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Flood Monitoring and Early Warning Systems – An IoT Based Perspective

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Abstract

One of the most frequently occurring calamities around the world is a flood. For flood prone areas or countries, an essential part of their governance is flood management. The necessity to continuously review and analyze the adverse or ambient environmental conditions in real-time demands developing a monitoring system so that floods could be detected beforehand. This paper discusses different Internet of Things (IoT) based techniques and applications implemented for efficient flood monitoring and an early warning system and it is observed that in the future, the combination of IoT and synthetic aperture radar (SAR) data may be helpful to develop robust and secure flood monitoring and early warning system that provides effective and efficient mapping during natural disasters. The emerging technology in the discipline of computing is IoT, an embedded system that enables devices to gather real-time data to further store it in computational devices using wireless sensor networks (WSN) for further processing. The IoT-based projects that can help collect data from sensors are an added advantage for researchers to explore in providing better services to people. These systems can be integrated with cloud computing and analyzing platforms. Researchers recently have focussed on mathematical modelling-based flood prediction schemes rather than physical parametric-based flood prediction. The new methodologies explore the algorithmic approaches. There have been many systems proposed based on analog technology to web-based and now using mobile applications. Further, alert systems have been designed using web-based applications that gather processed data by Arduino Uno Microcontroller which is received from ultrasonic and rain sensors. Additionally, the machine learning (ML) based embedded systems can measure different atmospheric conditions such as temperature, moisture, and rains to forecast floods by analyzing varying trends in climatic changes.

Keywords: IoT, Wireless Sensor Networks, Sentinel Image, Flood Monitoring, Early Warning System, Machine Learning Model.

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1. Introduction

The impact of global warming prompt decision making authorities to enhance flood-risk management processes to address issues related to the causes of floods. Risk mitigation can be done simultaneously with multiple factors [1]. Floods occur when water levels of rivers exceed and there is sea rise during heavy rains. A very common natural disaster that affects the lives of people, and private and public properties are floods, especially in inhabited areas but in urban and rural areas, this could jam road networks disrupting commuters from reaching their destinations. Although the flood rescue teams from the local government units provide support to the people using different communication channels, the dissemination of flood related information needs to be conveyed quickly. Humans have been trying for a long, but not always have been fully successful in controlling and foiling the destructive consequences of floods. Synthetic flood banks have been made and river courses have been straightened. Further, the riverbed is deeply dredged. These methods are effective but likely to have adverse effects on the river

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habitat. There is an obligation on the part of national and international environmental organizations with an important role in controlling floods and protecting public and private properties. Moreover, the situation has further deteriorated due to the increase in the number of flash floods. Most of these organizations have blamed global warming where the melting of ice glaciers and heavy snow results in rising inundation levels rapidly causing 'flash floods' [2]. It is common these days to hear major floods making news due to the impact they inflict upon human lives and property. Further, the satellite-based flood assessment to detect the severity of the damage can be crucial in decision making and addressing mitigation plans by the respective risk management authorities.

The remote sensing data with diverse areas acquired from satellites such as the Sentinel-1 series can be used effectively in tackling severe real-time flood levels and mapping them more appropriately. This has been analysed by researchers by using various mapping and monitoring techniques on large remote sensing datasets of floods [3]. The Sentinel images (i.e., C-band SAR images) could be used for regular flood monitoring. Further, classifying and evaluating the data in flood-prone regions over a particular duration can pave the way for detecting and evaluating the changes using time-series analysis [4]. The SAR satellite sources have been increasing and have enhanced their provisions in flood extent mapping. The sensor features for the predictive modelling techniques to analyze the flood dynamics need to be developed for complete SAR image-based information extraction. The process of flood mitigation can be achieved through various hybrid machine learning (ML) techniques such as support vector machine (SVM) combining it with metaheuristic optimization procedures. Some of these procedures are the imperialist competitive algorithm, grey wolf optimization (GWO), and differential evolution [5].

In this paper, an overview of the problem of monitoring floods and various techniques addressing this issue is presented. Section 2 presents the reviews on various IoT-based flood monitoring techniques that includes monitoring the air quality and environment, flood forecasting, early flood warning, and applications of ML techniques. Section 3 covers existing IoT-based flood monitoring and alert systems over IoT sensors, computer vision, and cellular communications. Section 4 provides the possibility of developing an IoT-based flood monitoring with satellite images and proposed a framework for the development of a new Flood Monitoring and early warning system (FMEWS). Section 5 exhibits the conclusions and future work required for the development of FMEWS based on the conducted study.

