AN INTELLIGENT REAL-TIME STORMWATER MANAGEMENT MONITORING WITH SMART PREDICTION

Dr. Mangesh Dindayal Nikose[1], Prof. Namrata D. Ghuse[2], Dr. Swati Avinash Gade[3]

Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

The primary benefit of remote sensors is the smart intelligent predictive real-time stormwater management monitoring (SISWM2), which automatically recognises and detects rising water levels and notifies locals of impending flooding. The goal of the study was to determine how adding sensors to green infrastructure (GI) may reduce stormwater rise in urban areas. The problems connected with stormwater runoff from infrastructure, such as habitat destruction and river siltation, call for monitoring. The primary purpose of an early warning system for flash flood control due to rapidly increasing stormwater is to notify residents of the possibility of impending floods. Technology advancements are required to safeguard people's lives and property, which is why some towns have installed flood prediction sensor networks.

Keywords: Stormwater occurrences, flood control techniques, sensor networks, and green infrastructure.

[1]Associate Professor, Department of Electrical and Electronics, School of Engineering and Technology, Sandip University, Nashik, Maharashtra 422213
[2]Associate, Professor, Department of Computer Engineering, Sandip Institute of Technology & Research Centre, Nashik, Maharashtra 422213
[3]Associate Professor, Department of Electrical Engineering, Sandip Institute of Engineering and Management, Nashik, Maharashtra 422213

Email: [1]mangesh.nikose@sandipuniversity.edu.in, [2]namrata.ghuse@sitrc.org, [3]swati.gajeshwar@siem.org.in

DOI: 10.31838/ecb/2023.12.s3.117

1. Introduction

Tens, hundreds, or even thousands of people perish as a result of flash floods each year in the United States. The National Weather Service reports that 8307 people died in flash floods between 1940 and 2020. Even with the pandemic, there were 57 flash flood fatalities in 2020, compared to 187 deaths from flash flooding in 2015, 92 deaths from flash flooding in 2019, and 187 deaths from flash flooding in 2015. When individuals are walking through floods or driving through stormwater loss control, they drown. To effectively address the problems brought on by urbanisation and climate change in contemporary society, a predictive real-time stormwater monitoring is required. The creation of an adaptable, cost-effective forecasting system will enable swift action for creative investments in human health. Urban flood runoff has detrimental environmental health consequences from pollution and economic repercussions, which resulted in property losses costing the U.S. an estimated $3.75 billion in 2019. It has substantial negative effects on the economy, people, and environment, including harm to individuals and damage to infrastructure.

A stationary stormwater infrastructure system that includes adaptive real-time monitoring will also result in significant environmental safeguards. Increasing urbanisation creates a large number of impervious surfaces, which make it difficult to control flooding sustainably and result in flooding during severe rains. Due to fast population expansion, particularly in metropolitan areas of the world, land usage considerably boosted building activities, which disrupted ecosystems and interfered with the natural hydrologic cycle (O. Aladesote, 2019). As there is less evapotranspiration and infiltration in most metropolitan areas, impervious surfaces placed more demands on communities (Raeder et al., 2008).

Also, because of poor drainage brought on by clogged drains during rising floodwaters, aged grey infrastructures largely contributed to the issues created by today's climatic changes. Floods happen in most parts of the world, and because of climate change, they can happen at any time of year. The majority of low-lying terrain areas and river sites are vulnerable to flooding during severe downpours. (O. J. Aladesote & Hunter, 2020).

The primary purpose of an early warning system for flash flood control due to rapidly increasing stormwater is to notify residents of the possibility of impending floods. The goal of this study is to develop a low-cost, straightforward sensor for measuring water levels, and the information gathered will be used to predict flood danger. This study's main goal is to create sensors that can detect water levels early and warn locals of potential threats. sending out warning signs to protect people from the possible risk of floods (Bae & Ji, 2019); as stormwater runoff from rain is a normal occurrence. The flood prediction sensor network deployed in many towns is a result of the requirement for technology advancements to preserve human lives and property. Better warning networks will be produced by gathering large quantities of spatial resolution dimensions data utilizing an intelligent stormwater prediction system. The flood project uses low-cost sensors that work well with either grey or green infrastructures using a predictive sensing system as a resilient technique to construction designs.

