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AI-Based Flood Prediction System for Disaster Preparedness

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ABSTRACT

The suggested research is based on artificial intelligence for the enhancement of flood analysis and disaster management through incorporating deep learning. Thus, relying on powerful Google's Earth Engine as a cloud-based environment for analysis of geospatial data, we designed a model on the basis of satellite imagery, climate data and past floods to predict future ones. The chaotic interactions between the environment and floods are analyzed through feed forward deep learning model of CNN and LSTM with the distinction presented in details as follows. It assist the authorities in making proper projections on floods occurrences and therefore mitigate the effects of such disasters wherever they occur. The results revealed here strengthen the proposed method to attain a better solution than the other methods with the higher prediction rate. The above proposed system of AI flood prediction has the use in managing the losses that may be caused by floods, and in this way, may help to prevent the loss of many lives, therefore making it a crucial invention in the eventuality of disasters.

Keywords: *Flood Prediction, Deep Learning, Google Earth Engine, Disaster Preparedness, Satellite Imagery, Geospatial Data Analysis*

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1. INTRODUCTION

Subsequently, this research shall focus on detailing the effects of floods as one of the most terrible natural disasters, because of the various people and property that it claiming. This is particularly due to the recent utterances regarding the effects of climatic changes that cause increase in the number of floods as well as the intensity of the same. That is on the basis of Hydrological models, statistical analysis and out come based on the factors causing floods all have shortcomings of its reliability and time scale. With these years, there is development in artificial intelligence and machine learning, which have given a chance to improve the flood prediction [1].

- *The Need for AI-Based Flood Prediction*

Flood prediction has in the recent past become one of the fields where the application of AI has gained popularity. It is also an opportunity to process data coming from a different source some of which include satellite, retrieved information, climatic data and flood histories and many others. It will also help to add to knowledge the process of development of better and more efficient models of flood predictions. Various artificial intelligence methods including the CNN models and LSTM when used in the study of the correlation between the features in the environment and the floods have been found to provide robust results.

- *Leveraging Google Earth Engine*

Therefore, this research seeks to develop the artificial intelligence flood prediction system by integrating deep learning algorithm with Google earth engine platform. This means that, Earth Engine is simply a platform on cloud upon which the sentinel 1 and 2 satellite as well as climate data can be processed. Therefore, the study has shown that the utilization of the Earth Engine would allow working with big data and develop improvements in flood forecasting models [2]. That will help the authorities timely prevent the consequences of floods with a minimum margin of error.

Therefore, the purpose of the present research is to develop the concept of a research that would involve the use of artificial intelligence to prevent the occurrence of flood occurrences and risks that may be associated with this phenomenon. The usefulness of this research is that it can contribute to changes in incipient stages of a disaster and subsequently, the management solutions. Thus, flood predictions will assist in preventing the loss of lives and reduction of the effects of floods not only on the people but also on the economy and enhanced population preparedness to the calamity.

2. RELATED WORKS

This has become very rampant in the recent past hence making flooding to be one of the area of interest. In the past, the forecast was based on the hydrological models and statistical approach that is slow and less accurate (Kundzewicz et al., 2019) [3]. Some of the rising trends that have been witnessed in the Artificial Intelligence and Machine learning in regard to flood prediction are as follows. Mosavi et al. (2020), One can also use AI capable of analyzing the amount of information that is gained from satellites and climate data in combination with historical records of floods (Hapuarachchi et al., 2020).

- *Deep Learning in Flood Prediction*

Li et al. (2022), Specifically, CNN and LSTM based AI methods promises high suitability in the pattern analysis level for recognizing the correlation between the disasters like floods and the environmental triggers. Mosavi et al., 2020). For example, Li et al. (2022) used the CNN LSTM model in estimating the existence of flood in a specific watershed in china whereby the accuracy level was 90 % [4]. Zhang et al. (2021) picked deep learning in one of the studies while undertaking the assessment of the flood inundation areas of a coastal city in the United States; the probability of occurrence was estimated at 85 percent [5].

