Engineering Technology
Open Access Journal

Juniper PUBLISHERS key to the Researchers

Research Article
Volume 5 Issue 1 - May 2023
DOI: 10.19080/ETOAJ.2023.05.555655

Eng Technol Open Acc

Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms

Ying Bai*, Ph.D. Professor

Department of Mathematics and Computer Science Engineering, Johnson C. Smith University, Charlotte NC 28216, USA

Submission: April 9,2023; **Published:** May 18, 2023

***Corresponding author:** Ying Bai, Ph.D. Professor, Department of Mathematics and Computer Science Engineering, Johnson C. Smith University, Charlotte NC 28216, USA

Abstract

It is very critical and vital to predict and evaluate the possibility of occurring of floods correctly and accurately nationwide, and this prediction can be used to effectively avoid possible damages and disasters due to this kind of disaster. The disasters and damages incurred by flooding are tremendous and terrible, and sometimes they are invaluable and thus cannot be estimated in values, just as those huge floods recently occurred in south California in USA. By developing this research project, two artificial intelligence predicting system models are built by using an Adaptive Neural Fuzzy Inference System (ANFIS) and a Neural Network with Deep Learning (NNDL) technology to estimate and predict the general flooding height based on various weather parameters in real time.

Keywords: Flooding Height Predictions; Adaptive Neuro Fuzzy Inference System; Artificial Neural Network; Flooding Disasters

Introduction

Today across the entire world, the frequency and size of flooding events are rapidly increasing, and these destructive disasters result in billions of dollars lost per year. It is a crystal important to correctly estimate and predict the possibility of occurring of flooding, and furthermore to effectively reduce the damages caused by those damages. Based on that fact, quite a few of researches have been reported in recent years. Rathnayake et al. built an algorithm to estimate the projected water levels and future floods [1]. Abinash Sahoo et al. developed an ANFIS-GOA technique used to predict the occurring of floods [2]. Mandeep Kaur and Sahoo et al. reported to use ANFIS methods to detect and estimate the flood levels with some framework and systems [3,4]. An ANFIS algorithm used to forecast the flood in river systems was reported by Ullah et al. [5]. Remesan and Wang et al. developed some ANFIS and NNARX based models to detect and identify the rainfall and downstream water levels [6,7].

Ghose et al. introduces a hybrid model integrating an adaptive neuro-fuzzy inference system with harris hawk's optimization (ANFIS-HHO) for forecasting river flood events in Barak river basin, India [8]. Their model's performance is compared with simple ANFIS based on Nash-Sutcliffe efficiency (NSE), and root mean square error (RMSE). Results obtained indicate that the hybrid ANFIS-HHO model gave best performance with NSE of 0.9885, and RMSE of 61.87. Rezaeianzadeh et al. presented research to use artificial neural networks (ANN), adaptive neuro-fuzzy inference systems (ANFIS), multiple linear regression (MLR) and multiple nonlinear regression (MNLR) to forecast the maximum daily flow at the outlet of the Khosrow Shirin watershed, located in the Fars Province of Iran, with the precipitation data as inputs [9]. Dushyant Patel , Dr. Falguni Parekh reported to explore the applicability of ANFIS in forecasting the flood for a case study of Dharoi Dam on the Sabarmati river near village Dharoi in Kheralu Taluka of Mehsana District in Gujarat State, India [10]. Samantaray et al. investigated the usability of support vector machine (SVM), back propagation neural network (BPNN), and integration of SVM with particle swarm optimization (PSO-SVM) models for flood forecasting [11]. Anuar, Nurul Najwa et al. utilized an ANN model to forecast the water discharge of hydroelectric station. The discharge flow predictions were made based on fore bay elevation, inflow and the discharge of water flow. Elman Neural Network architecture was selected as ANN method and its performance was evaluated by considering the number of hidden nodes and training methods [12]. Nazim Osman Bushara and Ajith Abraham proposed an Adaptive Neuro-Fuzzy Inference System (ANFIS) to develop long-term weather forecasting model for rainfall prediction [13]. Monthly meteorological data that obtained from Central Bureau of Statistics Sudan from 2000 to 2012, for 24 meteorological stations distributed among the country has been used. Agnihotri et al. proposed an adaptive neuro-fuzzy inference system (ANFIS) combined with ant colony optimization (ACO) algorithm which optimize model parameters for predicting flood at Matijuri gauge station of Barak River basin, Assam, India [14]. Tawatchai et al. employed an ANFIS algorithm to forecast daily flood flow of the Yom River Basin in Thailand with many inputs [15].

Related to above research reviews, a key issue is that most current state-of-the-art flood predications utilizes limited inputs and the models rely on mathematical growth predictions and physics-based models, which are difficult and computationally expensive to run. In this study, we develop and build a system with ANFIS and ANN to correctly estimate the flood height levels in real time based on given input parameters related to a practical Metro Manila Flood Landscape DataSet [16]. This dataset was acquired by applying spatial kriging (using ARCGIS, and some python scripts) on flood reports, including latitude, longitude, elevation and average precipitation all around Metro Manila in Philippine based on data acquired from public government data. This paper is organized and divided into six sections; Definitions and structures of the Metro Manila Flood Landscape DataSet are given in section 2. An introduction to ANFIS and ANN algorithms with our study results are provided in sections 3 and 4. Section 5 provides the conclusions, and the acknowledgement and disclaimer is given in section 6.