2. From 1980 to 2021, an estimation of the cost of stormwater management in the United States A. Events costing $1 billion or more that will have an impact on the US between 1980 and 2021

Table 1: (Butler et al., 2018) as a source

Disaster type	Events	Events/ Year	Percent Frequency	Total Costs	Percent of Total Costs	Cost/ Event	Cost/ Year	Deaths	Deaths/ Year
drought	29	0.7	9.40%	$285.48	13.20%	$9.8B	$6,8B	4,139	99
flooding	35	0.8	11.30%	$164.2B	7.60%	$4.7B	$3.9B	624	15
freeze	9	0.2	2.90%	$32.8B	1.50%	$3.6B	$0.8B	162	4
Severe storm	143	3.4	46.10%	$330.7B	15.30%	$2.3B	$7.9B	1880	45
Tropical cyclone	56	1.3	18.10%	$1,148.0B	53.20%	$20.5B	$27.3B	6,697	159
wildfire	19	0.5	6.10%	$120.2B	5.60%	$6.3B	$2.9B	401	10
Winter storm	19	0.5	6.10%	$78.6B	3.60%	$4.1B	$1.9B	1,277	30
All Disasters	310	7.4	100.00%	$2,159.9B	100.00%	$7.0B	$51.4B	15,180	361

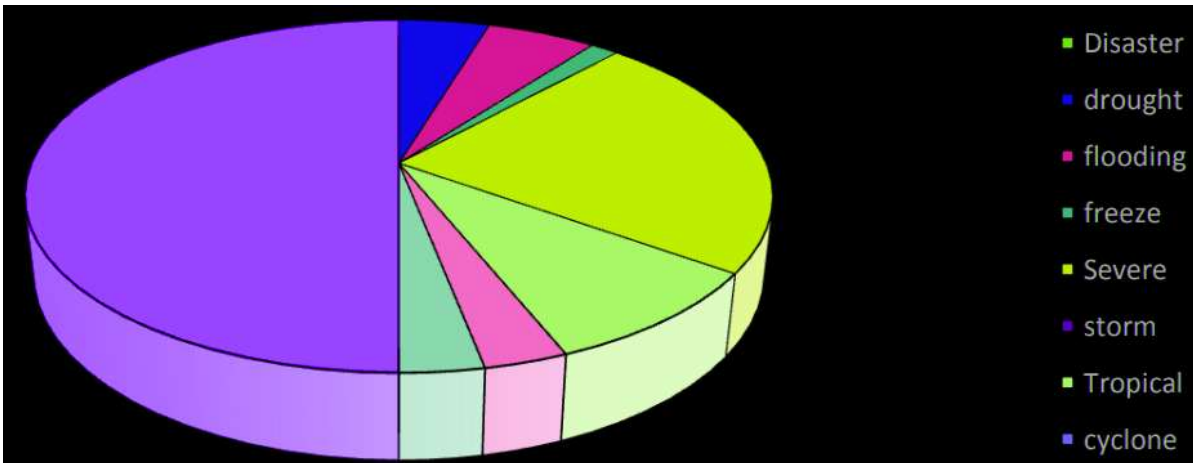

Figure 1: From 1980 through 2021, the US saw billion-dollar occurrences

B. Comparisons of Drought, Freeze, Severe Storm, Tropical Cyclone, Wildfire, and Winter Storm Data in the United States throughout Time

Table 2: (Butler et al., 2018) as a source

Time Period	Billion Dollar Disasters	Events/ Year	Cost	Percent of Total Cost	Cost/Year	Death	Deaths/Year
1980s (1980-1989)	25	2.5	$175.2B	8.8%	$17.5B	2,706	271
1990s (1990-1999)	45	4.5	$228.3B	11.4%	$22.8B	2,851	285
2000s (2000-2009)	60	6.0	$540.1B	27.1%	$54.0B	3,044	304
2010s (2010-2019)	105	10.5	$807.7B	40.5%	$80.8B	5,012	501
Last 5 Years (20172021)	79	15.8	$714.2B	35.8%	$142.8B	4,475	895
Last 3 Years (20192021)	51	17.0	$271.6B	13.6%	$90.5B	975	325
Last Year (2021)	18	18.0	$142.4B	7.1%	$142.4B	681	681
All Years (1980-2021)	275	6.5	$1,995.7B	100.0%	$47.5B	14,556	347

