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A Machine Learning and IoT based approach for Flood Monitoring and Prevention

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ABSTRACT
The Internet of Things and Machine Learning algorithms have brought about a revolution in the field of technology as it has treated several common problems at ease. Things have become automated and easier due to the advent of these techniques. Floods have drained out civilizations and are a serious threat as ever. Internet of Things along with Machine learning is tried out in this paper to bridge the gap between arrival of the flood and the cautionary measures to prevent loss of life and property. In this study, a unique, advanced and a very efficient IoT based sensor system is proposed to set the scheme of sending the notification through SMS alert whenever water level and rainfall count crosses the threshold value. The other extent of this paper is the future prediction of upcoming floods and heavy rainfall through Machine Learning algorithm.
***Keywords* -** Node MCU, Ultrasonic Sensor, Water Flow Sensor, SMS Alert, Machine Learning, Internet of Thing

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I. INTRODUCTION

Flooding has become one of the major issues in India. It has become a disaster in many places of India leading to loss of life, time, property and money. As such India is one of the world's most flood prone countries today. One of the major causes for heavy rainfall is the South West Monsoon winds hitting India in the monsoon months. Human beings suffer much due to the showers since they are not aware of the upcoming events. An alerting and future predicting system cannot prevent floods but can help to save people, property or money. Internet of things furthermore referred to as the commercial net has been able to successfully connect billions of devices together. It is expected that 50 billion devices are supposed to be connected by the end of 2020 through IoT technology. IoT coverages the advancement of various arenas like industry, agriculture, healthcare and automobiles. It also provides improved home automation along with automating numerous routine activities. The array of applications smoothened by the Internet of Things has made exchanging data and information much faster. IoT displays a fundamental role to incorporate many smart applications in real life. The smart IoT flood monitoring system shows a major role for helping the government and society to manage the situation of flood victims and henceforth, it reduces the disaster effect. The alarm monitoring is a vital task in complex industrial services like power systems [1], chemical industries [2], oil refineries [3] and large-scale networks like computer [4], sensor networks [2] and communication [6]. These are generally controlled with a large number of communication devices, sensors, control modules and actuators. It is a great challenge for designing an efficient alarm system considering the complex features of these components, such as nonlinearities, process correlations etc. Likewise, in this paper we deploy IoT to send information from the sensors connected to Node MCU to the Thingspeak server. This data is used to generate SMS notification whenever there is a fluctuation beyond threshold level. Furthermore, we use Machine Learning algorithm ARIMA to predict the occurrence of the upcoming floods.