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2. IOT-based Flood Monitoring Techniques

There are different models from some of the existing research that is based on different flood predicting methods which highlight the importance of implementing different approaches in tackling floods. These models use WSNs to build energy efficient monitoring and early alert systems. These models can support in designing of an efficient system to predict and prevent damages caused by floods [6].

2.1. Monitoring of Air Quality using Smart Sensors

A smart sensors network for monitoring indoor and outdoor air quality was designed by Postolache et al. in 2009 [7]. They installed nodes of some of the sensors inside rooms which consisted of sensors such as tin dioxide connected to the central unit through hardwires or wirelessly [8]. For the accuracy of the result, the concentration of gas in the temperature and humidity is measured. In order to compensate for the influence of the above measurements, they applied MISO neural network (NN) which is based on multiple inputs single output. IEEE 802.11 (Wi-Fi) technology was used for communication between sensors.

2.2. Monitoring Environment using Controller Area Network

Controller Area Network (CAN) based environmental monitoring system was proposed by Rao et al. in 2012 [9]. The CAN and ZigBee technology was utilized for effective communication among the sensors [10]. The sensors are connected to the microcontroller, ATMEL-89S52 through an interface of CAN to further share this data to the server using ZigBee Communication. This is used since the CAN protocol provides a higher data rate. For any specific area, the benefit of this system is that it uses a precise and dependable method for data broadcast. Communication is inexpensive and there is no loss in terms of data.

2.3. Flood Forecasting

A flood forecasting model that uses Wireless Sensor Networks was created by Seal et al. [11]. This design used simple and fast calculations using multiple variable robust linear regression methods for flood forecasting. Its implementation is very cost-effective and also simple and easy to understand. It used very low-cost hardware resources. It has all the features desired by any real-world algorithm such as real-time predictions and reliable accuracy. This model does not specify the number of parameters required which means that any kind of parameter can be added or removed. A polynomial represented the rise in water level based on which flood warning level can be determined easily. In order to identify the time interval between each successive reading, a time multiplier function was added. The design strategy does not prevent floods or damage caused by them. It can only predict the occurrence of floods and send a warning to people by methods such as ringing an alarm bell. it is observed that the Wireless Sensor Network is effective when flood warnings are to be communicated. Nevertheless, it is necessary to collect and analyze the sensor data since the calamity alerts could be given to the public at risk with sufficient time to respond during relief operations.

2.4. Early Flood Warning

Flood Detection using WSN: An early detection of flood system was implemented by Basha et al. [12] by means of a short description of sensor networks in Hondurasi meant for the people who are at risk of getting affected by the flood [12]. It included the analysis detailing the significance of sensor networks, available operational applications, and their lower cost in developing countries. The issues pertaining to the detection of floods and cautioning people in the events of disasters were discussed since it can turn into a complex situation. After in-depth analysis, a solution was proposed that uses WSNs. This solution contains four different categories such as flood prediction, notification to the authorities, alerting the community, and evacuation of people. The proposed solution was validated by conducting various experiments. The tests were carried out for different communication ranges such as 144 MHz radio usability. The testing activity requires US antenna towers with line-of-sight for reliable communication in the air available between sensors at those ranges. According to them, sensor network technology could be the best way to prevent damage by detecting floods in developing countries.

An early flood warning system described the architecture and deployment strategy to meet the requirements. It permits enhancing the forecasting capability of the system using model-driven control. The design was created in Honduras with its utilization to detect and analyze the flood forecast. An integrated form of the forecasting technique that includes network design and testing of the attached components was utilized by the developer of this system. By deploying the system on the banks of the river in Massachusetts, they achieved a successful outcome in the field examinations. According to the framework, a very unique heterogeneous communication system was utilized by setting sensors over the river basin. These sensors could read real-time data and auto-monitor to adjust their readings if required. These readings help in estimation techniques to address disasters such as floods.

The proposed model as shown in Fig. 1 has an innovative procedure to forecast floods and which utilizes information received from installed sensors that are spatially distributed in nature. A productive Sacramento Soil Moisture Accounting (SACSMA) model has been utilized for detecting floods effectively. Nonetheless, in the case of flood detections in developing countries, SACSMA is an expensive strategy for deployment. Their methodology has easier calculations in comparison to the traditional method to handle floods, using continuous data from sensor hubs. It has an advantage over the SACSMA model. An early warning system is shown in Figure 1.

