Paper ID: 337

Introducing a LSTM based Flood Forecasting Model for the Nilwala river basin with a Mobile Application – a Review

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***Abstract*—** Flooding is one of the most devasting natural disasters in the world. The impact of flooding is damage to property, Agriculture, Infrastructure of a country and destroy human life. Flood Forecasting models and proper awareness about floods, sufficient communication between the flood victims and the responsible authorities are important to safeguard the life of human and the infrastructure of a country. This paper contains review of different Machine Learning methods and Algorithms like Artificial Neural Networks (ANN), Support Vector Machine (SVM), Multilayer Perception (MLP), Convolution Neural Networks (CNN) and Long Short-Term Memory (LSTM) which are used to forecast floods. Long Short-Term Memory is one of the Recurrent Neural Network models to forecast Flood. According to the reviewed literature Long Short-Term Memory networks are better than ANN, MLP and SVM because Long Short-Term Memory models can learn long-term patterns better.

***Keywords*—** Flood forecasting, LSTM, Mobile Application

Introduction

Flooding is one of the most destructive natural disasters in the world. It affects the infrastructure of a country, agriculture, human life and the socioeconomic system. Flood is a result of natural and different human activities. Because of the high rainfall in the river and coastal areas water level of rivers are increasing. As a result, floods occur. Flooding becomes worse because of climatic changes and exclusive urbanization. Pacific Region and Asia have considered highly disaster-affected areas in the world as a result floods occur frequently.

Flood Forecasting can secure village and city dwellers life and minimize the damage due to flooding. Further flood prediction is a method to reduce only the damage because there is no proper method and mechanism to avoid floods satisfactorily. Creating the Machine Learning modules for flood prediction is based on historical information of flood events. Machine learning is a way to create a machine or a program can learn by themselves through experience. The datasets usually used are rainfall and water level of the river basin. The flow of building a machine learning model is data collection, analyse the data, build model, train the model and testing the model. Data sets are used to train the model, testing, verification and validation. Machine Learning prediction models provide cost-effective solutions and better performance. Flood prediction models can be used to reduce property damage, minimize the loss of human life.

In Sri Lanka flood is associated with two monsoons. According to the Ministry of Disaster Management ("Flooding in Sri Lanka 2018," 2018) two monsoons are Southwest monsoon season (May-September) and Northeast monsoon (December-February). During the southwest monsoon season Southern and Sabaragamuwa provinces are affected and North and North-Central

provinces are affected during Northeast monsoons.

Nilwala River basin is identified as a major flood (Mawatha, 2011) affected area in Sri Lanka. Flood affects human life and damage infrastructure and agriculture in Sri Lanka. According to Lakmali and others, (Lakmali et al., 2017) Nilwala river started at Panilkanda near Deniyaya in Sri Lanka after traversing about 72km the river flows to Indian Ocean at Matara. The annual rainfall of the upper basin is 3000 mm and lower areas receive 1900mm.During March to June and August to December monthly rainfall is above 200 mm. In other months rainfall is 150mm.

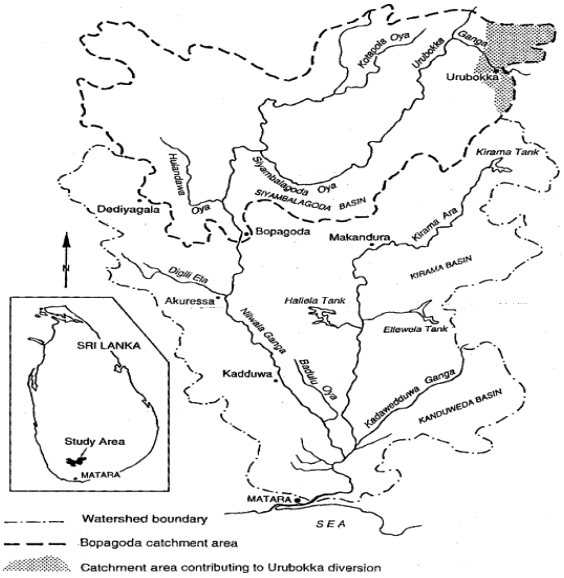

Figure 1: Catchment area of the Nilwala River(Mungai et al., 2004)

This study focuses on doing a review on flood forecasting and find the feasibility to forecast flood in Nilwala river.

In Sri Lanka, a successful Flood alert related mobile app has not yet been introduced to the public. Due to this reason, there is very limited communication between the people who very often get affected by floods and the responsible authorities. Thus, the relevant authorities find it difficult to provide the required assistance to the people in risky areas.