Metro Manila Flood Landscape DataSet

The Metro Manila Flood Landscape Data is a compiled dataset of flood reports that include specific coordinates, average precipitation, land elevation and reported flood height in Metro Manila, Philippines. The data is acquired by applying spatial kriging (using ARCGIS, and some python scripts) on flood reports, elevation and average precipitation all around Metro Manila based on data acquired from public government data. The initial intention for this dataset is to create a heat map to find a correlation between all the parameters in this dataset.

The dataset is composed of five columns, as shown in (Figure1), they are:

i. Latitude
ii. Longitude
iii. Elevation
iv. Precipitation
v. Flood Height

The range for each parameter is also given in (Figure 1).

The meaning and presentation of the parameter on each column are defined as below:

Latitude-lat

Longitude-lon

Elevation-elev(meters)

sPrecipitation - prec (millimetres/hour)

Flood Height - flood_H

0 - No flood

1 - Ankle High

2 - Knee High

3 - Waist High

4 - Neck High

5 - Top of Head High

6 - 1-storey High

7 - 1.5-storey High

8 - 2-storeys or Higher

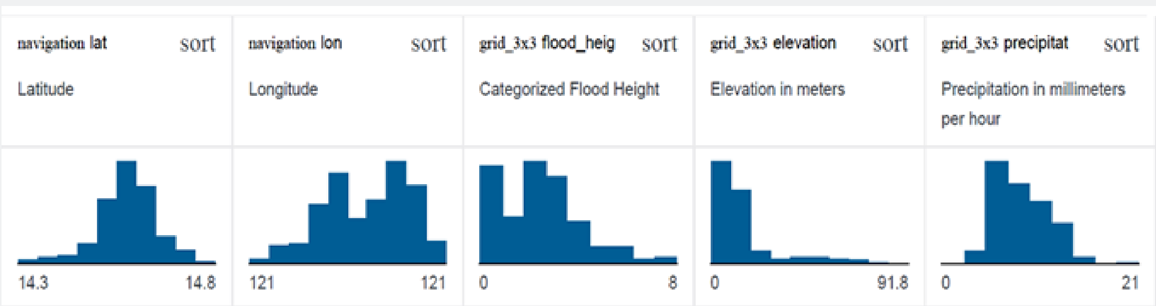


Figure 1: The structure of the Metro Manila Flood Landscape DataSet.

Among those parameters, those parameters in column 3 belong to the outputs and all other columns work as inputs to our ANFIS and ANN flood predication system.

Due to its sequence structure, this Metro Manila Flood Landscape DataSet cannot be directly used by our study with our ANFIS and ANN algorithms. Some modifications must be made to

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655

make it meet the requirements for general ANFIS and ANN training and checking purposes. A modification algorithm is developed with MATLAB to convert the original dataset to an appropriate one to be used by ANFIS and ANN training and checking purpose. The resulted dataset is composed of a matrix with a size of 3000 x 5, or 3000 input data rows with each data containing 5 columns.

Where the data in columns 1, 2, 4 and 5 work as inputs and the data in column 3 as outputs. In summary, the Flood Height value is a key parameter, and it could be used to indicate how dangerous and in what degree a flood would be occurred. Some research and study results had been reported to use that value to analyze the flooding conditions and build related models [16]. However, few studies were concentrated on deriving the flood height values with ANFIS or ANN algorithms.

The Adaptive Neuro Fuzzy Inference System (ANFIS)

Some research reports related to using ANFIS to predict flooding had been released recently.

The so-called ANFIS is exactly a combination of two soft-computing techniques: Artificial Neural Network (ANN) and Fuzzy Inference System (FIS), which was first introduced by Jyh-Shing Roger Jang in 1992 [17]. The FIS used a Sugeno fuzzy inference system, and its structure is similar to a multilayer feed forward neural network structure, but the difference is that the (Figure 2) links between nodes in ANFIS define the signals' flow direction and there are no associated weight factors with the links. (Figure 2) shows a Sugeno fuzzy model with nine rules along with a corresponding ANFIS architecture. In our case, nine rules in the method of "If-Then" for the Sugeno model are considered with *x*, *y* and *z* as inputs and *f* as output [18]. Sixteen rules are defined as below $(lat = x, lon = y, elev = z, prec = w)$:

R_1: If *x* is H and *y* is L and *z* is L and *w* is L, then $f_{11} = p_{11}x + q_{11}y + r_{11}z + s_{11}w + c_{11}$

R_2: If *x* is M and *y* is L and *z* is L and *w* is L, then $f_{12} = p_{12}x + q_{12}y + r_{12}z + s_{12}w + c_{12}$

R_3: If *x* is L and *y* is L and z is L and *w* is L, then $f_{13} = p_{13}x + q_{13}y + r_{13}z + s_{13}w + c_{13}$

R_4: If *x* is H and *y* is H and z is L and *w* is L, then $f_{14} = p_{14}x + q_{14}y + r_{14}z + s_{14}w + c_{14}$

R_5: If *x* is M and *y* is M and z is L and *w* is L, then $f_{21} = p_{21}x + q_{21}y + r_{21}z + s_{21}w + c_{21}$

……

R_{16}: If *x* is L and *y* is H and z is H and w is L, then $f_{44} = p_{44}x + q_{44}y + r_{44}z + s_{44}w + c_{44}$

(Figures 3 & 4)