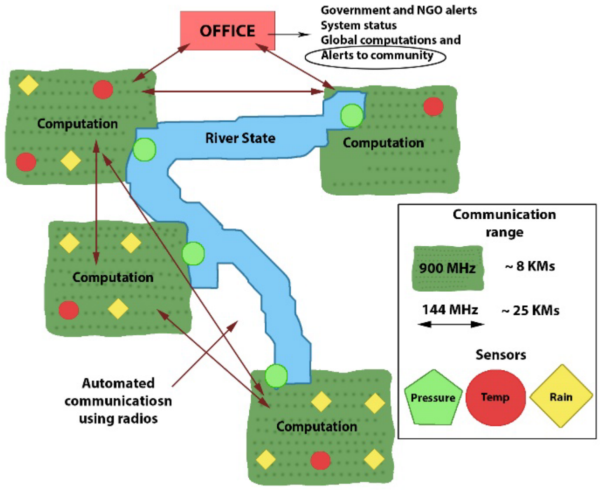

Figure 1. Early Flood Warning Model [12]

By alluding to the model executed as a reference, certainly, developing and underdeveloped nations are greatly influenced by floods on an annual basis. A low-cost and efficient flood detection mechanism can be created and effectively deployed using currently accessible technologies such as WiFi and ZigBee. Additionally, planning and securely documenting the identified information for further flood prediction. The IoT and cloud computing efficiently store and helps in analyzing the sensor data.

2.5. Applications of Machine Learning Techniques in the Environmental Field

The deep learning (DL) variant of the artificial neural network (ANN) can be used to detect flood-prone regions which can elucidate complex methods such as classification and regression. Traditional hand-crafted methods have been used to automate inundation detection from satellite images. However, these methods do not produce the accuracy required for precise flood detection. To address this limitation, Pallavi et al. [13] proposed a model that combines the water index feature with the generalizable features based on deep convolutional neural networks (DCNN). This combination technique and the DCNN model use Sentinel-2 images for training and testing. This model was implemented on the blend of green/SWIR and blue/NIR water indices. The outcomes depict that the VGG16 model-based trained proposed model outperformed when compared with the NDWI, MNDWI, AWEI, Mishra & Prasad's [14], and Li et al.'s [15] indices.

Satellite images and observations of hydrology are important sources of information for early warning systems regarding flash floods. This information is supported by DL models such as UNET, a convolutional neural network (CNN) approach in the segmentation process with higher performance. A combination of the particle swarm optimization algorithm (PSO) and the UNET model known as particle swarm intelligence optimized UNET deep learning (PSO-UNET) was proposed which strives for the maximum layers with parameters over the PSO architecture [16]. By comparing the UNET model, the Dice coefficient value was found to be 79.75% which was approximately 8.59% higher. The dataset used for the implementation from the year 2019 comprised 984 Sentinel-2 images acquired from the national project. The result obtained was found to be based on the best hyper-parameters providing higher accuracy.

Intelligent and efficient drought and crop productivity prediction can be achieved using ML techniques based on IoT. An IoT-based WPART (Wrapper Partial Decision Tree) method is based on the wrapper feature selection combined with the partial decision tree algorithm. An intelligent farming system integrated with the WPART method was proposed for predicting crop yield and drought situations [17]. This system applied SVM and neural network (NN) supervised ML algorithms for the data classification. In total, five datasets were processed and classified which achieved higher accuracy, precision, and F-score in contrast to the traditional ML techniques.

The prediction of drought using weather data has been attempted using various ML models. However, it is not certain which model performs better. A detailed study was carried out by using a real-world open Kaggle publicly available dataset [18]. Three months of 18 meteorological indicators were used to predict drought levels which included evaluating around 16 ML and 16 DL models. Based on the results indicating max, mean, and standard deviation values, the DL models performed better than the ML models. The extreme gradient boost (EGB) algorithm attained maximum accuracy and the SVM model had a maximum F1 score as well as Matthews Correlation Coefficient (MCC). The Gated Recurrent Unit (GRU), Long Short-Term Memory (LSTM), and XceptionTime models achieved higher accuracy, F1 score, and MCC respectively. These results represent that the multiple models are recommended to achieve the highest accuracy.
The satellite images-based flood monitoring system normally provides lower accuracy when compared with unmanned aerial vehicles (UAV) imaging systems. The CNN based flood management system was developed that detects flooded regions using feature selection [19]. The landmarks identified from spatial rich information-based UAV images are studied using the Haar cascade classifier by adding them to the training dataset for implementing the CNN algorithm. The classification process detected flooded regions and the outcomes evaluated represented that the roads and buildings identified showed 94% and 91% accuracy. Additionally, landmark detection can help rescue stranded people. However, a huge dataset of UAV images consumes a lot of memory. To address this limitation, they are distributed into smaller patches. This dataset cannot analyze the extent of the inundation intensity. Therefore, the depth in the flooded region can be detected using Digital Elevation Model (DEM) and Light Detection and Ranging Equipment (LiDAR) technologies.