II. LITERATURE SURVEY

The existing works refer to systems for monitoring flood and giving early alert of the same. They focus on real time data of river conditions and water levels. Leman stated the current condition of Malaysia Disaster Management and the need of developing efficient flood management and prediction system to maintain low risk [7]. Lo suggested the system for cyber surveillance and image processing methods to obtain instant waterlogging and flooding feedback [8]. Baharum proposed the system of sending SMS messages on readings of a flood detector [9]. Jana Priya [10] and Satria [11] have used Ultrasonic sensor to monitor the water level and alert the neighbourhood. Sakib presented an intelligent flood monitoring system based on wireless sensor networks [12]. Matgen proposed a hybrid methodology from SAR images combining radiometric threshold and region growing approach enabling flood extent extraction [13]. Kuang developed a remote flood monitoring system based on plastic optical fibre (POF) sensors and a wireless distant network [14]. Dottori presented some recent advances of an experimental technique for real time flood mapping and control assessment [15]. Manfreda established a flood assessment monitoring system using basin morphology [16]. Oddo integrated a socio-economic loss valuation model with a real-time flood remote sensing and judgemental support device [17]. Bhosale explained an overall review on the implementation of flood monitoring structure in the different flood effected areas around the globe [18]. The distributed sensor nodes collect information about the water level from river, rainfall, wind speed, air pressure from a selected site by using the IEEE 802.15.4 protocol. The sensor data are conveyed to the alert centres by the means of Arduino and Xbee transceivers. At the receiving centres using Raspberry pi and Xbee transceivers generate alert based on the sensor data after analysing with neuro fuzzy controller and then store in a database. However, this system is a bit costly and less effective. Adam proposed a compact broadband ambient RF energy harvester operating from 1800 MHz up to 2.5 GHz that utilizes the conversion of enormous amount of free and endlessly available RF energy in the surroundings into the operating energy [19]. Architecture of floods warning alert system was developed by Aziz with linkages among data collection to undertake risk valuations and improvement of threat monitoring services, communication on risk related information and survival of public response capabilities [20]. Bai in his paper focused on the formation of an urban flood control system in Xicheng district of Beijing using the detection of rain water monitoring sensors placed in some lower yards or long-standing water accumulation regions. This system took a good advantage of sensors and 3G network technology [21]. Balaji designed a ZigBee based Wireless Sensor Network for early flood monitoring and warning system safeguarding low cost and low power consumption. He ensured that the flood alert system provided the water level information to the public in their mobile application even without network connectivity. It helped them reach a safer place through stored images [22]. Zahir projected a Smart IoT Flood Monitoring system which had a simple and straightforward monitoring interface, adequate data on flood level, and upcoming temporary water level prediction [23]. Varma described a system which used Internet of Things to monitor flood situations near the dam with the help of MEMS Level, temperature and humidity sensors. The microcontroller along with these sensors, the data was processed and then these data were tested in the webpages from the database and generated an alert to the surrounding communities [24]. Singh established a Flood Monitoring and Alerting System with Weather Forecasting model which utilised temperature and humidity sensor DHT11/AM2302 and ultrasonic sensor for the detection of water level and by measuring time between transmitting and receiving sound waves [25]. To control devastating flood in Kolhapur, Sangli and Satara in Maharashtra faced recently, there was an urgent need of efficient flood monitoring systems. Concentrating on the fact, Joshi offered a model for measuring water level at dam or on river bridges. The measured value is regularly updated on cloud to send flood alerts to concerned authority and society for quicker action [26]. Hu suggested a data driven method by detecting frequent patterns in alarm floods from historical alarm data based on the formulations of the identification and removal of alarm floods. He adapted frequent alarm patterns for establishing the plots of alarm patterns [27]. Rani used rain sensors to measure the intensity of rainfall in millimetres and established a system providing the required information on IoT gecko platform by calculating the probable time taken for the flood [28]. Priya prepared a model using the mobile standard Global System for Mobile Communication (GSM) and ARP33A3 for the recording of voice message to residences for sending flood alerts [29]. Junior made a software tool for mobile application to send the confirmation generated by CEOPS, thus enabling information and flood warnings via text messages to people quickly [30]. The CEOPS/FURB is responsible for the warning system of Itajaí's Valley. This system demanded services in real time of hydrologic forecasting and simulation researches. Momo suggested Cloud Computing based model to meet the requirements of CEOPS [31]. Yumang developed a device based on Arduino Uno, GSM shield and sensors power-driven by a solar panel with generator and using LEDs mounted on PVC pipe generating the alarm service to the people in the community [32].

In this paper the primary objective is to develop a system by using the ultrasonic sensor, water flow sensor which gives real time alerts whenever there is excess of water flow or whenever the water level rises beyond a certain threshold. The future flood prediction system based on the previous records is an added advantage and makes the system more robust. This approach has not been taken till date to resolve the problem of flooding and prevention of life hazards at large.

III. SYSTEM METHODOLOGY

The working process of this system is based out of a Node MCU, Ultrasonic sensor, water flow sensor. The ultrasonic sensor measures the water level, the water flow sensor measures how much water has been transferred, i.e. the water flow rate and volume measurement. The data is recorded by using a microcontroller Node MCU. It has a ESP-8266 chip fitted on it. The ESP8266 chip helps us to send data from the Node MCU to the cloud server Thingspeak. These sensors provide information over IoT using the Node MCU. The data obtained in the cloud server is then monitored continuously and an alert is accordingly sent to the concerned people via IFTTT whenever an anomalous situation arises. Furthermore, the data can be visualised in an application made using MIT app inventor. The previous data of the sensors and rainfall are stored in the excel sheet for processing using Machine learning algorithm ARIMA in Jupyter Notebooks. The algorithm predicts the future days/time when there will be excess rainfall leading to floods. This entire system helps human beings evacuate a certain place timely without any risk. The block diagram for the above process is shown below in Figure1:

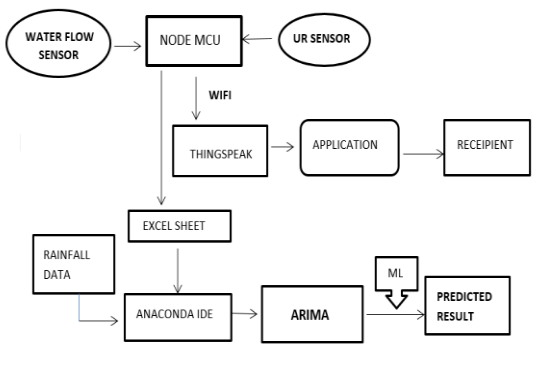

Fig 1: Block Diagram of the system

IV. Hardware Design

Node MCU: Developed by Espressif systems, it is a single board microcontroller having development kit for IoT projects. As shown in Fig2. It has an ESP-8266 chip on it which enables to send data over WIFI. The firmware as well as the scripting Language is the open source language. Its firmware uses Lua scripting language. RAM is 128kb and flash memory provided is 4Mb. It has I2C, I2S and SPI interfaces.

Fig 2. Node MCU

Ultrasonic Sensor: Usually labelled as HC-SR04, it is used to measure distance or level. It works on basis of sound waves. Whenever an obstacle is detected in trigger path the reflection is caught in the echo path. Dust, dirt, particulate matter doesn't affect the detection. Ultrasonic sensor is able to detect complex shaped objects. It is shown in Fig.3

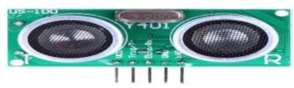

Fig 3. Ultrasonic Sensor

Water Flow Sensor: It is used to calculate the water flow rate and volume. A water rotor, hall-effect sensor and a plastic body comprises of the sensor. The rotor rolls as soon as water flows through it thereby changing the speed of rotation according to the flow rate. The output is provided by the hall-effect sensor as a digital pulse. Thus the rate of flow is calculated easily. The sensor is shown in Fig.4.

Fig 4. Water Flow sensor

V. Software Design

Thingspeak:

It is an open source IoT platform that allows us to visualise, access data. It is based on MQTT and HTTP protocols. Constant monitoring of data over the internet is possible through Thingspeak.

Machine Learning Algorithm- ARIMA:

It is a machine-learning model for time series forecasting. ARIMA stands for Auto Regression Integrated Moving Average Model. It is a more generalised model of simple Auto Regression and adds integration to it. Each of the words of this model is equally descriptive. The ARIMA model has normal parameters and the notation used is ARIMA (p,d,q) where p stands for the lag order, d stands for degree of differencing and q stands for moving average. A linear regression model is made by using

the specified number and type of terms and the data is prepared by a degree of differencing so as to make it stationary, i.e.to remove trend and seasonal structures that have a negative effect on the regression model.
The procedure of our work is depicted in the flow chart as shown in Fig.5.

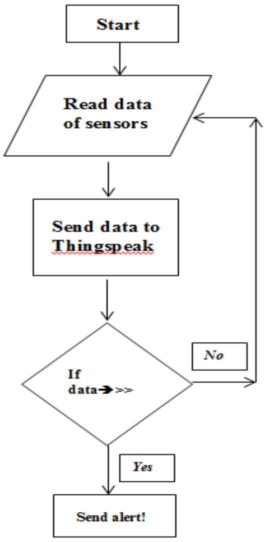

Fig. 5. FlowChart

VI. Work Flow

1. The first step starts with interfacing the Node MCU with the sensors. The sensors used here are the Ultrasonic sensor and the water flow sensor. They were used for measuring the water level and the water flow as well as the volume measurement. The circuit setup is shown in the Fig.6 below :