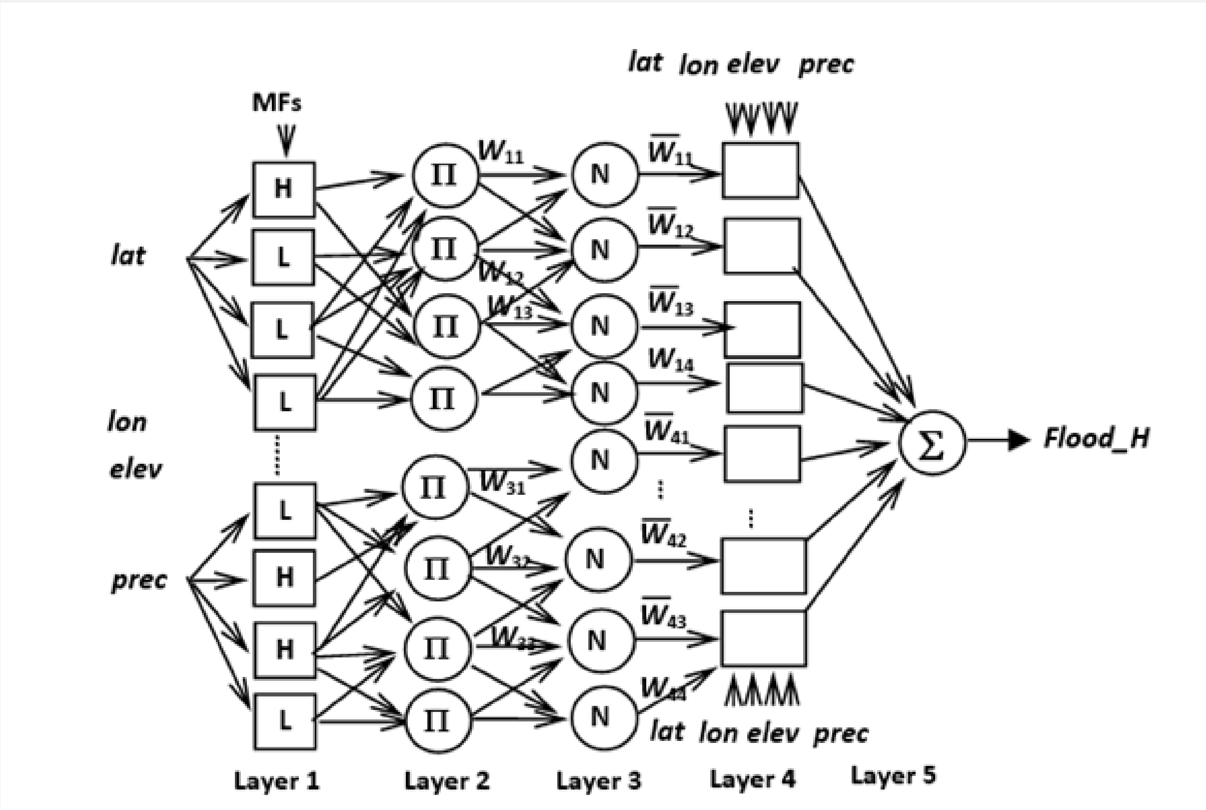


Figure 2: Architecture of the ANFIS for our study.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655

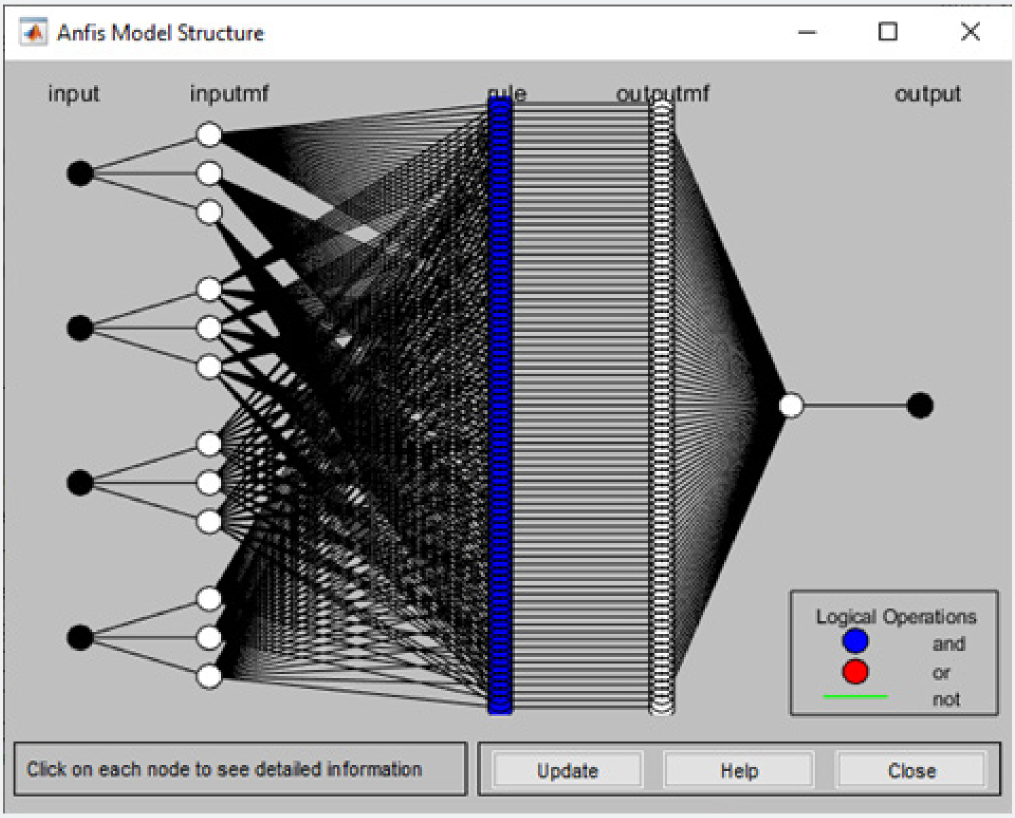


Figure 3: The structure of the ANFIS.

