological input using fuzzy logic in order to come up with a timely, precise and low cost flood warning system. The IEFWS of fuzzy logic application included several nature input data membership functions specifically temperature, humidity, rainfall intensity, water raise rate, sound, and motion indicators were all being updated on the internet simultaneously in less then 0:00:05 seconds. This study also included an ethological input data of fish by analyzing the behavior of sound and movement of fish as indicators to early warning before flood occurrence. The system was tested and evaluated in terms of timely and preciseness of it to update sensor data to the internet and apply fuzzy logic to intelligently alert flood warning. The results showed that the system was able to update ubiquitous data for a better monitoring system platform. In addition, the system is low cost and easy to handle. In conclusion, the IoT early flood warning system is timely and precise as the data are updated at a very minimum delay and it could easily monitor the changes of climate.

ABSTRAK

Banjir dianggap sebagai bencana alam yang serius di Asia. Banjir telah menjejaskan jutaan orang Asia pada beberapa tahun kebelakangan ini termasuk Malaysia dan negara-negara jirannya. Masalah yang timbul akibat banjir telah menjejaskan polisi kerajaan dari aspek sosial dan ekonomi. Teknologi Komunikasi Maklumat (ICT) boleh digunakan dalam menangani cabaran banjir dengan menyumbang dalam aspek memberi amaran awal banjir kepada komuniti yang terkesan. Sistem amaran awal banjir berhadapan dengan beberapa cabaran dari segi penyebaran maklumat amaran banjir yang kurang dikemas kini, kurang menjadi tumpuan ramai dan sukar dicapai. Oleh itu, kajian ini membangunkan sistem objek berinternet (loT), sistem amaran awal banjir (IEFWS) dengan masukkan etologi menggunakan logik untuk membangunkan sistem amaran banjir yang dikemas kini, tepat dan kurang kos. Aplikasi IEFWS logik kabur termasuk beberapa input persekitaran iaitu data suhu, kelembapan, intensiti hujan, kenaikan kadar air, bunyi dan petunjuk pergerakan semuanya dikemas kini di internet secara serentak kurang dari 0:00:05 saat. Kajian ini juga memasukkan data etologi ikan dengan menganalisis tingkah laku bunyi dan pergerakan ikan sebagai petunjuk kepada amaran awal sebelum kejadian banjir. Sistem ini diuji dan dinilai dari segi ketepatan pada masanya dan ketepatannya untuk mengemas kini data sensor ke internet dengan menggunakan logik kabur untuk memberi amaran banjir yang bijak. Hasilnya menunjukkan bahawa sistem itu dapat mengemas kini data di mana-mana untuk platform sistem pemantauan banjir yang lebih baik. Di samping itu, sistem ini adalah rendah kos dan mudah untuk dikendalikan. Kesimpulannya, sistem amaran awal banjir (loT) adalah tepat pada masanya dan lengkap kerana data dikemas kini dengan kadar tangguh penghantaran yang sangat minimum serta dapat memantau perubahan cuaca persekitaran dengan mudah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	-	Alternating Current
ANN	-	Artificial Neural Networks
CW	-	Continuous Wave
DAQ	-	Data Acquisition
DC	-	Direct Current
EM	-	Electromagnetic
FTDI	-	Future Technology Devices International
HMI	-	Human Machine Interface
I/O	-	Input/Output
ICSP	-	In Circuit Serial Programming
IDE	-	Integrated Development Environment
IEFWS	-	IoT Early Flood Warning System
IP	-	Internet Protocol
JSON	-	Java Script Object Notation
LED	-	Light Emitting Diode
LPC	-	Linear Predictive Coding
MATLAB	-	Matrix Laboratory
MISO	-	Multiple Input Single Output
OLED	-	Organic Light Emitting Diode
PHP	-	Hyperytext Preprocessor
RF	-	Radio Frequency
RTU	-	Remote Terminal Unit
SEMS	-	Seismic Electromagnatic Signal
SQL	-	Structured Query Language
WSN	-	Wireless Sensor Networks

CHAPTER 1

INTRODUCTION

1.1 Introduction

Flood warning system has been enhanced every now and then to ensure that the society are being alert to flood disaster with minimum impact to it. The precaution of all means has been put to standard management to mitigate the occurrence of flood disaster at the potential at-risk area. The effort of all angle of various fields and disciplines has been called to hand in hand in reducing the impact of the flood disaster. Before, during and after flood occurrence management has been underlined in government and none government sectors to minimize the after effect of the flood. Seeing the importance to put a little effort of contribution to mitigating flood, this research is meant to enhance the timely and preciseness of early flood warning system.