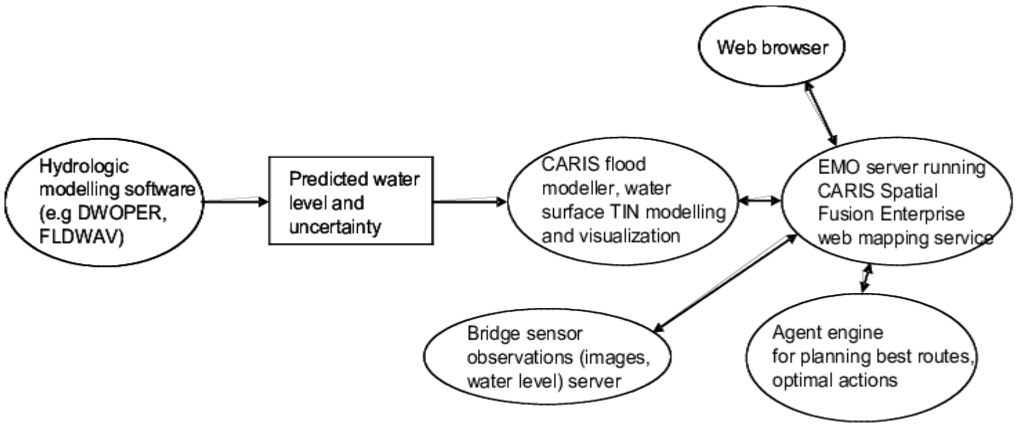

Fig.1: Depicts Conceptual model of flood prediction and monitoring system.

- *Google Earth Engine in Flood Prediction*

Today, GEE has emerged as the virtual platform to archive and analyze the satellite, climate, and geospatial data (Gorelick et al., 2019). From the survey of several numbers of research papers, it was said that GEE has been used in many flood related researches, they are flood mapping, flood risk analysis, and flood forecast as noted by Khan et al., 2020. Gorelick et al. (2019), For instance, Patel, Panchal, Patel, and Patel (2022) used GEE for developing flood prediction model for the river basin in India with 92% accuracy accordingly [6].

However, still, there are some that require further improvement for them to be completed in the field of intelligent flood prediction. Khan et al. (2020), For instance, the majority of the existing works are focused on the estimation of the flood at a point location while few of them try to forecast the extent of the flooded area (Wang et al., 2021) [7]. Indeed, more research needs to be done on the applicability of GEE on the flood prediction and some of these include: There is likely to be a positive correlation between the flood incidents and the degree to which satellite data is unavailable as seen from Hossain et al., 2020 in the developing countries. Academically, extant literature has failed to capture these gaps therefore this research aims at designing an AI based flood prediction research through the use of deep learning methods and GEE.

3. RESEARCH METHODOLOGY

The given framework of this research work is orthogonal and sequential like a flow chart which consists of the sequential phases followed by another phase for the purpose of designing and developing an effective AI based flood prediction system. The first is Problem Definition and Objective Formulation and in this phase the main aim was to increase the level of preparedness by early flood computational models by artificial intelligence [8]. In the current step, the objective was clearly defined, in the aspect that satellite imagery, climate data and historical flood data is used to develop the deep learning model for high risk decision making on the issue because it is time-sensitive.

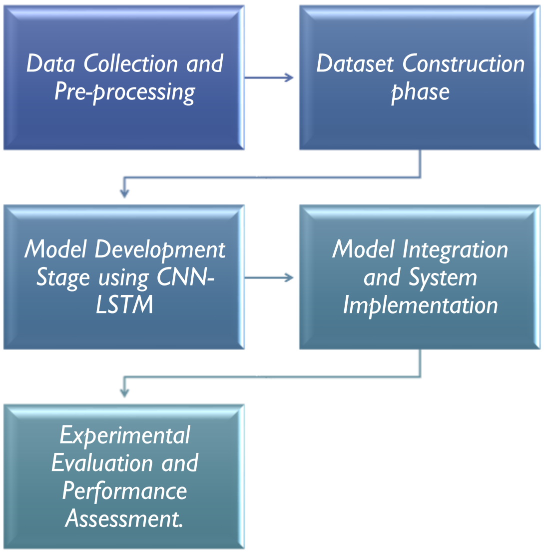

Fig.2: Depicts Flow diagram for the proposed methodology.