Literature Review

There are various predictive techniques that are used to make predictions. They are statistics, data mining, machine learning, modelling and Artificial Intelligence. Further, there are many ways of flood forecasting models all over the world. Machine learning techniques are popular in the predictive analysis due to good performance with large datasets.

Machine Learning Forecasting models are created by using the historical data of floods including the real-time data of rain gauges and other sensing data. The main data sets used to predict are rainfall and the river water level. On the other hand, soil moisture, river inflow, peak flow, typhoon rainfall and daily flows are used. Further, the high resolution of weather radar provides more accurate and reliable datasets to create a prediction model. There is a different type of machine learning models to predict floods. They are Artificial Neural Networks (ANNs), Support Vector Machine (SVM), Multi Linear Perception (MLP), Back-Propagation Neural Network (BPNN) and Long Short-Term Memory (LSTM).

ANN is a popular and significant machine learning algorithm used to model complex floods with accurate approximations. ANN algorithms have been used to predict floods started since the 1990s (Wu and Chau, 2010). ANNs have been used in different flood prediction applications. Some of them are river flow, water quality, streamflow cast and river time series. According to Paul and Das's model, (Paul and Das, 2014) it predicts flood through data set of river water level, amount of rainfall, degree of permeable soil, degree of ground saturation etc. Flood prediction is a non-linear problem, so ANN approach is used to solve this non-linear problem in this model. Further, in this case Multi Linear Perception based Artificial Neural Network's Feed Forward (FF) and Back Propagation algorithm are used to

forecast flood. This model shows results (flood water level) before 24 hours. According to that this ANN model is more accurate than the statistical models. Also Thilakarathne and Premachandra created (Thilakarathne and Premachandra, 2017) flood prediction model using machine learning and Data Mining technologies. This is a hybrid model created for predicting floods in the North Central province in Sri Lanka with the use of ANN. It is a combination of two predictive models. 1st model uses time series modelling to predict future weather-related measurements. 2nd model predicts the probability of chance of flood in upcoming months. Bruen and all (Bruen and Yang, 2005) implemented real-time rain fall forecasting. Autoregressive–moving-average model (ARMA) and functional networks are used in this model. Functional networks are generalized version of Artificial Neural Networks (ANN).

Long Short-Term Memory models learn the main principles throughout the training process with the use of input, observed data. Further, those data are optimized to predict the water discharges properly and accurately.

Xuan-Hien Le and others(Le et al., 2019) done an Application of LSTM Neural Network for Flood Forecasting. They used rainfall, Flow rate data and daily discharge as inputs. This research is based on "Da River" basin in Vietnam and data set from before 1985(1961 to 1984) of Hoa Binh Station. The efficiency for the three cases daily and two, three-day flowrate forecasting are 99%, 95% and 87%. According to them, there are two main methods for flow prediction.

The first approach is a mathematical model and the other one is Data-Driven method. Mathematical models are based on hydrology and hydraulics. This method needs more input data of rainfall forecasts and topography data which are not mostly available and easily accessible. The run time of these models are taken a long time. Also, this model does not predict the increase of the downstream flow when the upstream flows sudden fluctuations data-driven methods (DDM) based on the statistical relationship between input and output data. Artificial Neural Networks are the most common data-driven model. In this model they used to evaluate forecast model using statistical methods NSE and RMSE.NES gives an idea about the ability to predict variance accounted by model. The RMSE is mostly used to evaluate how closely the predicted values match the observed values, based on the relative range of the data. This model related to open-source software libraries. There are different characteristics considered in this model they are input data type, input data quantity and the correlation of the measured data.

According to Frederik and others (Kratzert et al., 2018) introduced Rainfall-runoff modelling using LSTM networks. They used freely available 241 catchments from CAMELS dataset. Further, they used 4 out of the 18 hydrological units with their 241 catchments. The major findings of this model are LSTMs can predict runoff from weather related observations with accuracies comparable to the well-established SAC-SMA + Snow-17 model. Pre-trained knowledge can be transferred into different catchments, which might be a possible approach for reducing the data demand and regionalization applications, According to this model the main advantage of LSTM is the ability to learn long-term dependencies between the provided input and output of the network.

Multilayer Perception is an advanced representation of ANNs. In Indonesia flood occurs frequently and it causes many damages to human life and properties. To reduce this problem Widiasari and others introduced (Widiasari et al., 2017) Deep learning multilayer perception (MLP) for

flood forecasting. This system contains two parts. They are the control centre and the

remote site. Equipment in the field of data measurements means the remote site and web service is the control centre. MLP is used to predict rainfall time, sense data and water level of rivers. According to this project, MLP gives better prediction results in water elevation level on the downstream canal. In this model the smallest and the biggest error percentages are 0.82% and 46.48% respectively.