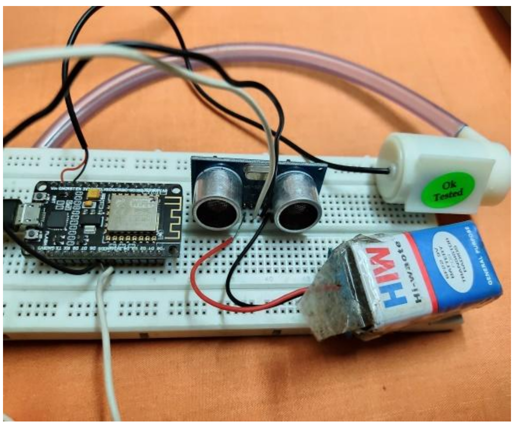

Fig.6 Interfacing the Sensors

2. The next step that was performed was to connect to the ThingSpeak server so that the data of the sensors were monitored continuously. The connection was established with the help of a WiFi network.

3. After the connection was setup, the data readings of the sensors were visible in the ThingSpeak server. The data were present in the form of several fields in the channel The visualised data of water level are shown below in Fig.7

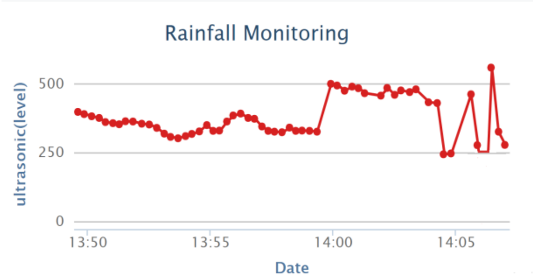

Fig.7 ThingSpeak channel display

4. Next, the data were taken into excel sheet rather the data obtained were imported into the excel sheet for applying machine learning algorithm. The rainfall data were also obtained from previous records externally.

5. The data obtained were then transferred into Jupyter Notebook for further analysis and prediction using ARIMA algorithm, i.e., for time series forecasting.

6. After cleaning the obtained data and arranged the data into suitable format, the ARIMA model was constructed for performing the further processes.

7. To stationarize the series by differencing, first the rolling statistics were found out. The plot obtained is shown below in Fig. 8

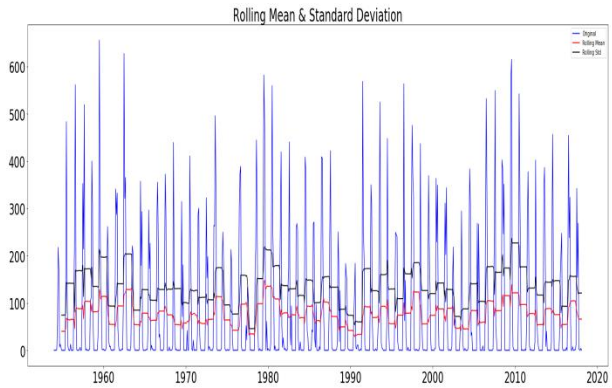

Fig. 8 Rolling mean and standard deviation

8. Dickey Fuller test was performed next to check whether the series was stationary or not. The output is shown below in Fig.9

```
Results of Dickey-Fuller Test:
Test Statistic                  -7.197294e+00
p-value                          2.415998e-10
#Lags Used                       2.000000e+01
Number of Observations Used      7.490000e+02
Critical Value (1%)             -3.439111e+00
Critical Value (5%)             -2.865407e+00
Critical Value (10%)            -2.568829e+00
dtype: float64
```

Fig. 9. Dickey- Fuller test.

9. The pattern of autocorrelations and partial autocorrelations were studied to determine if lags of the stationarized series and/or lags of the forecast errors should be included in the forecasting equation.

10. Based on the previous steps the model that was suggested was fitted and its residual diagnostics, particularly the residual ACF and PACF plots were checked. The plot obtained after performing this step is presented below in Fig.10