Regularly, four inputs should be adopted to derive the output flood height values. A modified dataset based on Metro Manila Flood Landscape Data is adopted for this study. Four columns training data, lat, lon, elev and prec, as inputs with one column flood_H as the output are used to train this ANFIS model. The MATLAB ANFIS Tool is utilized to train and validate this model. The structure of this ANFIS is shown in (Figure 3), and the training and testing result are shown in (Figures 4a & 4b).

The envelope described some inputs and the output and a rule-view of this generated ANFIS, which displayed an input-output relationship with columns, are shown in (Figures 5a & 5b). It can be found that the flood_H values can be obtained in real time by changing the input values, or just by moving the vertical bar along each input.

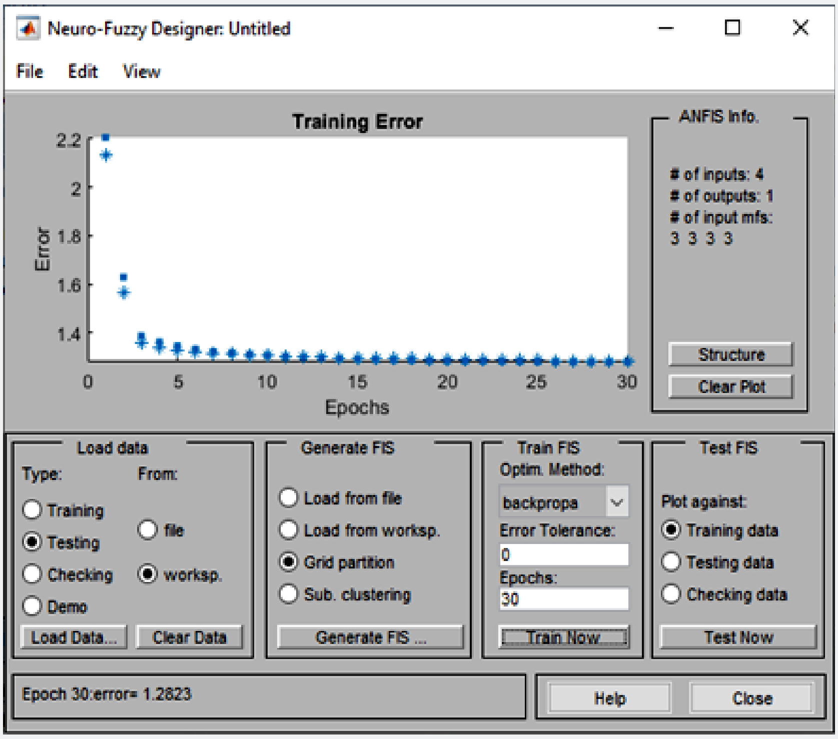
The Artificial Neural Networks (ANN)

Regularly a complete artificial neural network (ANN) has multiple nodes with multiple layers, including input layer, output layer and hidden layers [19]. (Figure 6) shows a model of (Figures 5 & 6) multiple layers feed forward ANN. The dash lines means that multilayer is included in this ANN and these layers cannot be observable. Exactly in (Figure 6), on each feed forward arrow branch from one node to another, a weight factor w_{ij} should be multiplied to obtain a complete transfer signal.

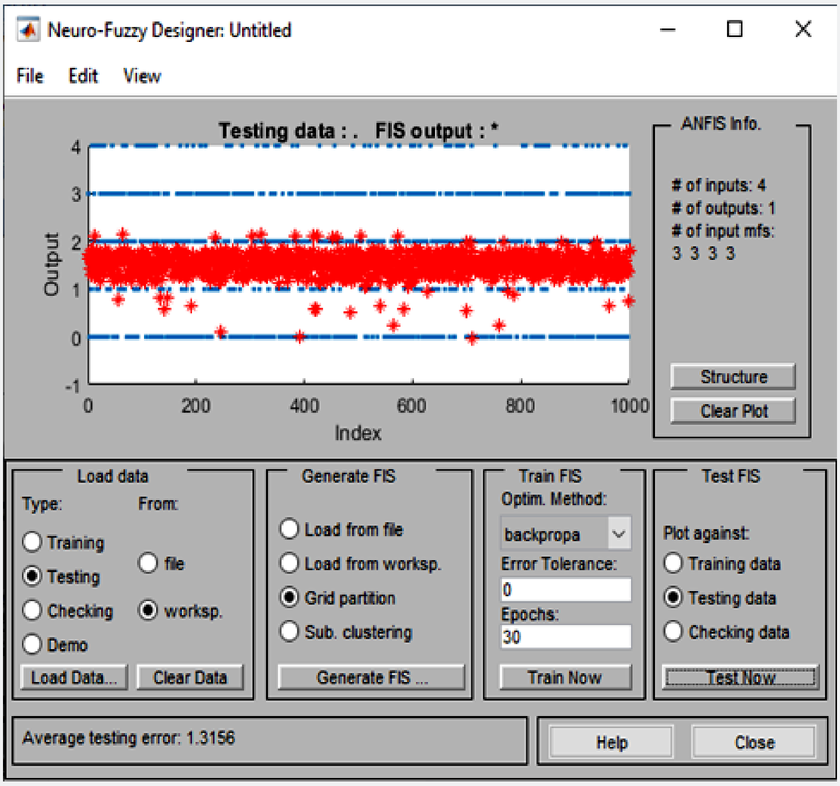
Overall, a feed forward ANN can be considered as a complex brain/machine system that is composed of multilayer with multi-neuron operating in parallel. In fact, the connections between nodes largely determine the network function. One can train an ANN to perform a specified function by adjusting the values of the connections (weight factors) between nodes via inputs *and* desired or target outputs. Generally, a neural network can be adjusted or trained, so that a particular input leads to a corresponding target output. Generally, a neural network can be adjusted or trained, so that a particular input leads to a corresponding target output. The network is adjusted, based on a comparison between the output and the target, until the network output matches the target. Typically, many such input-target pairs are needed to train a network.