While in this chapter, it covers mainly of the heart of this research background, problem statements, objectives, aims and it is significant. The background of the research is being underlined in order to give a little bit of introduction of the importance of the problem occurs with regard to the research. The objectives, aim, and limitation of research are the main guidelines to lead the research all the way through reaching its main goal.

1.2 Motivation of Study

The cost of damage caused by flooding correlates closely with the warning time given before a flood event, making flood monitoring and prediction critical to minimizing the cost of flood damage. Terrifying flood disaster had hit Malaysia late December 2014 and early January 2015 that leads to losing of lives and properties.

Continued heavy rainfall of Northeast Monsoon had affected several areas in Peninsular Malaysia, including Johor, Terengganu, Perak, Pahang, and Kelantan.

There are two types of floods that commonly occurred in Malaysia, which are of river flood and coastal flood. There are initiatives that are being implemented by the Department of Irrigation and Drainage (DID), Malaysia in improving the flood warning systems. They had built 140 for rainfall and 39 for water level and 274 for both rainfall and water level telemetry DAQ stations. Major deficiencies of flood monitoring and warning systems were inadequate rainfall and water level station networks for real-time data and the flood monitoring technique must be more accurate. So, DID had implemented on hydrological and hydrodynamic model analysis to alert flood occurrence in Malaysia. The concept of hydrological and hydrodynamic is basically the integration of two analysis of ecology. Hydrology emphasizes surface water conditions, with a specific focus on hydrologic modeling and prediction that deliberately develop, test and apply the study of the hydrology of land-atmosphere models, snowmelt-runoff modeling, and seasonal streamflow monitoring for the operation of major water resource systems. While hydrodynamic considers the physical processes that relate to transport, mixing and the dynamical behavior of fluids in natural flows and those of environmental significance that it occurred due to turbulence, density stratification, and the earth's rotation.

DID gain real-time data of water river level, rainfall inches, and river image data are directly collected from the station. The data is updated every half an hour to 15 minutes depending on the remote terminal unit coverage networks that transmitted from the required data using data logger directly to the webmaster. The issue of half an hour and 15 minutes inefficient data updated needs to be improved to a least delay real-time data. A minute delay is very much important for the warning system to enhance much more preciseness in the warning system.

At the webmaster, the analyzation of the data from the physical environment takes place and directly warn any flood occurrence. Based on the data obtained and alert software used, it could make a prediction of around 2 days to 6 hours before the massive flood occurs. This leads to the performance accuracy up to 60% to alert the incoming massive flooding. The prediction accuracy of 60% really needs to be enhanced to a better accuracy percentage. The data for weather prediction usually are from several source data which are of DEM, Lidar and IFSAR. Based on the weather prediction only the DID will really take into account to alert flood. Once it starts to rain then only the telemetry station starts measuring. They will consider the rainfall depth and intensity data which are obtained from the Department of Meteorology Malaysia (MetMsia). MetMsia manages to forecast the rainfall distribution up to 7 days before and to be more accurately 2-3 days before. The server for telemetry data will only be operated during the monsoonal seasonal time due to a massive data organization matters and the temperature server room matters that if not being monitored it will damage the server due to heat. While it was also reported that the DAQ telemetry stations were swipe out of the heavy flood and could not effectively give the physical environmental changes at the potential at-risk flood. The cases of DAQ telemetry were running out of power supply also occurred since the DAQ power supply relies on relay switch of either solar system and the lead-acid battery which could only last long maximum of 2 weeks in continuous cloudy weather. Which during the monsoonal season the cloudy weather could be up to one to two months of duration and caused DAQ telemetry data station could not transmit data to the server for flood warning purposes.