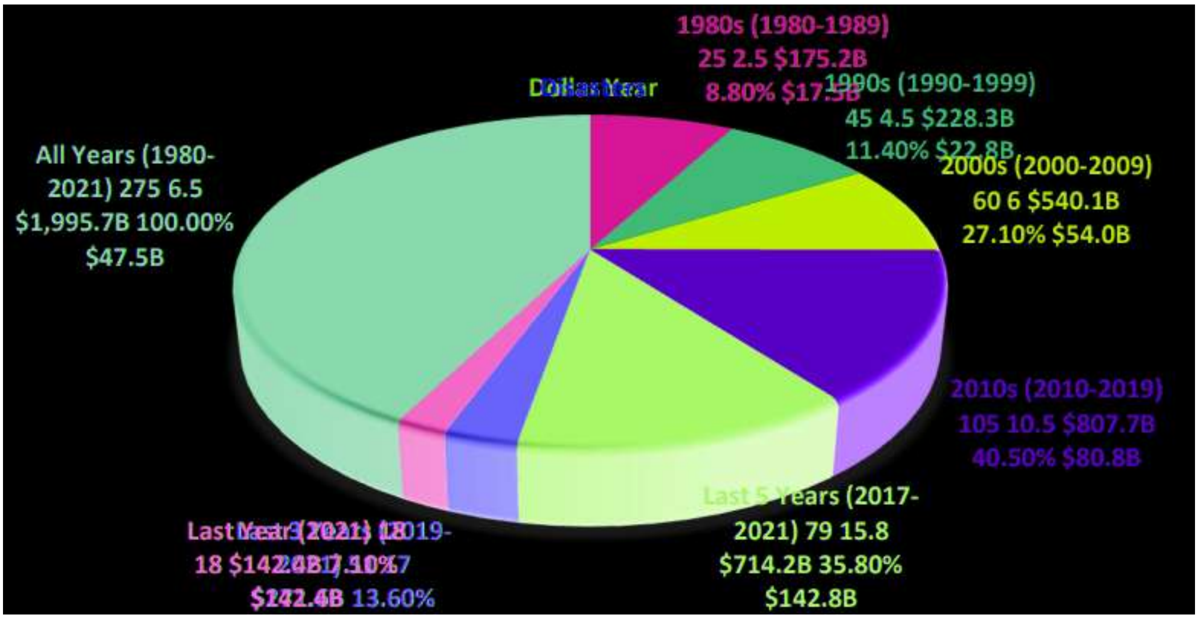

Figure 2 compares the time periods of US billion dollars.

3. Python Rainwater Prediction Using Weather Map

Create an account and log in to Openweathermap.org, then select the API tab, current weather data, API doc, and API call sections. From there, follow the on-screen instructions to establish an API key. Install Pyowm (Python Open Weather Map API) after downloading Python, then copy the API key from Open Weather Map and put it into Python 3.9.6. To obtain the most recent weather information for a certain place, issue an import request from Python.