As we did for the ANFIS, A modified dataset based on Metro Manila Flood Landscape Data is utilized to train, check and test this ANN. Four factors, *lat*, *lon*, *elev* and *prec*, work as inputs and the *flood_H* as a single output. Totally 3000 set of data are used with 70% as training data, 15% as checking data and 15% as testing data. The Levenberg-Marquard training algorithm and MATLAB Deeping Learning Toolbox are used to perform these tasks to generate our desired ANN model with 8 neurons or nodes. The ANN training results are shown in (Figures 7a & 7b) (Figures 7 & 8).

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655.
DOI: 10.19080/ETOAJ.2023.05.555655



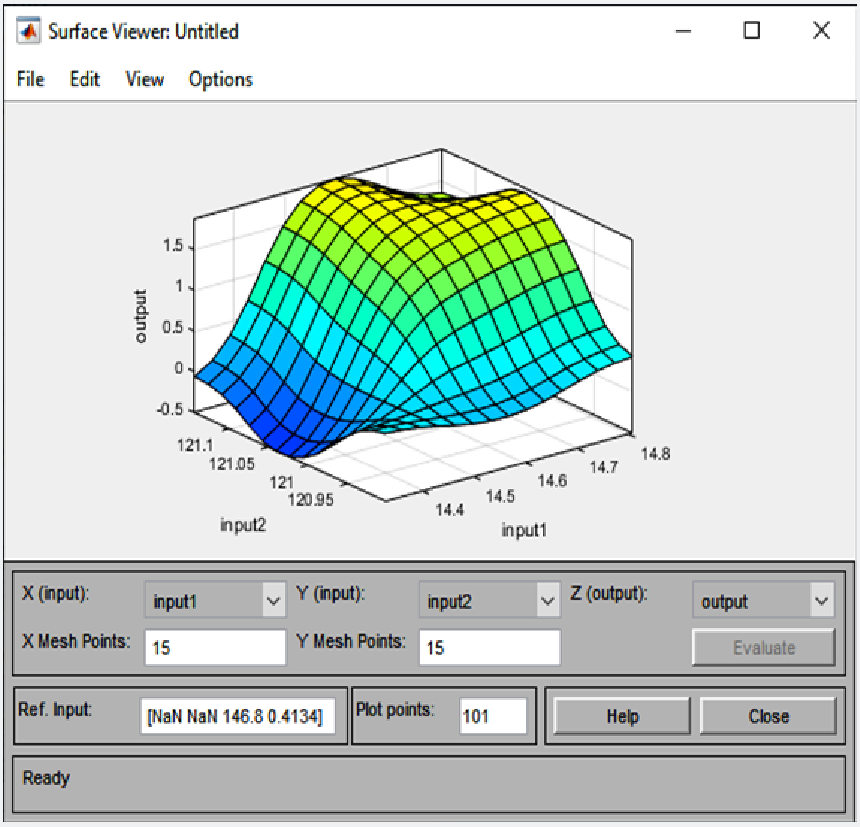
(a)



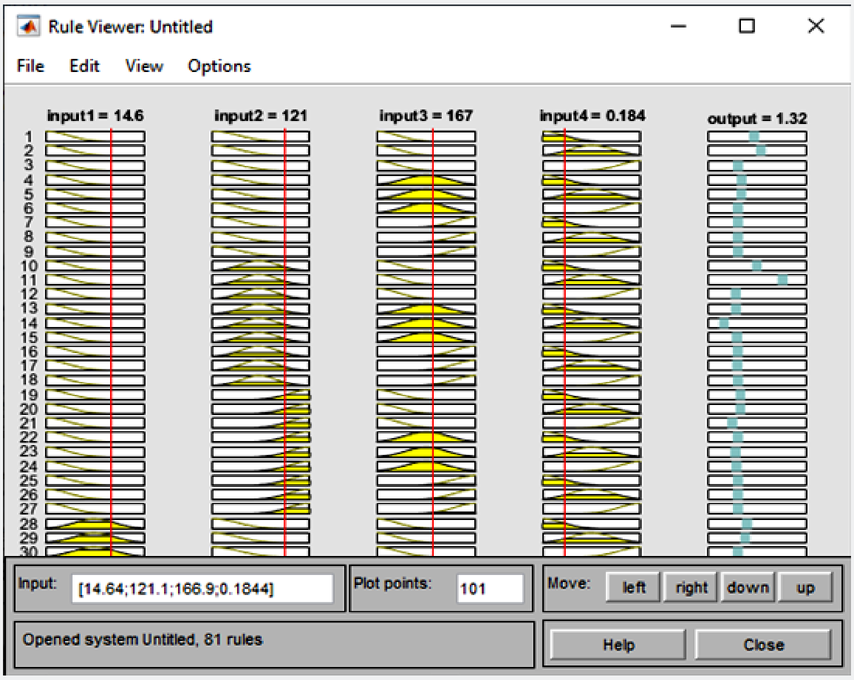
(b)