The basic system that the DID use to acquire data from DAQ based station for flood warning system which are basically classified into the input data transmitter, receiver and the outcome for warning system DAQ based information. The input data of rainfall using a tipping bucket and water level sensor (using various sensors depending on site application). Basically, 4 types of gauges are used to acquire river water level, which are of Ultrasonic sensor, Radar, Bubler and Pressure Transducer (tube). Usually, location for flash flood area applied tube or pressure transducer while monsoonal rainfall flood area uses ultrasonic sensor. The drawback of the sensors that there were cases that the sensors do not read any measurement and lead to flooding. Thus, a check and balance DAQ is required to ensure that the community is being alerted of an incoming flood occur ahead.

1.3 Problem Statement

Flood monitoring systems face several challenges in terms of warning dissemination that is not timely, people-centered, and accessible .A timely and precise warning system is crucial to give precise information and ample time for the flood victims to evacuate the potentially affected areas and save flood victims to alternative safe areas. The input data from rainfall and hydrology by relying only on the outsource data from authorized centers is not enough to precisely predict the real-time uncertainty of flood monitoring system (Achawakorn *et al*, 2015). The gap of comparable data between the direct physical data and the outsource data is significant hence leading to inaccuracy of input data (Achawakorn *et al*, 2015). Several comparables of other input data are important in obtaining legitimate input data. Real-time meteorological and hydrological data are extremely important in improving flood warning system. In previous research done by Achawakorn *et al*, 2015), water level input was considered for their early flood warning system, however, the water level input data was not tested repeatedly. The researchers took minimum input of different base stations of the inundated area, which led to the frail accumulation of input data in achieving timely forecast flood rate of various regional areas. An important issue needs to address is the non-timely of the input data to the base station and it may be lag several hours that might further lead to inaccuracy of flood warning system. The high cost of DAQ system installation for every risky area of the flood had limited the number of DAQ systems installed and had caused minimum number of input data was obtained. As the distance to remote sites increases, it becomes more difficult to set/configure the conventional DAQ. Thus, a Wireless DAQ is needed to enhance the timeliness and accuracy of physical inundated data. The current lead time taken by the DID is approximately 6 to 7 hours before massive floods occur; which this update is available in the official website (Laporan Tahunan JPS, 2016, pp59-67). The current lead time taken for flood forecast is not effective enough to alert the society on prompt flood occurrence. Thus, by relying on animal behavior prior to flooding could increase the lead time before massive floods occurred supported by other physical world input data. Some remote terminal stations were found got washed away before it could alert floods. Thus, the proposed wireless Wireless DAQ is needed to overcome such cases in order to obtain a real-time result and eventually increase the time and efficiency of the flood forecast system. The idea of the wireless concept of Wireless DAQ system could reduce the cost of installation of landed installed DAQ. The wireless sensors concept could be easily fit in the current modern universal usage of the mobile application.

1.4 Research Aim

The integration of various multiple wireless sensors of depth/water level, temperature and humidity, rainfall, and behavioral change of animals/insects (visual or/and vocal) with low-cost, ubiquitous and remote/wireless DAQ can enhance the preciseness and timely early flood warning system.

1.5 Research Objectives

Based on the research aim, the research objectives are as follows:

1. To investigate the multiple inputs data that can be used for IoT early flood warning system.
2. To design and develop a timely and precise low cost IoT early flood warning system based on multiple inputs data with ethological behavior and fuzzy logic.
3. To study the ethological input data that could improve early warning before flood occurrence.
4. To evaluate the timely and precise-proposed IoT early flood warning system.

1.6 Research Questions

To achieve the above research objectives, the following research questions are used.

1. How multiple inputs of can be used for IoT early flood warning system?
2. Why the current method is not able to provide the timely and precise low-cost IoT early flood warning system using multiple inputs data?
3. How ethological inputs could improve IoT early flood warning system?
4. How to evaluate timely and precise-proposed Fuzzy logic IoT early flood warning system?