3. Existing IOT-based Flood Monitoring and Alert Systems

3.1. The Implementation of an IoT-Based Flood Alert System

A system to detect inundation stages by measuring the upsurge in water levels and alerting local residents was proposed by Shah et al. [20]. The waterfall model as a methodology with Raspberry Pi was used to gather information from deployed sensors which transmitted it to the Global System for Mobile communication (GSM) module. The system further would alert the resident by sending an SMS as an outcome. As quoted by the author, researchers have estimated that if the sea level rises by 4 inches by 2030, it could be a reason for dangerous flooding that could be affecting many parts of the world. There is an emphasis on the usage of the GSM module since there is an increment trend in the usage of mobile users have been positive. This makes it easier for the system to alert authorized people when in an emergency. This system followed a waterfall model and discusses the use of different technologies as mentioned below. The authors used a water sensor, SEN113104 model, and USB 3G modem Huawei mobile broadband E173. This was set up along with a resistor 10K, and a jumper cable to connect with Raspberry Pi. The sensors were placed at different heights and the water height increased; they triggered data to the Raspberry Pi. This data is added to GSM Module for additional processing. This system calculates the time and speed with which the water level rises. IoT-based flood alters system is shown in Figure 2.

The performance testing shows that the performance is evaluated using delay in time. The first type of test was carried out with 30 series of data captured manually and automatically using the system. The results verify the system has been accurate in fetching the data using sensors. The second test was to identify the delay time in sending SMS to alert authorities in case of emergency and the third test was to identify the range of water increment which summarized the findings. The system highlights the importance of using sensors that can help gather relevant data helping authorities in Malaysia to take necessary measures.

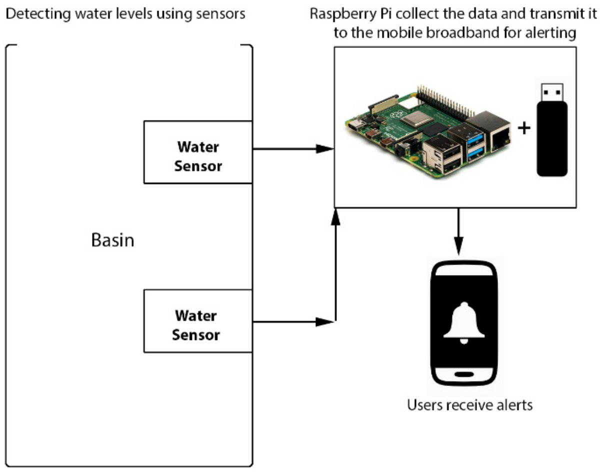

Figure 2. An IoT-Based Flood Alert [20]

3.2. IoT- Based Flood Information Monitoring System

Another system was designed for monitoring information related to floods. This was based on IoT which helps users to identify flood activity by reviewing weather conditions and inundation levels [21]. The ultrasonic sensor HC-SR04 and another type of rain sensor were used to gather information related to flood altitude. It uses an Arduino Uno microcontroller to generate web-based data. The wireless router, TL-MR3020 is connected to the controller and linked with the gathered data and is shared with the users. This system was developed to address the situation of floods in Indonesia. The Ultrasonic and rain sensors are part of the input section whereas, the Arduino Uno Microcontroller is part of the process. An IoT-based flood information monitoring system is shown in Figure 3.

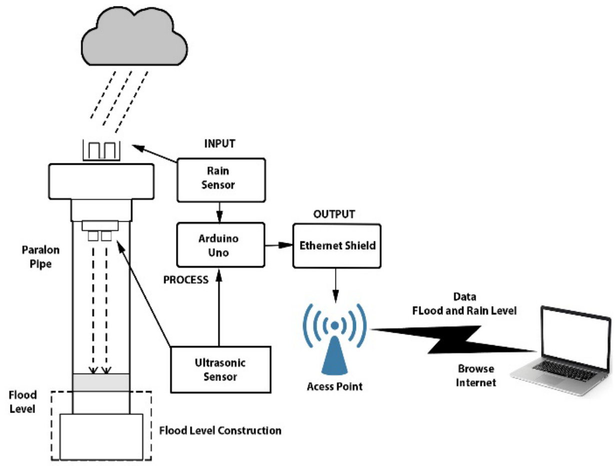

Figure 3. Design of an IoT-Based Flood Information Monitoring System [21]

The Ethernet shields and the wireless access points constitute the output section which is well integrated. Both sensors are placed upper side of the system with a cork float inside which will reflect an echo signal which sensor acknowledges through its trigger. The rain sensors will detect rain conditions and the water height is checked in the pipe. The Arduino Uno Microcontroller receives the data from sensors that are saved in the web server. The early warning system is a web-based system that users can access which includes web flood information.