Figure 4: The training errors and testing result.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655.
DOI: 10.19080/ETOAJ.2023.05.555655



(a)



(b)

Figure 5: The input-output envelope and rule-view of the generated ANFIS.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655

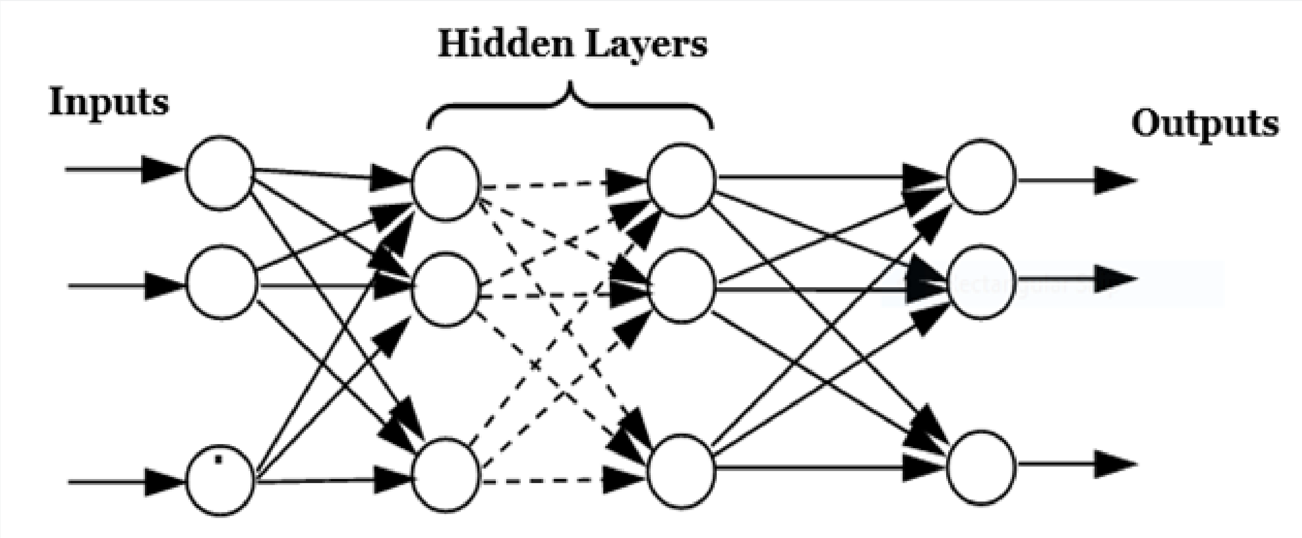


Figure 6: A model of multilayer feedforward ANN.

A comparison study is performed for the validation errors between the ANFIS and ANN model, and this comparison result is shown in (Figure 8). Both validation errors are RMS values by comparing the actual output and the checking data inputs for ANFIS and ANN systems used in this study. This comparison is based on a fact, which assumed that the flood height results are correct. It can be found that relatively speaking, the ANFIS method can get better estimated flood height result compared with the ANN algorithm for our study, exactly the ANFIS algorithm is about 41% better than that of ANN algorithm by checking the validation RMS error values shown in (Figure 8) for our study.

Conclusion and Discussion

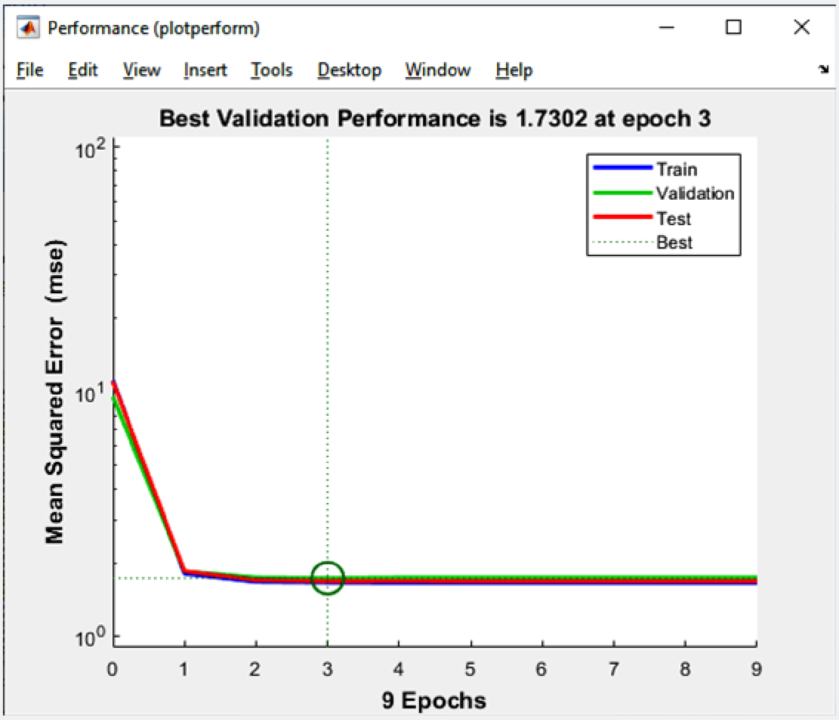
In this study, an adaptive neuro fuzzy inference system (ANFIS) and an artificial neural network (ANN) algorithm are developed and used to correctly predict and estimate the possible flooding height via a modified dataset based on Metro Manila Flood Landscape DataSet. These methods can be adopted by some decision makers to effectively estimate the dangerous degree of possible flooding events, and furthermore to issue some commands and processing steps to protect national and personal properties from being damaged and to reduce the degree of those damages. Based on these two approaches, a comparison study is performed to compare the estimation accuracy by using two methods. The ANFIS algorithm is over performed compared with the ANN algorithm based on our study.

