## Talk on "Artificial Intelligence Techniques for Hydrological Modelling: Advantages, Challenges, Future Prospect"

by Ir. Chew Weng Yuen

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The talk entitled "Artificial Intelligence Techniques for Hydrological Modelling: Advantages, Challenges, Future Prospect" held on 19 November 2015 and attended by 28 participants, was jointly organized by the Engineering Education Technical Division of IEM, Engineers Australia Malaysia Chapter, and the Institution of Mechanical Engineers, Malaysia Branch. It was delivered by Dr. Amin Talei of Monash University, Malaysia.

Dr. Amin commenced by stating that hydrological processes such as rainfall-runoff (R-R) relationship are nonlinear and are affected by a variety of factors including rainfall characteristics, watershed morphology, soil moisture, etc. Currently many methods and approaches have been introduced to model the R-R relationship, namely the physically-based models, conceptual models, system theoretic models, etc. Although the physically-based models help us in understanding the physics of hydrological processes, they require more data, sophisticated mathematical tools, and significant user expertise to operate, whereas the system theoretic models apply a different approach in identifying a direct mapping between rainfall and runoff without the need for a detailed consideration of the physical processes. Dr. Amin cited several examples of system theoretic models, namely the Autoregressive Moving Average with Exogenous Inputs (ARMAX), the Artificial Neural Networks (ANN), and the Neuro-Fuzzy Systems (NFS). He informed that these models are fast and their results are often comparable with the physically-based models; notwithstanding they devoid us of any information about the physics of the problem.

Currently, intelligent computing tools based on Fuzzy Logic and Artificial Neural Networks (ANN) have been used in hydrological modeling and a new approach of combining these two powerful artificial intelligence (AI) tools, known as Neuro-Fuzzy Systems (NFS), has attracted researchers in various fields. Dr. Amin explained that NFS is a fuzzy system that uses a learning algorithm derived from neural network theory to determine its parameters (fuzzy sets and fuzzy rules) by processing data samples and has the significant advantage of reduced training time in comparison with ANNs. Dr. Amin also informed of the Takagi-Sugeno-Kang (TSK) Fuzzy models which are able to accurately model a system both globally and locally, and are widely used in nonlinear system estimation. The Adaptive Network-Based Fuzzy Inference Systems (ANFIS) is an

example of a TSK-models and has been used for R-R modeling, flood forecasting, evaporation estimation, river stage prediction, rainfall forecasting, ground level prediction, etc. Dr. Amin lamented that although many studies have been carried out using this approach in rainfall-runoff (R-R) applications, there are relatively few studies being undertaken to evaluate the fundamental behavior of such models. He then presented case studies conducted by himself that employed the NFS model for R-R modelling in an attempt to address issues related to

(i) input selection for NFS in event-based R-R modeling specifically for tropical catchments,
(ii) Training event selection for NFS in event-based R-R modeling,
(iii) Adaptability in NFS for R-R modeling, and
(iv) Interpretability in NFS for R-R modeling

Slides of hydrograph shape graphs generated from the study of training events selection were shown. He explained that events with a single peak in the hydrograph were found to be better choices compared to events with multiple peaks for training the ANFIS model, similarly the lag times closed to the median lag time of the historical events were also chosen for the training of the model. ANFIS results were found to be comparable with results obtained from the Storm Water Management Model (SWMM) and superior to that of the Autoregressive Model with exogenous Input (ARX) model.

Next, a neuro-fuzzy system which uses online learning known as Dynamic Evolving Neural Fuzzy Inference System (DENFIS) was introduced for continuous and event-based rainfall-runoff modeling in 3 different catchment sizes. DENFIS was able to capture the rainfall-runoff relationship well and its results were found comparable when compared with the results obtained from physically-based models, and superior to the one obtained by the ARX model. Although the improvement in results obtained by DENFIS over ANFIS were modest, it had a shorter training time compared to ANFIS. Dr. Amin informed that a real time version of DENFIS (RT-DENFIS) which has real time learning capabilities was developed in the study and was compared with ANFIS that employs an offline learning algorithm. The results revealed that an ANFIS model trained with historical data needed to be retrained periodically in order to maintain reasonably good predictions, whereas RT-DENFIS does not need retraining since the model is constantly being updated when new data is available.


*Dr. Amin Talei discussing the results of some findings during the presentation.*

In another study, a similarity-based neuro fuzzy system known as the Pseudo Outer Product Fuzzy Neural Network with Approximate Analogical Reasoning Schema (POPFNN-AARS) was introduced and employed for both event-based and continuous R-R modeling for 3 different catchment sizes. The results obtained from the POPFNN model were shown to be comparable with that obtained from the physically-based models, and were superior to that of ARX model. Although the improvement in results obtained by POPFNN over ANFIS was modest, POPFNN has a more flexible rule structure as compared with ANFIS.

Dr. Amin concluded by informing that NFS models have good potential to be used for different hydrological modeling. Notwithstanding, they are not supposed to be competitors for physically-based models but as supplementary models that can be used for a reliable estimation of the process when limited information is available about the physics of the hydrological problem.

Lastly, Dr. Amin took several questions from the participants before the talk ended.