3.3. RiverCore: IoT Device for River Water Level Monitoring Over Cellular Communications

The Development of the IoT system “RiverCore” is intended to monitor the river for flooding through data acquisition and data processing. This was implemented for a particular area of the Colima state of Mexico. The data was retrieved using a 3G cellular network and used Message Queuing Telemetry Transport (MQTT) protocol. The system uses a database with data being secured using encryption. A graphical representation displays flood analysis and prediction. Floods are a significant threat in many countries, and it is increasing due to climate change which is confirmed by United Nations Office for Disaster Risk Reduction (UNISDR). The monitoring of floods is based on IoT technology that uses ML and artificial intelligence supports improving data acquisition methods [22]. An ultrasonic sensor with cellular transmission is installed by using telemetry methods to reduce the load of input data. An IoT device for river water level monitoring is shown in Figure 4.

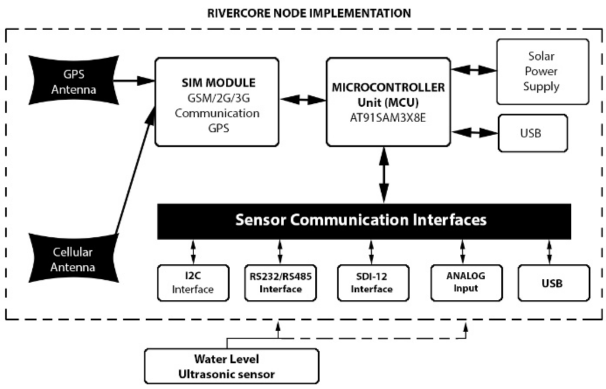

Figure 4. IoT Device for River Water Level Monitoring [23]

The ultrasonic sensors used temperature and humidity sensors to achieve better sound waves which are further combined with flash flood sensors installed on bridges for convenient access to the river. The use temperature sensor (OFTPS) helps detect temperature as well [23]. The Fabry-Perot interferometer (FPI), and fibre Bragg grating (FBG) form the structure. The server-side environment of the system implements data acquisition methods using Eclipse Mosquitto broker and receives the data from fixed nodes and is further kept in the repository. The security is provided using MQTT protocol through encryption for each device and its user.

From Fig. 4, it is observed that the RiverCore mobile module was implemented to monitor the drifter device which integrates a GPS module to retrieve variables such as location, time, and speed. The web application contains a dashboard that displays data from all nodes and shows notifications based on the sensors' responses connected. Additionally, it shows the map where fixed nodes are installed. A run-time water depth, environmental temperature over time, and relative humidity measurement charts have been generated with data collected at the one-second interval. As a result, this data help predicts changes to the natural variables for monitoring flood situation. Similarly, a web-based flood monitoring system was developed with an SMS alert option by Natividad et.al. [24]. The ultrasonic sensors measure the distance of the water level, and the Arduino micro-controller processes the signals from the sensors. The GSM module sends the data from the microcontroller to the server.

3.4. Computer Vision and IoT-Based Sensors in Flood Monitoring and Mapping

Computer vision techniques with the use of IoT sensors can be used to implement the Otsu method in predicting inundation levels by analyzing previous and current frames of images of flood-prone areas [25]. The Gaussian and averaging filter could also be utilized by comparing thresholds identified in different identified locations to fetch accurate data. This study concludes that computer vision focuses on a single point in the field of view whereas IoT sensors provide more accurate real-time data to identify inundation levels.

3.5. IoT, big data, and HPC based smart flood management framework

An IoT-based smart flood monitoring and alert system through a combination of HPC and Big-Data were proposed by Sood et al. [26]. To implement this system, a number of IoT devices were installed in classified geographical regions. In this framework, the flood related data consisting of attributes that are gathered by these IoT devices are processed by using High Performance Computing (HPC) and Big-Data. The attribute reduction is carried out by using singular value decomposition, the flood situation is identified using K-mean clustering algorithms (K-Means unsupervised classification technique) and the predictions for the future are done using Holt-Winter's method.