One possible reason for those predicted errors may be due to the limited data on a selected small territory with local latitudes and longitudes. Some better and more accurate results could be obtained if more data or a larger set of data were collected in larger territories with different latitudes and longitudes.

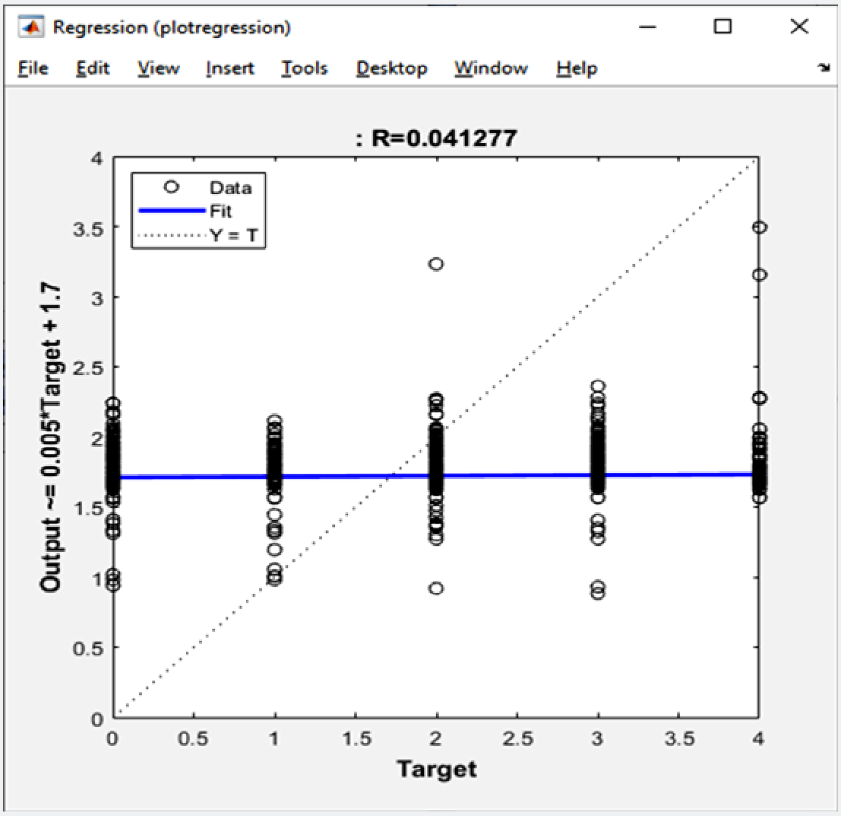
Acknowledgement and Disclaimer

This research is based upon work supported by the U.S. Department of Homeland Security under Grant Award #2015-ST-061-ND0001-01. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655



(a)



(b)

Figure 7: The training results.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655

