

Interactive comment on “An artificial neural network model for rainfall forecasting in Bangkok, Thailand” by N. Q. Hung et al.

N. Q. Hung et al.

Received and published: 20 May 2008

The authors greatly appreciate the positive and insightful comments on the paper as well as the recognition of interest on the topic from Dr. Elena Toth. The reviewer clearly conducted a throughout revision, which resulted in very valuable suggestions that will provide us valuable guidance, allowing us to improve the presentation of our paper. We have responded to comments made and have completed the appropriated modification. Please see the response below:

General comment

The paper describes an application of artificial neural networks (ANN) for the real-time forecasting of rainfall values up to 6 hours ahead. Reliable short-term rainfall forecasts are crucial for the implementation of real-time flood forecasting systems: therefore

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



the topic is certainly suitable for the journal and of broad international interest, not only for researchers but, more importantly, for operational hydrologist and decision makers. In addition, the case study, referring to a real-world application on the Bangkok metropolitan area, is of extreme interest. The methods are correct and sound and the good results obtained by the authors (with model F) confirm that the implemented ANN are an adequate tool for short-term forecasts. The English should be carefully revised in sections 4 and 5.

I agree with the comment made by Referee #2 that the main weak point of the paper is how it deals with continuous against rainy data: there is a strong need to add a detailed description of the model implementation with and without rainy days. This point is in fact indicated as crucial (and innovative) at the beginning of the paper, but it is not adequately developed in the description of the methods.

Response: Sections 4 and 5 were carefully revised and edited. A detailed description of the model implementation, including both rainy and non-rainy days has been updated in the manuscript. Please refer to the answer provided in the section "General comment from Anonymous Referee #2"; and within the final manuscript.

Comment: Secondly, there is confusion in the description of training and testing data: it is not clear if the year 1998 is part of the first or of the second set and it seems that the validation data are different in the exploratory test (over station E18, section 5.1 and 5.2) and in the test over the whole raingage network (section 5.3).

Response: Yes, there was a mistake on documenting the work. In the exploratory test, split-sample test was applied, no validation set was used. Data of the year 1997 and 1999 was selected as training data, and the year 1998 was set as testing data. In the forecasting stage, the optimum model (model F) was applied and trained to forecast rainfall with cross validation. Through application of the cross validation method, 80% of three years data (1997, 1998 and 1999) was set as training set and 20% is validation set. Testing data set in this stage varied with stations, from the year 2003 to 2005 data.

[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

Detailed explanation of the data was updated to manuscript.

Comment: In addition, the number of nodes in the hidden layers is very large, especially in the more complex models, and this aspect deserves some comments from the Authors.

Response: Yes, the number of nodes is quite large for model F. In fact, in the designing stage we already trained several other models with the same set up as model F but with different number of hidden nodes; and model F has given the best results so far. It means that the choice of the numbers of hidden nodes is actually based on the practical test. More explanations on numbers of hidden nodes were updated to the manuscript.

Comment: Lastly, I would suggest to add a comparison of the results of the models against the use of a simple persistent model, in order to understand the real advantage provided by the models.

Response: Previously studies comparing ANN with other models i.e. Auto-Regressive Moving-Average model, K-nearest neighbors method, Multivariate Adaptive Regression Splines, pointed out the advantage of ANN. This work is one part of the study at Asian Institute of Technology, Thailand, but also related to one project about rainfall forecasting and real time hydrologic information system for cities, case study Bangkok city, Thailand. The project has three main components: 1) rainfall forecast by using ANN model with rain gauge data, 2) rainfall forecast by translation method using weather radar data, and 3) urban drainage model to simulate the flooding situation. Because of the set up of the framework and the limitation of time and human resources, the comparison of ANN with other simple persistent model is not available at this moment. We expect the comparison of ANN with translation method in coming paper, which could satisfy the above comment.

Specific comments

Comment: p.185 (l. 27)-186 (l. 16): I suggest to divide the literature referring to clima-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



tologic forecasting (monthly and seasonal periods, which may be not strictly needed here, by the way) from that referring to short-term rainfall forecasting.

Response: Manuscript has been rearranged as suggested. Climatologic forecasting was moved to the end of the literature section. We added these works in the literature part because in these works, they investigated the correlation between rainfall and other parameters, given the idea of using not only rainfall data in training ANN model for rainfall forecast.