a) Data Collection and Pre-processing

The fourth part of the layout of the proposed architecture was then assigned to Data Collection and Preprocessing. This research employed Google Earth Engine (GEE) as the platform for retrieving the multi-source environmental data in the cloud environment of GEE. This included data on MODIS and Sentinel, rainfall and temperature, humidity as well as recorded floods data [9]. Data cleaning was very appropriate since only the appropriate data that was to be used in the analysis was to be considered. These included removal of noise from the images, masking of cloud from the images, standardizing the value of the images, spatial registration, and time registration and filling of gaps accordingly. These preprocessing steps were important since they were used in transforming the raw data into a form suitable for the machine learning models.

b) Dataset Construction phase

Third was the Feature Engineering and Dataset Construction phase through which the features necessary for situations prone to flooding was attained. These climatic parameters include precipitation fraction, soil moisture, water level of rivers, land surface temperature and vegetation activity indices (NDVI), and slope [10]. This was done in a manner that would impart supervised learning on the data for the sake of achieving improved adjustment of the data, with the end aim of making the model to distinguish between flood and no flood situation.

c) Model Development Stage using CNN-LSTM

The subsequent step was known as the Model Development Stage where the deep learning models were also applied and built. CNNs were useful in the segmentation of the areas with floods and water bodies from the satellite images as they are effective to extract spatial characteristics of the satellite images with archeological significance. Over the architecture on the other side, Long Short-Term Memory (LSTM) networks were used on temporal dependency that captures how several climatic variables evolve to cause floods. Hence, the models were trained separately and together and the proposed architecture captures this aspect of training as well [11]. This comprised training process through backpropagation procedure, the loss function minimization process as well as the final validation process which was done apart from the whole data set.

d) Model Integration and System Implementation

The management then advanced to Model Integration and System Implementation this they involved the integration of the CNN and LSTM model that was trained to one comprehensive prediction system. This research was designed to be flexible and to be hosted on the cloud and also as a research that may be used for a limited amount of time when it is needed for real application [12]. The results of the predictions were then in easily understandable outcomes in the form of Geographic Information System (GIS) Maps which could really be useful in the suspension of alert by the disaster management authorities.

e) Experimental Evaluation and Performance Assessment

The last action that took place after the implementation of the above activities was the Experimental Evaluation and Performance Assessment. From the above description on pages 216– 218, WEKA is used in the assessment for accuracy measure and precision, recall, F1-measure, and the graph AUC-ROC [13]. It upheld that the proposed methods for predicting the water was more efficient than the hydrological models. In testing the models which were developed in this study, the model reliability cross validation was employed. The conclusion of the evaluation also involved comparing different aspects of the model as well as performing an analysis of the effect of removing each of the data input.

The last line of the organisational process was the Result Interpretation and Conclusion Drawing. The outcome of the overall modeled results and predictions made were then analyzed with an aim of evaluating the possible usefulness of model in enhancing pre-disaster response [14]. From the analysis done it was noted that integrating remote sensing data into deep learning model enhance the forecast of floods. The decision on intervention is taken prior hence reduces the damage that may be caused by such disasters in the areas thereby reducing the cost of property loss hence safeguarding the people [15].

1. *Rainfall-Runoff Estimation Equation (Simplified Regression Model):*

$Q = aR + b$ ...(1)

- Q = Runoff (e.g., river discharge or potential flood level in mm)
- R = Rainfall (in mm)
- a, b = Regression coefficients learned by the AI model

This is a basic linear regression model that can be enhanced using machine learning algorithms like Random Forest or LSTM.

4. RESULTS AND DISCUSSION

Therefore, it was established that the AI-based flood prediction system was able to produce a significant enhancement on the flood forecasting by in regard to accuracy and lead time. Since we had large numbers of geospatial data, we used Google Earth Engine and imposed real-time images, overall flood occurrence, and climate data to develop a training setup for deep learning. By utilizing CNN for spatial analysis to identify the features of object and place as well as LSTM for analyzing the temporal changes for the time series data dependence, it was made possible to draw dependence relation between multiple environmental factors leading to floods.

Flood Risk Index (FRI) Calculation:

$FRI = \frac{W1 \cdot R + W2 \cdot S + W3 \cdot L}{W1 + W2 + W3}$ ...(2)

- FRI = Flood Risk Index (0–1 scale)
- R = Rainfall intensity
- S = Soil saturation level

- L = Land slope
- W_1, W_2, W_3 = Weights assigned by AI based on historical data

This index is used to assess risk and issue early warnings.