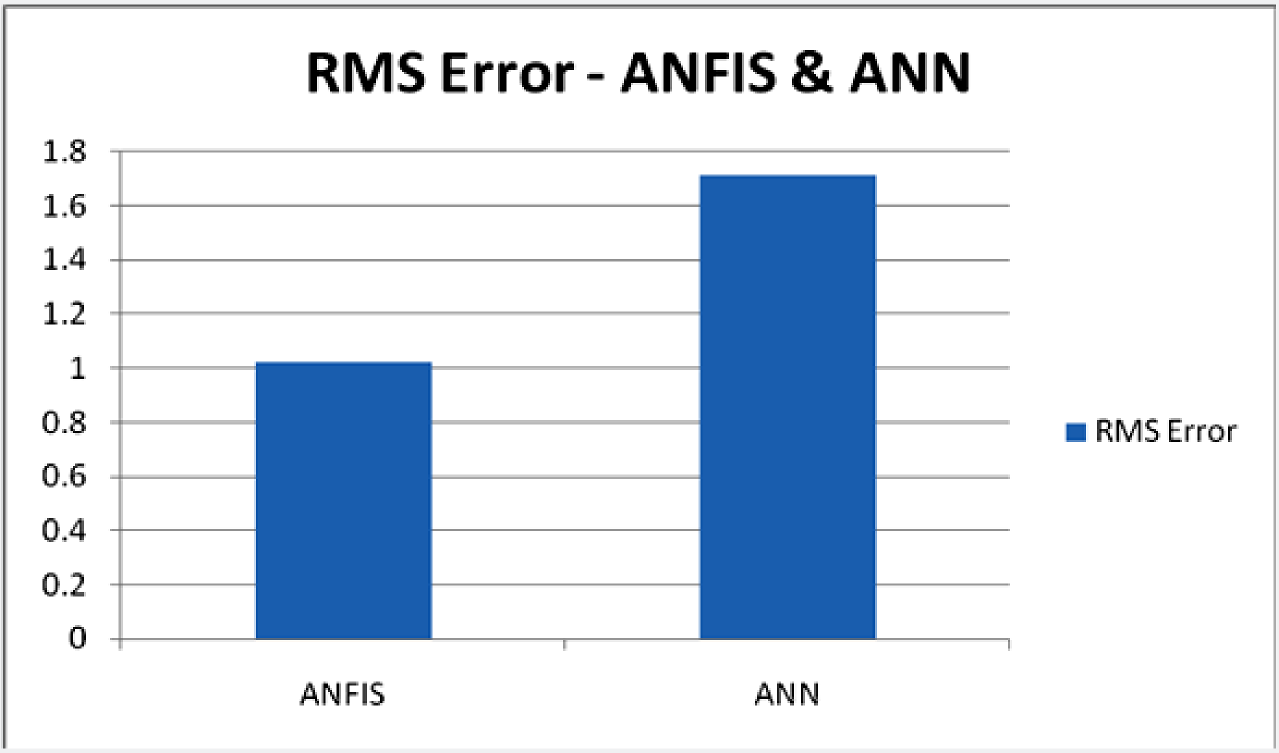


Figure 8: A comparison for RMS errors between ANFIS and ANN algorithm.

References

1. Rathnayake N, Rathnayake U, Chathuranika I, Dang TL, Hoshino Y (2023) Projected Water Levels and Identified Future Floods: A Comparative Analysis for Mahaweli River, Sri Lanka. IEEE Access 11: 8920-8937.
2. Abinash Sahoo, Sandeep Samantaray, Siddhartha Paul (2021) Efficacy of ANFIS-GOA technique in flood prediction: a case study of Mahanadi river basin in India. H_2 Open Journal 4(1):137-156.
3. Mandeep Kaur, Pankaj Deep Kaur, Sandeep K Sood (2022) ANFIS-based flood detection and vulnerability assessment framework. Hydrological Sciences Journal 67(15): 1-17.
4. Sahoo Abinash, Samantaray Sandeep, Bankuru Srinivas, Ghose Dillip K (2020) Prediction of Flood Using Adaptive Neuro-Fuzzy Inference Systems: A Case Study. Smart Intelligent Computing and Applications 159: 733–739.
5. Ullah Nazrin, Choudhury P (2010) Flood Forecasting in River System Using ANFIS. International Conference on Modeling, Optimization, and Computing ,AIP Conference Proceedings 1298: 694-699.
6. Remesan R, Shamim MA, Han D, Mathew J (2008) ANFIS and NNARX based rainfall-runoff modeling. 2008 IEEE International Conference on Systems, Man and Cybernetics pp. 1454-1459.
7. Wang AP, Liao HY, Chang TH (2008) Adaptive Neuro-fuzzy Inference System on Downstream Water Level Forecasting. 2008 Fifth International Conference on Fuzzy Systems and Knowledge Discovery, Jinan, China pp. 503-507.
8. Ghose DK, Tanaya K, Sahoo A, Kumar U (2022) Performance Evaluation of hybrid ANFIS model for Flood Prediction. 2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India pp. 772-777.
9. Rezaeianzadeh Mehdi, Tabari Hossein, Yazdi A, Isik Sabahattin, Kalin Latif (2013) Flood flow forecasting using ANN, ANFIS and regression models. Neural Computing and Applications 25: 25–37.
10. Dushyant Patel , Falguni Parekh (2014) Flood Forecasting using Adaptive Neuro-Fuzzy Inference System (ANFIS). International Journal of Engineering Trends and Technology 12(10): 510-514.
11. Samantaray S, Sahoo A, Agnihotri A (2023) Prediction of Flood Discharge Using Hybrid PSO-SVM Algorithm in Barak River Basin. Methods X 10: 102060.
12. Nurul Najwa Anuar, Reyasudin Basir Khan M, Jagadeesh Pasupuleti, Aizat Faiz Ramli (2019) Flood Risk Prediction for a Hydropower System using Artificial Neural Network. Environmental Science 8(4).
13. Nazim Osman Bushara, Ajith Abraham (2015) Using Adaptive Neuro-Fuzzy Inference System (ANFIS) to Improve the Long-term Rainfall Forecasting. Journal of Network and Innovative Computing 3: 146-158.
14. Agnihotri A, Sahoo A, Diwakar MK (2022) Flood Prediction Using Hybrid ANFIS-ACO Model: A Case Study, In: Smys S, Balas VE, Palanisamy R(eds.), Inventive Computation and Information Technologies. Lecture Notes in Networks and Systems, Springer, Singapore 336: 169-180.
15. Tawatchai Tingsanchali, Chau Nguyen and Xuan Quang (2004) Application of Neuro - Fuzzy Technique in Flood Forecasting. Journal of World Scientific 1539-1546.
16. https://www.kaggle.com/datasets/giologicx/aegisdataset.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655.
DOI: 10.19080/ETOAJ.2023.05.555655

17. Jang JR (1992) Self-learning fuzzy controllers based on temporal backpropagation. IEEE Transactions on Neural Networks 3(5): 714-723.

18. Mohammed Imran, Sarah A Alsuhaibani Chapter 7, A Neuro-Fuzzy Inference Model for Diabetic Retinopathy Classification, In: Jude Hemanth D, Deepak Gupta, Valentina Emilia Balas (eds.), In Intelligent Data-Centric Systems, Intelligent Data Analysis for Biomedical Applications, Academic Press, pp. 147-172.

19. Beale MH, Hagan MT, Demuth HB (2018) Neural Network Toolbox™ Getting Started Guide, MathWorks.

How to cite this article: Ying Bai. Estimate and Predict Flooding Height Using ANFIS and ANN Algorithms. Eng Technol Open Acc. 2023; 5(1): 555655. DOI: 10.19080/ETOAJ.2023.05.555655