Support Vector Machine (SVM) is used in predicting floods. SVM flood forecasting modeling is a supervised learning method works with statistical learning theory and structural risk minimization rule. SVMs are used to classify both linear and nonlinear classifications. According to Opella and Hernandez's conceptual framework (Opella and Hernandez, 2019) the primary objective is the Geographical Information System (GIS) data in mapping the flood susceptible area in Wahig-Inabanga in the Philippines. It used two different machine learning techniques like Support Vector Machine and Convolutional Neural Network to product accurate maps for the flood. CNN is known in computer vision application with the advantage of learning visual features in this model. CNN is used for image processing tasks.

Above table shows the different machine learning modelling techniques used to forecast floods in different countries.

Singh and Borah (Singh and Borah, 2013) developed a prediction model with the Back Propagation Neural Network(BPNN)s to predict heavy rains and flood. Proposed model can predict seasonal rainfall amounts for next 5 years. The data set include time period of 1871-2010 on a monthly time period. They trained and tested five neural networks separately and compared them with another existing model

Table 1: Comparative Analysis of different ML Flood Forecasting models

Reference	Modelling Technique	Input Parameter	Prediction Type
(Paul and Das, 2014)	ANN (MLP)	River water level, amount of rainfall, degree of permeable soil, degree of ground saturation	Daily
(Thilakarathne and Premachandra, 2017)	ANN	Forecasted weather values and historical flood data	Monthly
(Le et al., 2019)	LSTM	Rainfall, Flow rate data and daily discharge	Daily, two, Three-day flowrate prediction
(Opella and Hernandez, 2019)	SVM and CNN	Rainfall data	Not mentioned
(Nayak, 2013)	SVM and ANN	Weather patterns	Hourly rainfall-runoff
(Widiasari et al., 2017)	Deep Learning and MLP	Rainfall time sense data and water level of rivers	Not Mentioned
(Kourgialas et al., 2015)	Statistical analysis and ANN modelling	Five years hourly based data set	Leads 3h, 12h, and 19h flood prediction
(Singh and Borah, 2013)	BPNN	Rainfall data l include time period of 1871-2010 on a monthly time period	Rainfall values for 5 years
(Lin et al., 2006)	SVM	Historical records of monthly river flow discharges	Long-term
Proposed Model	LSTM	Rainfall and water level	

The results show the BPNN models were fast and accurate with forecasting nonlinear floods. Due to nonlinear nature of Indian

summer monsoon rainfall prediction is more complex. Lie and others (Li et al., 2017) have conducted a project on ML algorithms and feature extraction for time-series. According to them SVM and RNN can be used to predict on a variety of time series data sets.

Flood prediction in short-term is a difficult task. But short time predictions are important for water resource management. Mosavi and Ozturk (Mosavi et al., 2018) have presented a paper on Flood prediction models. According to that Short-term flood, prediction can be done through single and hybrid methods.

Further, flood risk assessment contains four main processes. They are finding the geographical data of the specific location, analyses the variety of hazard and intensity, evaluate hazard, susceptibility and specify the area is beneficial to send an early alert with quick responses. Flood can be predicted hourly, Real- time, daily, weekly, monthly, seasonally and annually. According to the available literature, Machine learning can be used to predict both short-term and Long-term floods.

Methodology

Requirements are gathered through questionaries, observation and interviews from the people who are prone to floods, Department of Irrigation and Meteorology Department of Sri Lanka. Historical Weather data of Nilwala river of Sri Lanka have been collected from the department of Irrigation Sri Lanka. The main data sets collected are the water level of the river sub-basins and rain fall data. Panadugama, Pitabaddara and Bopagoda are sub-basins related to Nilwala river.