Comment: p. 189 (l. 22): the FFC does not make any use of the SCOUT radar data, but uses only raingauge data for issuing flood forecasts?

Response: In practice, BMA used both forecasting results, whereas SCOUT was mainly used to forecast from 1 to 6 hours, while ANN model was used to extend the forecast from 7 to 12 hours.

Comment: p. 190, l. 4: for which period the data were collected?

Response: Hourly rainfall and meteorology data were collected from 1991 to 2005. After analyzed data, period from 1 Jan 1997 to 31 Dec 1999 were selected to train ANN models in the designing stage, and other data in the period from the year of 2003 to 2005 were used in the forecasting stage.

Comment: p. 190, l.7-9: the meteorological data were collected in the same (and all) stations of the raingauge network?

Response: Bangkok area has 18 air quality-monitoring stations and only 1 100-meter tall meteorological mast station; this system is differed with rain gauge system. Meteorological data were collected this meteorology station and used for all rain gauge stations.

Comment: Section 3, p. 190-193: there is confusion in the description of the MultiLayerPerceptron (MLP) and the BackPropagation (BP) algorithm, which are not the same thing. In addition, it is not clear which training algorithm was actually used in the appli-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



cations. The description of the BP (from p191, l. 8 to p. 192, l. 13) should be moved to the end of the section, specifying that it is the one that was used in the study (if it is so)

Response: In section 3, a short description on the two network types and training algorithm that we used in the study were presented. This included the Multiplayer Perceptron and Generalized Feedforward network, and the training algorithm BackPropagation. The manuscript has been modified as commented in the following manner: firstly, two networks are introduced and then the description of training algorithm.

Comment: p. 194, ll. 11-13: year 1998 is used in training or in validation?

Response: In the designing stage, to train six ANN models with 1-hour forecast at station E18, the data of the year 1998 was used as testing set; training data is 1997 and 1999.

Comment: p. 195, ll. 5-8: it is not clear how the Authors dealt with the problem of no-rain periods in models A, B and C

Response: Model A viewed as a starting point in the try-and-error process to find the optimum ANN set up. Therefore model A began with simple set up, four lag time rainfall and present rainfall input, to train model. To deal with no-rain periods, the number of the hidden nodes in model B was increased from 5 to 10 in each hidden layer. Since the results of forecast in model B is still poor, we tried model C with another transfer function. Changing transfer function from sigmoid function to hyperbolic tangent is how model C deal with no-rain period problem.

Comment: p. 194-195: the number of hidden nodes seems too large, thus needing an extremely high number of parameters: in model F there are 42 nodes, resulting in 33 biases values and 440 weights values, if considering only feed-forward connections (and here a generalised model is used, with more connections), to be parameterised. I believe that an Authors comment on this point is needed.

Response: There are no fix rules as to how many nodes should be included in hidden

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



layers. If there are too few nodes in the hidden layer, the network may have difficulty in the generalization. As commented by referee, the more hidden nodes mean more parameters to be estimation, and it lead to the problem of local minima. In the other hand, increasing hidden nodes allows model to consider the presence of non-stationarities of the data. Such as trends and seasonal variation often appear a lot with rainfall. Additionally, increasing the hidden nodes will help to fit of a larger fluctuation of target function. Please refer to the answer in the general comment above: as summarized, the choice of the number of hidden nodes was based on the test of several models, which were not listed in the paper. Details of discussion on the number of hidden nodes were updated in the manuscript.

Comment: Section 5: this section is too detailed (and long) in the description of the numbers, that is of the indexes of performance that are all already reported in the tables, whereas it lacks an interpretation of the results.

Response: Section 5 has been carefully revised and updated in the manuscript

Comment: p. 198: ll. 19-27: this paragraph is far from clear and lacking: an interpretation of the results obtained for the testing data (which are often not consistent with those of the training data) is needed. In addition there are no comments on the results obtained when excluding the rainfall data from station E18 itself (and such results are not presented in Table 3 neither). Furthermore, the analysis of the role of surrounding stations is made excluding all of them and not one by one, which may have given some insights on their relative importance. Lastly, the results obtained excluding the surrounding stations are strongly dependent on the chosen station, therefore, this sensitivity analysis can not be extended to the entire raingauge network. A new sensitivity analysis using the results obtained with model F over the entire network would be more significant.