A. SISWM2 Architecture network

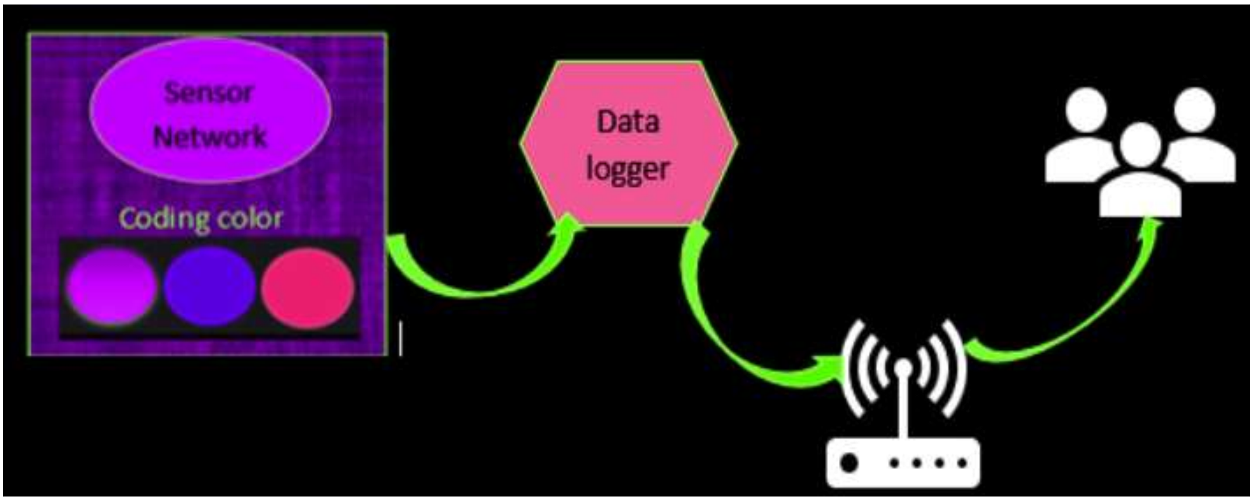

Figure 3

B. Materials for Stormwater Management Used in Pole Installation

Table 3

Activity	**Supply List**	**Remark**

Equipment/tools	water level sensors (HC-SRO4) Arduino MEGA 2560 Rev3 or SunFounder Mega 2560 R3 Temperature sensor (DS18B20 Arduino 125 degrees centigrade) Humidity sensor (DHT22) Containers to hold the sensors tipping bucket rain gauge safety color coding light will be coded as yellow (warning), coral color (flooded road), and green (clear).	
Hardware/software	Computer with Software Data logger (Adafruit Data Logging Shield) Antenna cable – 2.4 GHz, 6dBi, IPEX 170 mm long Cellular antenna Internet wifi Bread board Jumper wire (11.8in) 10mm LED's Solar panel 12 V batteries SD Card	software for reading the transmitted sensors data
Materials	Long Metal pole mast Rebar (metal) screws wires Gloves Padlock, hasps with screws. 5 by 18 inches metal sheet Ruler Water (one bucket) Hammer Drill kit Small bag of cement and sand	Screws for solar panel installation Some of these materials maybe available in the laboratory.
Record/Documentation	Camera Paper pen	Optional

5. Hardware/Software Design for Stormwater Management for Water Level Sensor

The HC-SRO4 is a low-cost, simple-to-install ultrasonic water level sensor with a usable measuring range of 2-400cm (0.2-4.0m). The control circuits, an ultrasonic transmitter, and a receiver make up the HC-SR04 module. It offers 3mm-precision non-contact measuring. It contains four pins, which are the ground pin, the receiver's echo pin, and the trigger pin (GND). Its features include a 15° measurement angle, a 5V DC operating voltage, and a 15mA working current.

Additionally, real-time data collection at the stream will be enabled by the prototype operation of the temperature, humidity, and ultrasonic sensor devices. This data will be interfaced with the microcontroller (Cypress/Arduino Uno ATmega328 microcontroller) that is connected to the IoT Wi-Fi module coordinate of the node. The device will be solar-powered, able to sample data at intervals of less than 2s, and have a micro-SD card for backup storage. Some suggested water level sensors include the MB7066, an ultrasonic device with a larger range of around 20 cm to 1064 cm. For analysis, it will be attached to a 32-bit microcontroller, solar power with a rechargeable battery (12V 80 Ah), and cellular communication module. For planning and assessing flood risks, this study's surface flooding data will be employed.