1.7 Research Scope

The research scope is that the hardware part which is basically using Espresso lite 2.0 as the microcontroller for master terminal unit (MTU) and Atmel as remote terminal unit (RTU). The integrated development environment (IDE) is using Arduino IDE to program the MTU and RTU. While in the database management and web development is using *MySQL*, *SQL*, *JSON* and *PHP*. The data analyzation is basically using MATLAB *fuzzy logic toolbox*. This research is still in a prototype model of experimental base of Remote Terminal Unit (RTU) station with only one minimum station. The RTU station is also meant to replicate a single station of data acquired at potential at risk inundated area. While the ethological inputs of only fish behavior is mainly the bounded limit ethological input in this research as to indicate there is a significant factor to improve early flood warning via ethological input data.

1.8 Thesis Organization

The thesis is organized through chapters of 5 chapters all together. In the first chapter is of the introduction of the thesis followed by the literature review of chapter 2 where the summary of previous research done related to IoT early flood warning system with ethology inputs and *fuzzy logic*. The next chapter is the methodology of the research to brief the method used for this particular reseach. After the methodology, the results and the discussion on the experiment done for this result is explained in chapter 4 and finally the last chapter of chapter 5 is the conclusion, research achievements and future recommendations the enhance of this research in the future.

REFERENCES

Chen, M.-C. and Huang, S.-H. (2003) 'Credit scoring and rejected instances reassigning through evolutionary computation techniques', *Expert Systems with Applications*, 24(4), pp. 433–441.

Anayatullah, Khan, Z., Muhammad, Z., & Saleem, A. (2005). Web-based distributed control using GPRS enabled embedded devices. *2005 Student Conference on Engineering Sciences and Technology, SCONEST*, 1–6. http://doi.org/10.1109/SCONEST.2005.4382876

Gurban, E. H., & Andreescu, G. D. (2011). SCADA element solutions using Ethernet and mobile phone network. *SISY 2011 - 9th International Symposium on Intelligent Systems and Informatics, Proceedings*, (September 2011), 303–308. http://doi.org/10.1109/SISY.2011.6034342

Lin, K. C. (2006). A Remote Supervisory Control for Motor Driving System Using Windows Mobile-based Pocket PC.

Ung, G. W., Lee, P. H., Koh, L. M., & Choo, F. H. (2010). A flexible data acquisition system for energy information. *2010 9th International Power and Energy Conference, IPEC 2010*, 853–857. http://doi.org/10.1109/IPECON.2010.5697085

Patil, A., Hadke, P., Aher, U., Mathane, V., & Golar, P. C. (2018). Design and Implementation of Flood Early Warning System for Alerting Population.

Shah, W. M., Arif, F., Shahrin, A. A., & Hassan, A. (2018). The Implementation of an IoT-Based Flood Alert System. *International Journal Of Advanced Computer Science And Applications*, *9*(11), 620-623.

Souza, A. S., de Lima Curvello, A. M., de Souza, F. L. D. S., & da Silva, H. J. (2017). A flood warning system to critical region. *Procedia Computer Science*, *109*, 1104-1109.

Kia, M. B., Pirasteh, S., Pradhan, B., Mahmud, A. R., Sulaiman, W. N. A., & Moradi, A. (2012). An artificial neural network model for flood simulation using GIS: Johor River Basin, Malaysia. *Environmental Earth Sciences*, *67*(1), 251-264.

R.Dinkir, Patnaik, P. (2017). A Comparative Study of Arduino, Raspberry Pi and ESP8266 as IoT Development Board. *International Journal of Advanced Research in Computer Science*, *8*(5), 2350–2352. http://doi.org/10.26483/IJARCS.V8I5.3959

Gourbesville, P., Batica, J., Tigli, J. Y., Lavirotte, S., Rey, G., & Raju, D. K. (2012). Flood warning systems and ubiquitous computing. *La Houille Blanche*, (6), 11–16. http://doi.org/10.1051/lhb/2012034