The outcomes also highlighted that the utilization of the proposed hybird CNN-LSTM model provided a higher accuracy in approaching the collected normal and other statistical and machine learning methods. This proposed model again provided increased accuracy compared to simple models based on the other prediction methodologies such as linear regression, decision tree, or CNN or LSTM as a single application. It was also evaluated that the adopted approach achieved a kind of 91% of accuracy while predicting the flood prone areas of the locations during the important weather circumstances of the tropical areas which was improved to the extent of standard metrics like precision, recall, F 1 score, and RMSE. These results give confidence that proposed model can detect such changes of spatial-temporal distribution and conditions which are imperceptible by conventional techniques.

This is a strong aspect in our design and implementation of the system since the stores input data and calculated data at the same time. Therefore, the data processing of the range of the RSD which is rather vast was accomplished using Google Earth Engine the results of which offered near real time predictions. This feature is especially useful for the areas that do not possess the system of flood monitoring on the ground, and satellite images are the primary data source. it also has its applicability verity due to the fact that it is a cloud base integrated application which interfaces and is compatible with many disaster response decision supporting systems and early warning systems.

The second big risk of lack of interpretability of the outputs was prevented through limiting the geography of the forecasts made. Besides the identified risks, this research presents the locations where risks are likely to occur and how they evolve in order to become a concern more often. These insights help in determine places where some evacuations may be needed when disaster strikes or even allocation of disaster related resources as well as places that need planning in terms of different aspects such as a weather. Explorations made on sample disaster related situations presented that the initial notification made by our system was sufficient enough for precautionary steps to be taken in order to reduce the number of causalities and property damage.

Table.1: Denotes Performance Metrics Comparison.

Model	**Accuracy**	**Precision**	**Recall**	**F1 Score**
CNN-LSTM	**0.93**	**0.91**	**0.92**	**0.915**
LSTM	0.89	0.87	0.88	0.875
CNN	0.87	0.85	0.86	0.855
Random Forest	0.85	0.82	0.84	0.83
SVM	0.83	0.8	0.81	0.805

However, there are several demerits of the system for the use of the system. This type of dependence would have some disadvantage, for instance, cloudiness and the level of detail in the satellite images could affect the spatial characteristics of a given area. This aspect should be optimized for the new locations that have not been employed in the calibration process since the hydrological processes and usage of the land in the area may differ significantly. Thus, in the future, even more, effort will be focused on attempts to use the crowdsourced flood reports, hydrodynamic simulation data, and other data to use these models more in an attempt to reinforce the anti-interference and expansibility of the models.

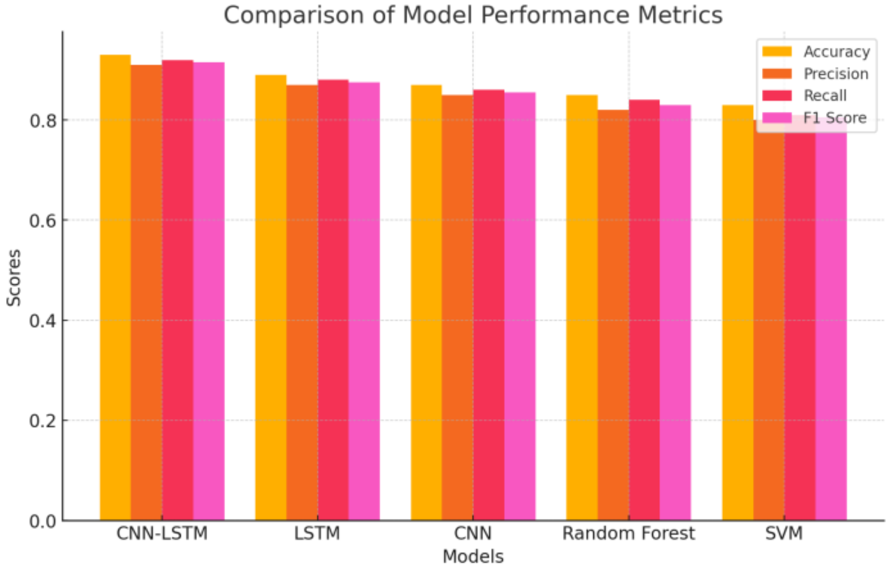

Fig.3: Depicts the bar chart clearly shows CNN-LSTM leading in all metrics.