A. Network architecture

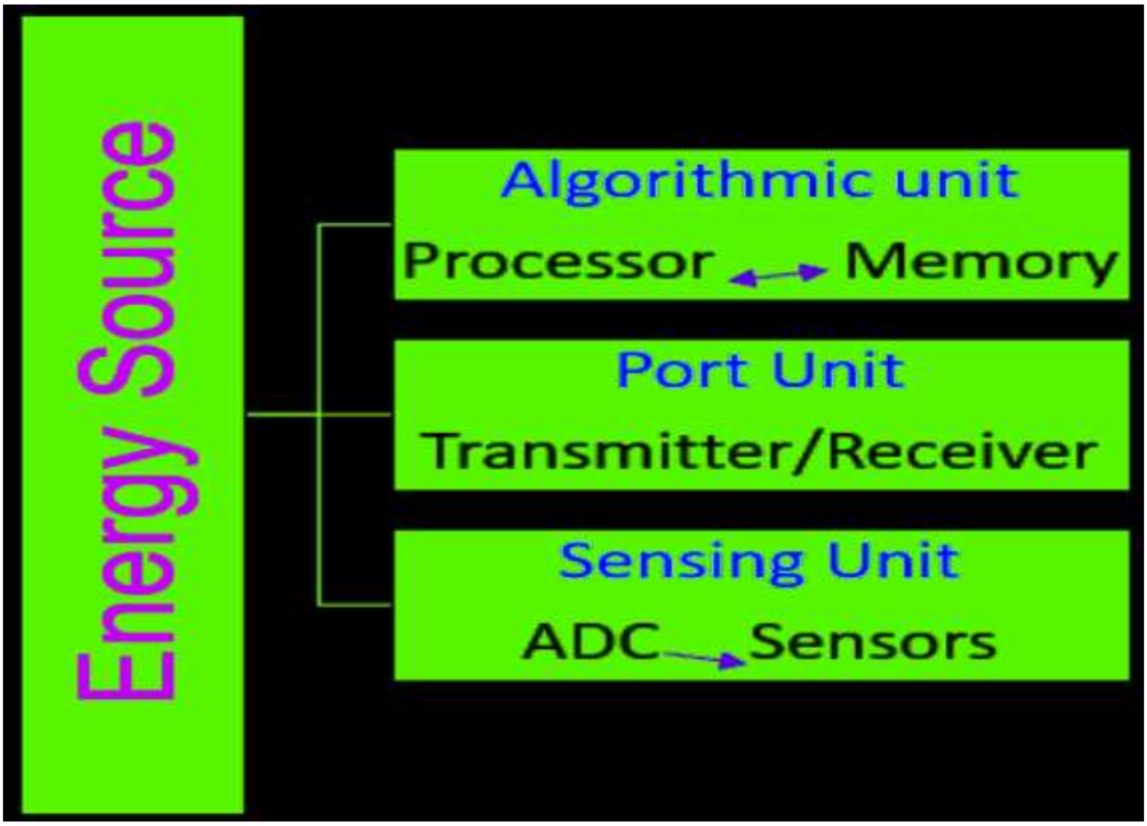

Figure 4

As flooding is a widespread problem that has an impact on humanity as a whole, this research performed an extensive evaluation of many studies carried out throughout the globe. It provides a summary of the methods for stormwater management that are most effective both locally and globally(Dachyar et al., 2019). Flooding has created numerous problems for people, particularly in highly populated metropolitan regions (Duncan et al., 2011), but technology has developed to address many of these issues on a regular basis. Natural occurrences like floods posed a serious threat to human life, especially when no early warning was given to individuals in various environmental contexts. An integrated optimization rule-based model is provided by (Ham, 2013) to reduce the effects of floods on rivers. In order to demonstrate the amount of precipitation hazard for one to six days, a flash flood early warning system research in the northeastern section (Hoang Su Phi) of Vietnam employed hydrological and geomorphological method with a warning map (Ham, 2013). The majority of low-cost technical designs are above water (Kim et al., 2019) to avoid corrosion and environmental factors.

5.2. Network architecture design

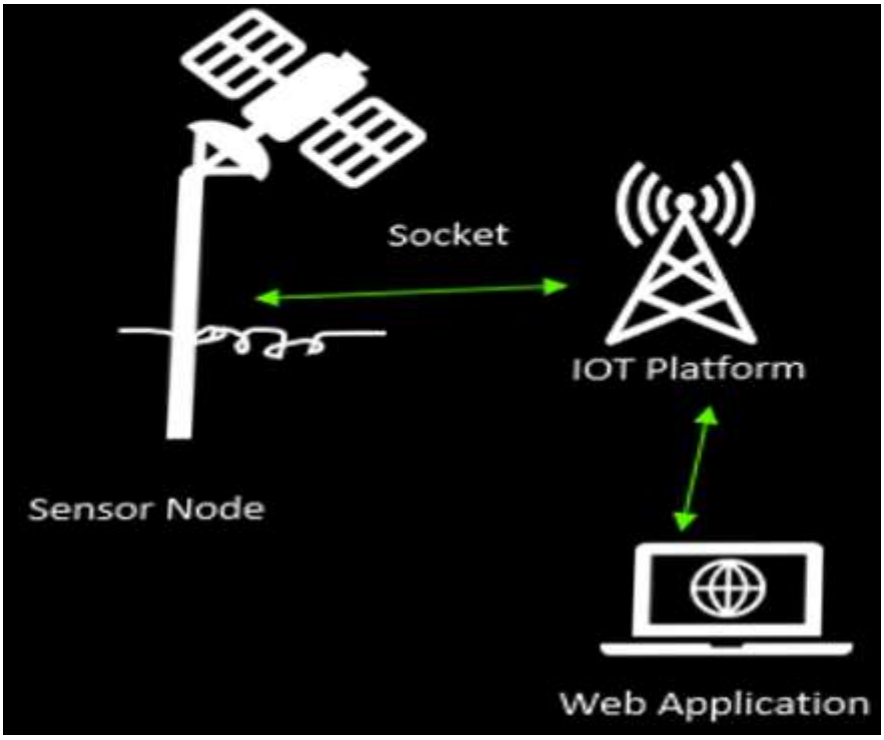

Figure 5

studied network video record for in-situ water logging monitoring photos during floods interfaced with urban flood motes sensors system. The network cameras were set up to collect video information, and the water level sensors were set up to receive information about the water level. The data processing module, which is run through a computer server and provides information to end users, receives signals from the network cameras and water level sensors (Leys et al., 2013).