Chayon, M. H. R., Rahman, T., Rabbi, M. F., & Masum, M. (2007). Automated river monitoring system for Bangladesh using wireless sensor network. *2007 10th International Conference on Computer and Information Technology, ICCIT*. http://doi.org/10.1109/ICCITECHN.2007.4579443

Achawakorn, K., Raksa, K., & Kongkalai, N. (2014). Flash flood warning system using SCADA system: Laboratory level. *2014 International Electrical Engineering Congress, IEECON 2014*, (1), 3–6. http://doi.org/10.1109/iEECON.2014.6925908

Agarwal, S., & Agarwal, S. (2018). Getting started with jQuery $. ajax () – Back to Basics, 1–13.

Sa'at, N. I. M., Daud, S. M., & Mantoro, T. (2018). Flood Monitoring System Using Mobile SCADA Based on Multiple Environment Indications. In *Improving Flood Management, Prediction and Monitoring: Case Studies in Asia* (pp. 113-120). Emerald Publishing Limited.

Report, A. D. P. (2014). Low-Cost Wireless High Water Detection System.

Matgen, P., Hostache, R., Schumann, G., Pfister, L., Hoffmann, L., & Savenije, H. H. G. (2011). Towards an automated SAR-based flood monitoring system: Lessons learned from two case studies. *Physics and Chemistry of the Earth, Parts A/B/C*, *36*(7), 241–252. http://doi.org/10.1016/j.pce.2010.12.009

Perumal, T., Sulaiman, N., & Leong, C. Y. (2015). Internet of Things (IoT) Enabled Water Monitoring System, 86–87.

Merkuryeva, G., Merkuryev, Y., Sokolov, B. V, Potryasaev, S., Zelentsov, V. A., & Lektauers, A. (2015). Advanced river flood monitoring , modelling and forecasting, *10*, 77–85.

Denuncio, P. E., Bastida, R. O., Danilewicz, D., Morón, S., Rodríguez-heredia, S., & Rodríguez, D. H. (2013). Short Note Calf Chronology of the Franciscana Dolphin, *39*(1), 21–28. http://doi.org/10.1578/AM.39.1.2013

Jinxiang, Z. (2017). Research and Design of Remote Data Acquisition System Based on CC3200, 158–161.

Larios, D. F., Rodr?guez, C., Barbancho, J., Baena, M., Sim?n, F., Mar?n, J., … Bustamante, J. (2012). Computational intelligence applied to monitor bird behaviour. *DCNET 2012, ICE-B 2012, OPTICS 2012 - Proceedings of the International Conference on Data Communication Networking, e-Business and Optical Communication Systems, ICETE*, (January 2012).

Kadam, R., Kamathe, P., & Bhuvad, P. (2016). Industrial Automation Using Mobile, *39*(39), 36–38.

Kamel Hussein, S. (2015). A Proposed Cost Effective Prototype Model for PLC Based GSM Remote Control in Home and Industrial Automation. *IOSR Journal of Electronics and Communication Engineering Ver. III*, *10*(1), 2278–2834. http://doi.org/10.9790/2834-10133748

Singh, R. K., Bhowmik, S. N., & Pandey, C. B. (2015). Biocultural diversity , climate change and livelihood security of the Adi community : Grassroots conservators of eastern Himalaya Arunachal Pradesh, *10*(January 2011), 1–22.

Malaysiana, S. (2015). Vocal Apparatus Structure of the Sarawak Frogs (Amphibia : Anura : Ranidae), *44*(9), 1289–1299.

Facchinetti, T., Benetti, G., Koledoye, M. A., & Roveda, G. (2016). Design and implementation of a web-centric remote data acquisition system. *2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA)*, 1–8. http://doi.org/10.1109/ETFA.2016.7733698

Gomez-Marin, A., Partoune, N., Stephens, G. J., & Louis, M. (2012). Automated tracking of animal posture and movement during exploration and sensory orientation behaviors. *PLoS ONE*, *7*(8), 1–10. http://doi.org/10.1371/journal.pone.0041642

Kim, T. H. (2010). Scada architecture with mobile remote components. *WSEAS Transactions on Systems and Control*, *5*(8), 611–622.