4. Possibility of IOT-based Flood Monitoring with Satellite Images

The Sentinel's SAR data provides the region's specific geographical coordinates. These details help in flood mapping and analyzing the situation more precisely [27]. The SAR images are unaffected by the atmospheric conditions when downloaded. The SAR sensors have their own source of illumination [28]. The data provided by the SAR images is efficient and can distinguish the water body and land areas. The SAR satellite images are available in Standard Archive Format for Europe (SAFE) format with the well-defined resolution-based level 1 data generally as a Ground Range Detected (GRD) product. They are in Full resolution, High resolution, and Medium resolution format[†]. This satellite data processing supports classifying flood-prone areas and monitoring them. Further, it will help in creating a robust flood monitoring system. By implementing various ML algorithms such as supervised Random Forest (RF), K-Nearest Neighbor (KNN) classification, and K-Means unsupervised classification methods on the processed SAR data, the satellite image-based observation of the distinctive water, urban, vegetation, and bare soil regions of flood-prone regions can be identified [29].

In Assam's Kaziranga National Park (KNP), different types of applications for flood mapping and monitoring have been generated using Geographical Information systems (GIS) and Remote sensing methods. A distinct set of inundated and highly moisturized cloud-covered areas is available as SAR data. The Sentinel-1 series satellite data

[†] *XML Encryption WG*. URL: https://www.w3.org/Encryption/2001/.

have been used to record flood levels and their severity which has helped in taking many important decisions [30]. In 2017, the dual-polarized Sentinel-1 SAR data and Landsat OLI data of KNP over unsubstantiated classification has been utilized in the analysis of spatiotemporal flood levels. In July and August 2017, the SAR images provided data on two flood waves. It was observed that the second wave had a higher intensity that had inundated huge regions. This SAR data was extremely helpful in real-time flood inundation mapping and monitoring. The SAR data is reliable as it is extracted from Sentinel's all-weather supply of imagery. Hence, this can be widely used to monitor any specific region from time to time repeatedly.

A flood monitoring system presented by Martinis et al. [31] utilizes a moderate-resolution imaging spectroradiometer (MODIS) and SAR images to gather flood data as part of its crisis management module. The TerraSAR-X based flood mapping service derives high resolution information for inundation level mapping. Though satellite image processing is widely implemented for flood monitoring, the process is dependent on the single data usage which is gathered in a specific period of time. The collection of information based on SAR data is quite accurate, but the execution of the process is exhaustive in terms of frequency and requires consideration of regional based environmental attributes. This drawback can be addressed by integrating IoT techniques for more robust and accurate flood monitoring.

4.1. Flood Monitoring using Sentinel Satellite Images

Some of the images do not address the bimodal distribution theory. The mountain shadows and the low backscattering intensity vegetation cause omissions due to salt-and-pepper noise and misclassifications. This was acknowledged in the year 2020 during heavy inundations in the Yangtze River basin of China. To address these issues, an improvised flood mapping over the Otsu method was proposed by Chen and Zhao [32]. This is an automated flood-mapping technique that can solve the issue of a higher segmentation threshold of images. The topological relationships and a Digital Surface Model (DSM) local search algorithm exist on Google Earth Engine (GEE). The Sentinel-2 data has been utilized to map vegetation and water areas and the Sentinel-1 data was used in mapping floods using the Otsu method. From the maps generated on the surface water occurrence, higher accuracy of 96.2 and 98.6% was achieved for plains and terrain. The frequency of approximately 0.5 denotes the water region inundated rapidly with heavy rain. The value of frequency of approximately 1 represents the permanent water region and the lower frequency represents the affected area. The time required to download data and storage could be drastically reduced by the deployment of the flood mapping algorithm. Yet there are a few limitations of this method. The misclassification was addressed by the immediacy and coarse resolution of Advanced Land Observing Satellite' Global Digital Surface Model (ALOS DSM) data. However, higher tolerance must be set due to the ALOS DSM accuracy. Additionally, monitoring narrow and smaller rivers or lakes is limited in Sentinel-1 images due to the resolution and imaging mode.