The main technology used to develop the model is Long Short-Term Memory. LSTM networks are a type of Recurrent Neural Network (RNN). This networks was introduced by the German researchers Schmidhuber and Hochreiter in 1997(Hochreiter and Schmidhuber, 1997). Long-term dependency problem can be avoided through

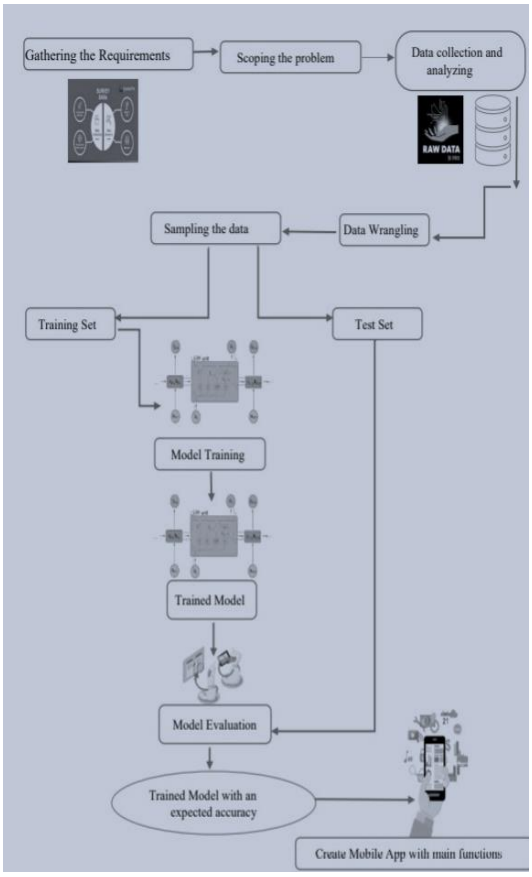

Figure 2: Methodology used to create the model

LSTM networks. LSTM networks have feedback connections. In this networks information stored in a cell. This cell allows read and writing also. This cell takes decisions about when to writes, reads and what to store through gates that open and close("A Beginner's Guide to LSTMs and Recurrent Neural Networks," n.d.). This cell contains three gates called input, output and forget. These gates are called "regulators".

Through a mobile application, flood alerts can be communicated to the people and relevant authorities. Further, the proposed mobile app included weather details, fund collections, Communication facilities given between flood-affected people and authorities like Disaster Management centres, Gramer sewaka etc.

Discussion

Flooding can be identified as one of the most destructive natural disasters, that affects the infrastructure of a country, agriculture, damage to human life and the economic system. Flood prediction methods differ from Machine Learning algorithm, data sets and their application.

According to the reviewed literature, there are different machine learning methods that are used to predict flood. Most widely used Machine Learning method is Artificial Neural Network due to the accuracy of the results, fault tolerance and parallel processing with complicated flood function. Further the study proves that LSTM, MLP, SVM methods work better than Artificial Neural Networks. Furthermore, the reviewed literature shows hourly models make forecasts flood in advance usually between 3 hours to 48 hours. According to the existing models, the main flow of ML prediction are data collection, data preprocessing, Creating the model, training and testing the model.

Long Short-Term Memory has feedback connections which used to processing and making predictions related to Time series data, speech recognition and Handwriting recognition etc. Flood forecasting is a time series related problem.

Mainly Flood forecasting models are based on past data. As a result, data gathering is one of the main steps of this flood prediction process. Researchers can gather data from Government agencies like the Department of Meteorology and Department of Irrigation. For rainfall and water level are measured by rain gauges or remote sensing technologies like multi-sensor systems, radars and satellites.

This study focuses on flood forecasting using LSTM machine learning network for the Nilwala river basin in Sri Lanka. Nilwala basin is an area where flood is a frequent threat. To create a flood prediction model, researchers can use two or more machine learning models, compare the results and give accurate flood forecasting for the users of this system. The study attempts to make aware of the authorities to safeguard the life of the resident in the Nilwala area. If this project becomes successful it could be improved to use in island-wide in future.

Conclusion and Future Work

Flood forecasting is useful not only to the local and city dwellers but also different government institutions like National Disaster Relief Service centre, Department of Meteorology and Department of Irrigation etc. According to the literature reviewed Machine learning technologies can be used to flood. Long Short-Term Memory networks are better to forecast flood. Datasets used to predict are historical rainfall and water level of river basin etc. With the proposed flood forecasting model flood-prone people can be made aware of the flood through the mobile application.

References

A Beginner's Guide to LSTMs and Recurrent Neural Networks [WWW Document], n.d. . Pathmind. URL http://pathmind.com/wiki/lstm (accessed 7.24.20).

Bruen, M., Yang, J., 2005. Functional networks in real-time flood forecasting—a novel application. Advances in Water Resources 28, 899–909. https://doi.org/10.1016/j.advwatres.2005.03.001

Flooding in Sri Lanka 2018 [WWW Document], n.d. URL https://www.jbarisk.com/flood-services/event-response/flooding-in-sri-lanka-2018/ (accessed 7.29.20).