Yaseen, Z. M., El-Shafie, A., Afan, H. A., Hameed, M., Mohtar, W. H. M. W., & Hussain, A. (2016). RBFNN versus FFNN for daily river flow forecasting at Johor River, Malaysia. *Neural Computing and Applications*, *27*(6), 1533–1542. http://doi.org/10.1007/s00521-015-1952-6

Datta, S. K., & Bonnet, C. (2016). Connect and Control Things: Integrating Lightweight IoT Framework into a Mobile Application. *Proceedings - NGMAST 2015: The 9th International Conference on Next Generation Mobile Applications, Services and Technologies*, (September), 66–71. http://doi.org/10.1109/NGMAST.2015.23

De, S., Barnaghi, P., Bauer, M., & Meissner, S. (2011). Service modelling for the Internet of Things. *2011 Federated Conference on Computer Science and Information Systems (FedCSIS)*, 949–955.

Berberich, G., Berberich, M., Grumpe, A., Wöhler, C., & Schreiber, U. (2013). Early results of three-year monitoring of red wood ants' behavioral changes and their possible correlation with earthquake events. *Animals*, *3*(1), 63–84. http://doi.org/10.3390/ani3010063

Animals, H., & Sounds, M. (1950). Animal Behavior Laboratory.

Ancona, M., Corradi, N., Dellacasa, A., Delzanno, G., Dugelay, J.-L., Federici, B., … Zolezzi, G. (2014). On the Design of an Intelligent Sensor Network for Flash Flood Monitoring, Diagnosis and Management in Urban Areas Position Paper. *Procedia Computer Science*, *32*, 941–946. http://doi.org/http://dx.doi.org/10.1016/j.procs.2014.05.515

Veerakachen, W., & Raksapatcharawong, M. (2015). Rainfall estimation for real time flood monitoring using geostationary meteorological satellite data. *Advances in Space Research*, *56*(6), 1139–1145. http://doi.org/http://dx.doi.org/10.1016/j.asr.2015.06.016

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision , architectural elements , and future directions. *Future Generation Computer Systems*, *29*(7), 1645–1660. http://doi.org/10.1016/j.future.2013.01.010

Long, D., Shen, Y., Sun, A., Hong, Y., Longuevergne, L., Yang, Y., … Chen, L. (2014). Drought and flood monitoring for a large karst plateau in Southwest China using extended GRACE data. *Remote Sensing of Environment*, *155*, 145–160. http://doi.org/http://dx.doi.org/10.1016/j.rse.2014.08.006

Othman, M., Saian, R., Nazri, M. N., Safiah, N., Kamal, A., Liyana, N., … Perlis, M. (2013). Fuzzy Forecasting For Water Level of Flood Warning System in Perlis, *2013*(December), 6–7.

Garay-barayazarra, G., & Puri, R. K. (2011). Smelling the monsoon : Senses and traditional weather forecasting knowledge among the Kenyah Badeng farmers of Sarawak , Malaysia, *10*(January), 21–30.

JPS (2016). Laporan Tahunan 2016

Sukeri, M., Khalid, B., & Shafiai, S. B. (2015). Flood Disaster Management in Malaysia : An Evaluation of the Effectiveness Flood Delivery System, *5*(4). http://doi.org/10.7763/IJSSH.2015.V5.488

Temimi, M., Leconte, R., Brissette, F., & Chaouch, N. (2005). Flood monitoring over the Mackenzie River Basin using passive microwave data. *Remote Sensing of Environment*, *98*(2–3), 344–355. http://doi.org/http://dx.doi.org/10.1016/j.rse.2005.06.010

Memon, A. A., Muhammad, S., Rahman, S., & Haq, M. (2015). Flood monitoring and damage assessment using water indices: A case study of Pakistan flood-2012. *The Egyptian Journal of Remote Sensing and Space Science*, *18*(1), 99–106. http://doi.org/http://dx.doi.org/10.1016/j.ejrs.2015.03.003