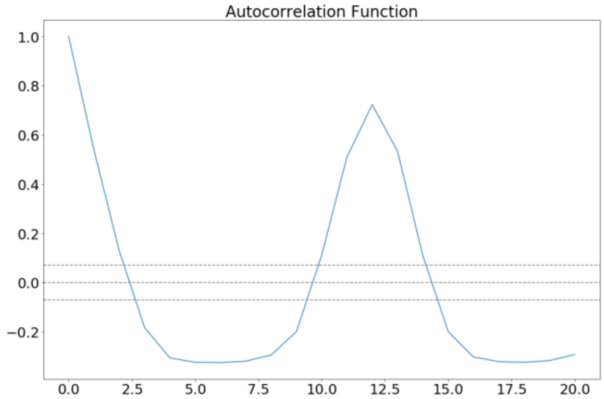

Fig. 10a. The ACF plot

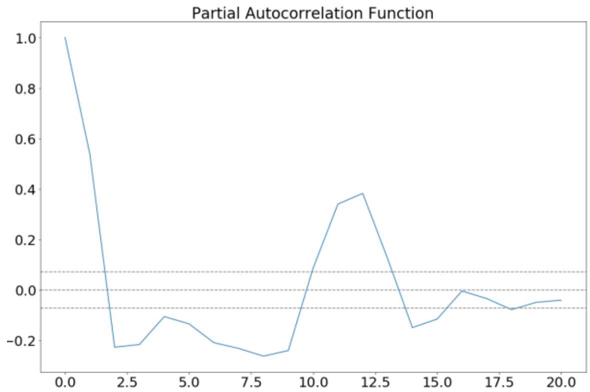

Fig. 10b. The PACF plot.

11. The model was now built and RSS technique was then applied to it in order to check the amount of error between the forecasting function and the dataset. The graph obtained is depicted below in Fig. 11

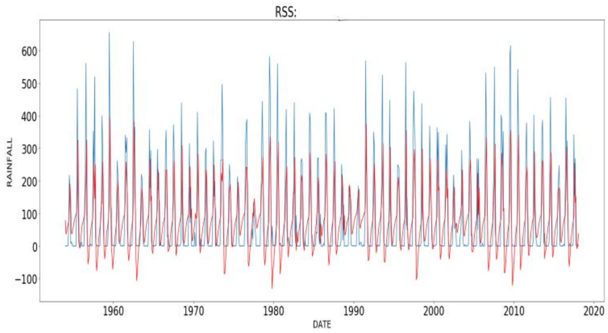

Fig. 11. Plot of Residual sum of squares.

12. Finally the forecasted data were obtained after these processes. A RMSE or root mean square deviation method was applied to check the variance between the obtained data and the values observed in practical. The RMSE plot is presented in Fig. 12. Finally after adjustments the predicted graph is obtained as in Fig.17

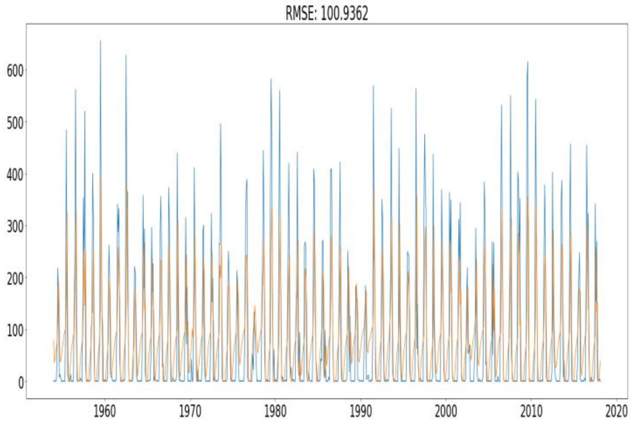

Fig.12. The RMSE plot

VII. Result Analysis

The circuit diagram of the hardware implementation of the system is as shown in Fig 13:

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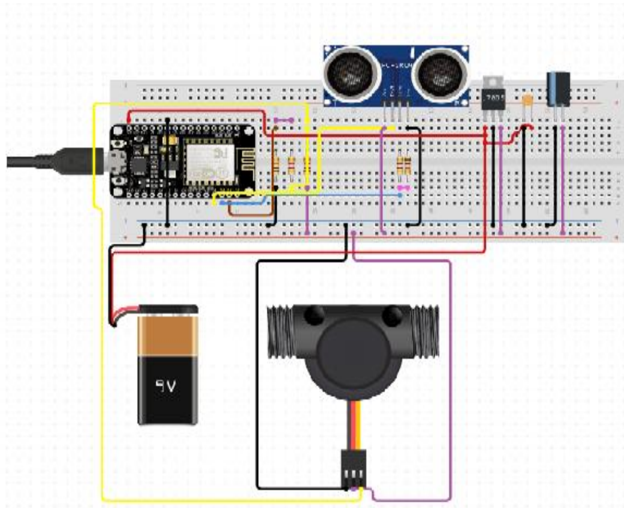