Xue et al. proposed the Sentinel image's normalized difference flood index (NDFI) with the summer permanent water bodies (SPWB) based NDFI-SPWB framework [33]. This framework aims to interpret the flood maps visually and decide the misclassification and omissions. This framework extracts the damages caused in the flood-prone region using NDFI and identifies the flooded area. To identify the range of SPWB, the probability of water area is detected through a combination of multiple remote sensing indexes. Further, the initially extracted results are optimized using the SPWB exclusion layer. The calculation of NDFI is done using the formula:

$$NDFI = \frac{\text{mean}\sigma 0\ (\text{“reference”}) - \text{min}\sigma 0\ (\text{“reference + flood”})}{\text{mean}\sigma 0\ (\text{“reference”}) + \text{min}\sigma 0\ (\text{“reference + flood”})}. \quad (1)$$

Where, the mean (“reference”) is considered as an average against the min (“reference + flood”) which is the minimum value of the image pixel's backscatter coefficient. The picture component when less than -1 or more than 0 is the outlier to be removed. This will ensure the consistency and accuracy of the results. The threshold is calculated using:

$$th = mean(NDFIflood) - k * std\ (NDFIflood). \quad (2)$$

Where, th is the threshold, std (NDFIflood) is the standard deviation, and mean (NDFIflood) is the average value of the difference image. Based on the proposed framework with no escalation in omission error, the overall accuracy is improved with no change in producer accuracy whereas the user accuracy increased by 10% and the Kappa coefficient increased by 0.08 approximately. The source for flood data is also available as Global Flood Monitoring (GFM) from Copernicus Emergency Management Service (CEMS). It is a robust setup that uses SAR data for monitoring floods globally and near real-time (NRT) monitoring. By using a local parameter with precipitation, the SAR imagery is clearly distinguished for classified and unclassified data. The process is based on an enhanced global data-cube algorithm structure with harmonic time-series analysis. This is an integrated component of GFM. The unresponsive regions and observations are featured exclusively. The Bayes classification decision engine that works on this algorithm executes faster during near real-time flood mapping [34].

4.2. Flood Monitoring with the Integration of IoT Techniques Using Satellite Images

An ensemble model has been proposed by M. Khalaf et al. [35] that the use of various ML algorithms with IoT sensor data is a reliable method of predicting the water levels severity. Automated analysis of previously stored information can be well utilized in the early prediction and prevent disasters. A set of 11 attributes from sensor data was analysed using the long short-term memory (LSTM) algorithm. The ensemble LSTM classifier data accuracy contributed towards the detection of water level severity. An IoT-enabled flood severity prediction model is shown in Figure 5.

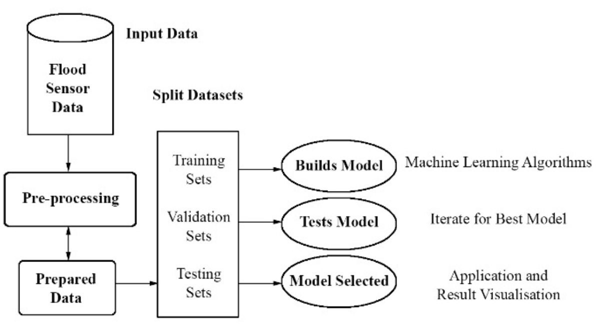

Figure 5. IoT-Enabled Flood Severity Prediction via Ensemble ML Models [35]

4.3. Proposed Framework for the New Flood Monitoring and Early Warning System

The development of a new FMEWS system with integration of SAR images implements image processing on Sentinel-l images is proposed. Additionally, an IoT sensors-based module that detects inundation levels would be a more appropriate approach for identifying flood prone areas and comparing them with the SAR processed images for accuracy. This is expected to guide the decision-making authorities in taking precautionary measures accordingly. Eventually, the use of ML algorithms and the integration of IoT sensor data and satellite images for flood monitoring would be an ideal way forward to achieve accurate, multi-variance data-based outcomes to analyze and evaluate the efficiency of processes. The proposed IoT-based flood monitoring and early warning system (FMEWS) is shown in Figure 6.

All methods have different techniques for performance evaluation and use different metrics to evaluate the effectiveness of relevant approaches. The use of various ML algorithms as a new approach that can be followed will also involve exploring and implementing optimization techniques by utilizing swarm optimization and genetic algorithms along with the use of IoT Sensors will always be an added advantage. The proposed SAR module would be supported by change detection techniques and the IoT sensor-based module uses SAR interferometry data further