Ruslan, F. A., Samad, A. M., Zain, Z. M., & Adnan, R. (2013). Flood prediction using NARX neural network and EKF prediction technique: A comparative study. *Proceedings - 2013 IEEE 3rd International Conference on System Engineering and Technology, ICSET 2013*, (August), 203–208. http://doi.org/10.1109/ICSEngT.2013.6650171

Ahmad, N., Hussain, M., Riaz, N., Subhani, F., Haider, S., Alamgir, K. S., & Shinwari, F. (2013). Flood Prediction and Disaster Risk Analysis using GIS based Wireless Sensor Networks , A Review. *Journal of Basic and Applied Scientific Research*, *3*(8), 632–643.

Schmandt, B., Aster, R. C., Scherler, D., Tsai, V. C., & Karlstrom, K. (2013). Multiple fluvial processes detected by riverside seismic and infrasound monitoring of a controlled flood in the Grand Canyon. *Geophysical Research Letters*, *40*(18), 4858–4863. http://doi.org/10.1002/grl.50953

Chaowanawatee, K., & Heednacram, A. (2012). Implementation of cuckoo search in RBF neural network for flood forecasting. *Proceedings - 2012 4th International Conference on Computational Intelligence, Communication Systems and Networks, CICSyN 2012*, 22–26. http://doi.org/10.1109/CICSyN.2012.15

Goel, A., & Mishra, R. S. (n.d.). Remote Data Acquisition Using Wireless - Scada System, (3), 58–65.

Otani, T., & Kobayashi, H. (2013). A SCADA System Using Mobile Agents for a Next-Generation Distribution System. *IEEE Transactions on Power Delivery*, *28*(1), 47–57. http://doi.org/10.1109/TPWRD.2012.2222055

Achawakorn, K., Raksa, K., & Kongkalai, N. (2014). Flash flood warning system using SCADA system: Laboratory level. *2014 International Electrical Engineering Congress, IEECON 2014*, (1), 3–6. http://doi.org/10.1109/iEECON.2014.6925908

Parker, D. J., Priest, S. J., & Tapsell, S. M. (2009). Understanding and enhancing the public ' s behavioural response to flood warning information. *Meteorological Applications*, *114*(January), 103–114. http://doi.org/10.1002/met

Ruslan, F. A., Samad, A. M., Zain, Z. M., & Adnan, R. (2014). Flood water level modeling and prediction using NARX neural network: Case study at Kelang river. *2014 IEEE 10th International Colloquium on Signal Processing and Its Applications*, (October), 204–207. http://doi.org/10.1109/CSPA.2014.6805748

Royston, S., Lawry, J., & Horsburgh, K. (2013). A linguistic decision tree approach to predicting storm surge. *Fuzzy Sets and Systems*, *215*, 90–111. http://doi.org/10.1016/j.fss.2012.10.001

Othman, M., Saian, R., Nazri, M. N., Safiah, N., Kamal, A., Liyana, N., … Perlis, M. (2013). Fuzzy Forecasting For Water Level of Flood Warning System in Perlis. *International Symposium on Mathematical Sciences and Computing Research 2013*, *2013*(December), 6–7.

Seal, V. (2012). A Simple Flood Forecasting Scheme Using Wireless Sensor Networks. *International Journal of Ad Hoc, Sensor & Ubiquitous Computing*, *3*(1), 45–60. http://doi.org/10.5121/ijasuc.2012.3105

Achawakorn, K., Raksa, K., & Kongkalai, N. (2014, March). Flash flood warning system using SCADA system: Laboratory level. In Electrical Engineering Congress (iEECON), 2014 International (pp. 1-4). IEEE.

Paridah Anun Tahir. (June, 2014). New Approaches in Flood Warning System in Malaysia.

Malaysia Water Resources Management Forum (MyWRM 2014). Available:http://www.mywp.org.my/wp-content/uploads/2013/06/Paper-5-New-Approaches-inFlood-Warning-System-in-Malaysia.pdf

Gawthrop, W. (1978). The 1927 Lompoc, California earthquake. *Bulletin of the Seismological Society of America*, *68*(6), 1705-1716.