Fig 13**:** Circuit Diagram

The forecasted data were obtained using the ARIMA model. The dataset of annual rainfall [from 1954-2017] , the water flow and water level data delivered the forecast. The results are shown below in figures 13 and 14:

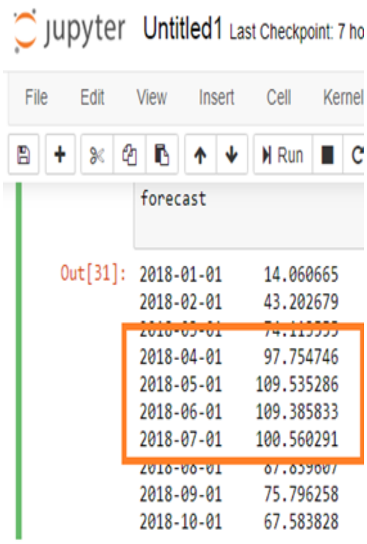

Fig 14. Predicted Output

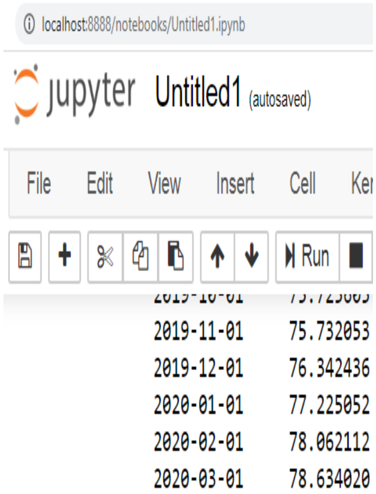

Fig.15 Predicted output

The readings shown in the figures 14 and 15 display the predicted output of the rainfall. It can be noticed that during the month of July and August, the rainfall was quite high with around 107-109 units, an indication of flooding. It is seen that there is reduction in rainfall as the monsoon months passed. The readings below depict the change observed. In the next figure (Fig. 15), it is witnessed that there was moderate rainfall and hence there was no flooding during that period. The reading ranges from 75-78 units which indicate that there was optimum rainfall. Hence there was no flooding. The outcome generated by our system corresponds with the occurrence of actual rainfall.

Fig16. Data display in app

The flood analytics app is designed for monitoring water level and generating flood alert shown in Fig.16. The reading of 65 units as seen in the screen of the app indicates that there was no flooding recently. Correspondingly an increase in water level beyond threshold will trigger an alert in the form of a SMS notification and the "alert" tab will change its colour to red.

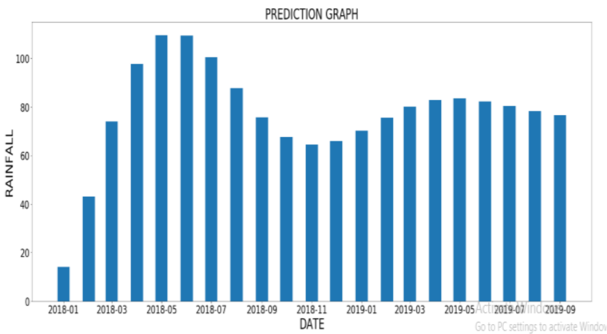

Fig17. Graph of Predicted output

The graph shown in Fig.17 shows the predicted output of the year 2018. As seen, there was high rainfall in the four months (April – July) due to which there was a flood in India. The data ranged over 100 units which indicated the fact that there would be flooding during that period. In the later phase of the graph the values were normal and there no floods took place.

VIII. CONCLUSION

India has been under flood disasters very often. Our IoT based flood monitoring system will help in water level observation and proper prediction of flood in India. The predicted data along with the sensor alert will help the management function more efficiently leading to proper evacuation of people and hence the saving of lives of human beings and can be used to diminish the huge losses faced by the society. This system can further be extended towards specific regions and areas which can face adverse effects.

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