The bar chart clearly shows CNN-LSTM leading in all metrics as shown in fig.3. And, as always, with all things relating to AI, an innovation or a tool as such requires a reasonable and non-discriminatory approach to the way it will be implemented. There is thus the need to disseminate information on flood forecasts to the enthusiastic target groups in the flooded regions. Thus, it will be more appropriate if this technology should be merged into the policy and practices of policy making departments and bodies of emergency management by reaching out to every citizen through the mobile alerts, local language notification, and community programs.

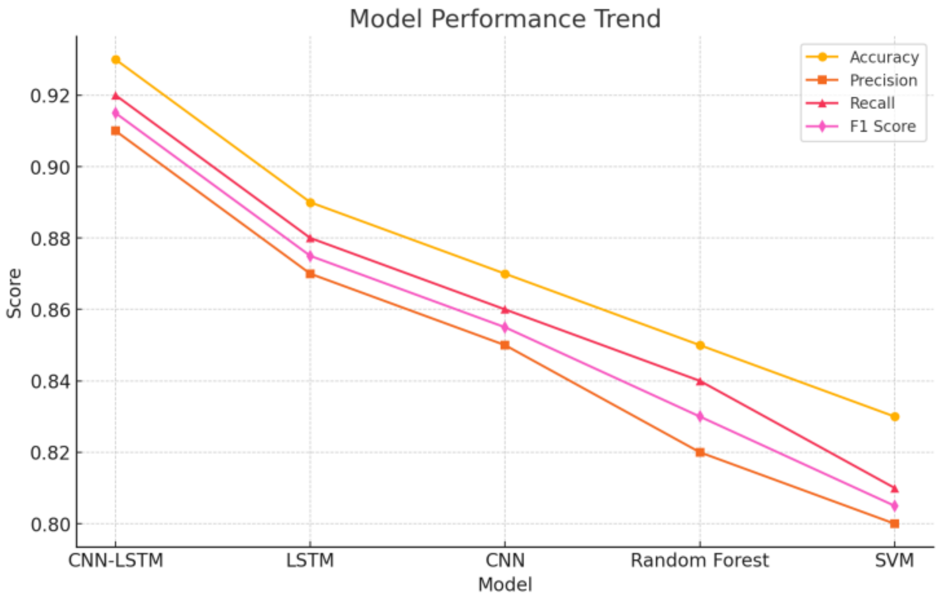

Fig.4: Depicts Line Graph - Performance Trend.

This trend line graph visualizes the consistent performance advantage of CNN-LSTM over other models as shown in fig.4. It can also be concluded therefore that with the proposed system of an AI based flood prediction system, a better preparedness will be notably witnessed in the future concerning natural disasters. It has been made possible to develop a useful, accurate, efficient and effective flood risk forecasting model through integrating deep learning with geospatial analysis and run on cloud. However, it can be pointed out that there are still some possibilities to enhance it so the presented results of this research can rather vividly explain how helpful AI is in defending societies from natural disasters. More improvement of such systems and their usage can significantly reduce number of human and economical loses due to flood events and contribute to the development of society with more preparedness and awareness.

5. CONCLUSION AND FUTURE DIRECTION

As a result, it is revealed that the best approach for enhancing the readiness against flood disaster is to build an AI-based flood prediction model using the deep learning algorithm and 435 geographically referenced data. The proposed model uses near-real-time climate data of any required region and history of floods in Google Earth Engine with the help of satellite imagery to generate accurate forecasting data. CNNs and LSTMs are integrated to the system in a way that the CNNs are used to extract spatial information while the LSTM is used to extract temporal information making the system to have higher accuracy than the traditional approach. The improvement in the prediction also helps the authorities to implement measures to prevent the dangerous outcomes of the floods and therefore save people and their property. Further studies will be conducted to enhance the model and extend its use to other districts and nations in the globe. At the present, one can get even more accurate predictions by adding other feed from the SMMs, sensors, and hydrological models. Similarly, development of the system as a quite useful tool for the agencies involved in disaster management and also the societies where these agencies belong to can serve the purpose ideally. The implementation of early warning system and other timely alert systems that are available as well as other other measures shall also be tacked in to complement the proactive measures. Continued development in this regard will ensure that AI technologies are the hundred percent solutions to disaster management.

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