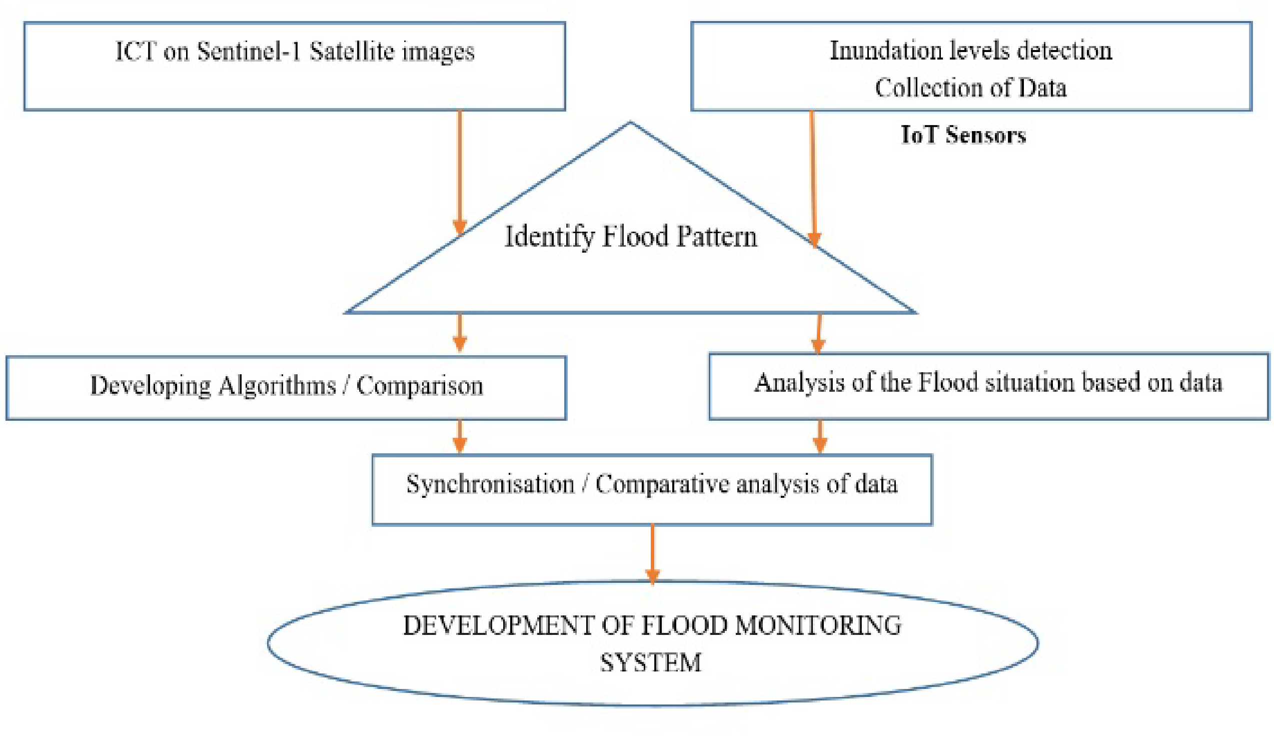

Figure 5. IoT-based flood monitoring and early warning system (FMEWS)

paving the way for effective comparative analysis and an enhanced outcome. The system will help in evaluating the quality of service based on the results generated. Further, using this integrated system can greatly influence the decision making of relevant authorities to mitigate the floods in the concerned areas and safeguard life and properties. The proposed framework can be improved further to address other potential risks such as landslides and emergency mapping support during earthquakes. The researchers should explore different ways with a strong commitment to study climate change and its impact based on data from hydrological, meteorological, and satellite-based information. This would help in measuring the inundation levels across different regions and address the issues accordingly.

5. Conclusion

IoT sensors-based flood monitoring systems tend to be lower cost, consistent and portable. However, when there are large areas, these systems are not recommended due to the fact that every sensor is generally invigorated by a vitality restricted battery. This paper reviewed and clarified different ecological and flood monitoring systems and various communication technologies that support enhancing the detection of viable floods and identifying cautioning issues. Further, these systems that are having highly reliable sensors with powerful IoT cloud platforms can be fundamentally utilized for large-scale environmental monitoring, and flood prediction and prevent damage caused by it. Even though the methodology of utilizing IoT in flood monitoring is not extensively explored at this point, we will see a colossal utilization of IoT and some new advancements in the near future. For example, AI and 5G techniques meet up for the prediction of floods as well as other natural calamities. The use of satellite images could be very helpful in flood monitoring as they help to keep an eye on the water bodies and the change in their behaviour from above. Some researchers have utilized data based on Google Maps to build a detection model. GSM modules also have been used in different ways similarly. Close consultation with hydrologists and learning machine-learning algorithms can further support building efficient monitoring and alert system. In the future, the usage of SAR data from the Sentinal-1 satellite is an added advantage in handling rescue operations and damage assessments based on data before and after floods. The wireless sensors can help in gathering flood related data by creating a database for further analysis. As a recommendation, there is a tremendous opportunity to explore the combination of IoT systems and SAR data to classify the images from flood-prone areas and develop robust and secure Flood monitoring and early warning system.

Declaration

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