Hochreiter, S., Schmidhuber, J., 1997. Long Short-term Memory. Neural computation 9, 1735–80. https://doi.org/10.1162/neco.1997.9.8.1735

Kourgialas, N.N., Dokou, Z., Karatzas, G.P., 2015. Statistical analysis and ANN modeling for predicting hydrological extremes under climate change scenarios: The example of a small Mediterranean agro-watershed. Journal of

Environmental Management 154, 86–101. https://doi.org/10.1016/j.jenvman.2015.02.034

Kratzert, F., Klotz, D., Brenner, C., Schulz, K., Herrnegger, M., 2018. Rainfall–runoff modelling using Long Short-Term Memory (LSTM) networks. Hydrology and Earth System Sciences 22, 6005–6022. https://doi.org/10.5194/hess-22-6005-2018

Lakmali, U.W.U., Navarathne, C.M., Fowze, J.S.M., n.d. Development of Flood Hazard Map for the Selected Areas of Nilwala Downstream using HEC-RAS 7.

Le, X.-H., Ho, H.V., Lee, G., Jung, S., 2019. Application of Long Short-Term Memory (LSTM) Neural Network for Flood Forecasting. Water 11, 1387. https://doi.org/10.3390/w11071387

Li, L., Wu, Y., Ou, Y., Li, Q., Zhou, Y., Chen, D., 2017. Research on machine learning algorithms and feature extraction for time series, in: 2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC). Presented at the 2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), pp. 1–5. https://doi.org/10.1109/PIMRC.2017.8292668

Lin, J.-Y., Cheng, C.-T., Chau, K.-W., 2006. Using support vector machines for long-term discharge prediction. Hydrological Sciences Journal 51, 599–612. https://doi.org/10.1623/hysj.51.4.599

Mawatha, W., n.d. SMALL ANICUT SYSTEMS IN NILWALA RIVER BASIN 43.

Mosavi, A., Ozturk, P., Chau, K., 2018. Flood Prediction Using Machine Learning Models: Literature Review. Water 10, 1536. https://doi.org/10.3390/w10111536

Mungai, D.N., Ong, C.K., Kiteme, B., Elkaduwa, W., Sakthivadivel, R., 2004. Lessons from two long-term hydrological studies in Kenya and Sri Lanka. Agriculture, Ecosystems & Environment, Environmental Services and Land Use Change: Bridging the Gap between Policy and Research in Southeast Asia 104, 135–143. https://doi.org/10.1016/j.agee.2004.01.011

Nayak, M.A., 2013. Prediction of extreme rainfall event using weather pattern recognition and support vector machine classifier. Theoretical and applied climatology v. 114, 583–603. https://doi.org/10.1007/s00704-013-0867-3

Opella, J.M.A., Hernandez, A.A., 2019. Developing a Flood Risk Assessment Using Support Vector Machine and Convolutional Neural Network: A Conceptual Framework, in: 2019 IEEE 15th International Colloquium on Signal Processing & Its Applications (CSPA). Presented at the 2019 IEEE 15th International Colloquium on Signal Processing & Its Applications (CSPA), IEEE, Penang, Malaysia, pp. 260–265. https://doi.org/10.1109/CSPA.2019.8695980

Paul, A., Das, P., 2014. Flood Prediction Model using Artificial Neural Network. International Journal of Computer Applications Technology and Research 3, 473–478. https://doi.org/10.7753/IJCATR0307.1016

Singh, P., Borah, B., 2013. Indian summer monsoon rainfall prediction using artificial neural network. Stoch Environ Res Risk Assess 27, 1585–1599. https://doi.org/10.1007/s00477-013-0695-0

Thilakarathne, H., Premachandra, K., 2017. Predicting Floods in North Central Province of Sri Lanka using Machine Learning and Data Mining Methods. Sri Lanka 6.

Widiasari, I.R., Nugroho, L.E., Widyawan, 2017. Deep learning multilayer perceptron (MLP) for flood prediction model using wireless sensor network based hydrology time series data mining, in: 2017 International Conference on Innovative and Creative Information Technology (ICITech). Presented at the 2017 International Conference on Innovative and Creative Information Technology (ICITech), IEEE, Salatiga, pp. 1–5. https://doi.org/10.1109/INNOCIT.2017.8319150

Wu, C.L., Chau, K.W., 2010. Data-driven models for monthly streamflow time series prediction. Engineering Applications of Artificial Intelligence 23, 1350–1367. https://doi.org/10.1016/j.engappai.2010.04.003

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