Response: Interpretation of the results obtained for testing data was updated. In this paper, sensitive analyze was simply done in order to give some ideas/view on the

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



different important role of the parameters to the model performance. The rainfall on the particular station was considered as the main parameter, therefore this parameter was not included in the sensitive analyze. The top three strongly connected stations (surrounding station) to the particular station were selected based on the results of the correlation analysis. Therefore the three surrounding station were considered to have the same relative important level, and for this reason, in the sensitive analyze, all three station were excluded. We agree that results of the analysis for all 75 stations should be included to improve the research; this could be done in a later research. Sensitive analyze section was also revised and updated in the manuscript.

Comment: p. 199, ll. 4-7: please explain better the cross-validation experiment (how are the 3 years data used?)and why it is different from the validation performed (in the above sections) on the data of station E18 alone.

Response: Firstly, we would like to clarify the terms used: 1) Training data is the set of data used for ANN model to learn; 2) Testing data is the set of data used to test the model after trained; and 3) In the training process, other data set may be used to validate the training process and referred to as the validation data set. The data collected is from the year of 1991 to 2005 for both rainfall and meteorology data; in some stations, data was not available for various periods. After analyzing data, we discovered that data of three years 1997, 1998 and 1999 were complete and available in entirety for all stations. Cross validation is a highly recommended criterion for stopping the training of a network but it is not required. In the try-and-error process to find a suitable ANN model, networks are often tried using just training data in order to see which works best, and then use cross validation for the final training. For these reasons, in the exploratory test, six different ANN models were tested with 1 hour forecast at E18 station, while the training data of the year 1997 and 1999, the year 1998 was used as testing data and no validation data was set.

For the final test, when applied model F for all 75 stations, three years 1997, 1998 and 1999 were used as training data. In model F, numbers of hidden nodes were very

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



large and illustrates that there will be improved learning of training sets as the number of iterations is increased. However, neural network researchers have found that the decrease in the training set errors were not always coupled to better performance in the test set. When the network is trained too much, the network "memorizes" the training patterns and does not generalize well. A practical way to find a point of better generalization is to set aside a small percentage of the training set, which can be used for cross validation. Monitoring the errors in the training set and the validation set should be carried during the training process. When the error in the validation set increases, the training should stop because the point of best generalization is reached. For this reason, cross validation was applied to the final training and 20% of the training data (1997, 1998, 1999) was set aside to use for cross validation. The testing data varied amongst stations and 2003, 2004 and 2005 data was used actually.

Comment: p. 199, l1-p. 200, l.4: this paragraph is not clear: the RMSE is already a mean value, why citing the number of rainfall observations (patterns)? In addition, please rephrase ll 3-4.

Response: If reviewing the data, the total pattern presented for rainfall in both observed and forecasted data is quite small comparing with the total number pattern. RMSE value was calculated for the entire data set. Therefore, this paragraph (p. 199, l1-p. 200, l.4) explained the reasons why the RMSE is very small but did not fully indicate the accurate of quantitative forecast. To make this paragraph clear and to answer the comment from Referee #2, RMSE values for rainy periods only were added in.

Technical suggestions

Comment: p. 189 (l. 19): it may be useful to specify the density of the raingage network (number of operative stations at hourly resolution for km2) p. 193: l- 16-18: this phrase is not clear to me. p. 194, l. 23-25: specify the number of hidden nodes in model C (10+10) p. 195: title of section 5.1: specify that it refers to 1-hour ahead forecasts for one station only p. 199: title of section 5.3: specify that it refers to 1 to 6-hours ahead

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



forecasts for the entire network

Response: The rain gauge network density was calculated while other corrections were updated in the manuscript.

Comment: Table 1: add in the Input description of Model F that the data from surrounding stations consists of present rainfall data. Tables 2 and 3: add in the caption to which forecast experiment (station E18) they refer. Figures 4, 6 and 8: a period of 24 hours (and with so few rainy hours!) is too short: you may substitute these hyetographs with those referring to a longer period (with 48 hours the graph should still be readable).

Response: Updated in the manuscript

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 183, 2008.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