Additionally, the findings of the Lockridge 2016 research demonstrated that the temperature measurement at the Dauphin Island Sea Lab was 0.154oC with a highly correlated regression temperature device value of r2 = 0.99, demonstrating that the devices' functional testing evaluation was sufficient (Leys et al., 2013).

5.3. Network mesh SISWM2

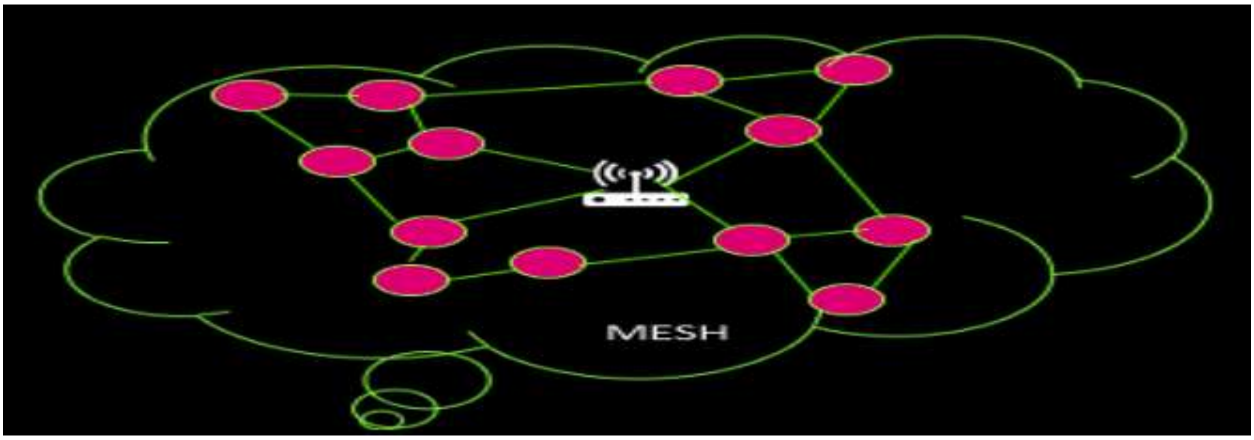

Figure 6

A static module and mobile drifter node system with a web-based data collecting platform interfaced with IoT and 3G cellular networks are described in Moreno et alRiverCore .'s IoT equipment at Colima, Mexico's hydrological area. The Message Queuing Telemetry Transport (MQTT), an open machine-to-machine low power network connection, is used in the fixed module architecture. The MQTT transmits continuous information bundles from stationary hubs to a server that saves data in a dataset, coupled with encryption and security measures. Using an ultrasonic distance sensor, the fixed RiverCore module measures different parameters in a river or stream, such as the water's height, breadth, and flow rate. Five distinct devices make up a RiverCore permanent hub: a regulated power supply, a solar charge controller, a 12 V 80 Ah battery, a 32-bit microcontroller unit, and an electronic board with a 3G cellular modem. The mobile drifter node connected to a GPS module and a micro-SD to acquire measured data and get time, position, and speed statistics. The gadget features a magnetic switch that engages it to log data for twenty-four hours at intervals of one second. The data collected as it is moving through the canal bed is saved on the microSD card for examination (Lockridge et al., 2016).

Another study by (Marin-Perez et al., 2012) at the Katulampa Dam in Bogor presents the findings of research work in which they created two devices for flood disaster early detection systems. The results demonstrated that the ultrasonic sensors were effective in detecting shifting water levels with a 97% accuracy that operate in a range of 14–250 cm, with the quickest message delivery test time of 8.20 and the longest period of 33.3 seconds.

Researchers Vitry et al. carried out a study using deep convolutional neural network machine learning models for water picture segmentation to identify flood level variations. This method of qualitative flood monitoring is flexible. Using the use of surveillance footage and static observer flooding index technology to detect changes in water level remotely, floodwater patterns were predicted.

A case study including the investigation of river floods in Flanders, Belgium, and the use of conceptual models. The researchers predicted flow and rainfall conditions using a predictive model controller and a prediction error approach that reduced uncertainty. The geographically shifting prediction coordination is one of the MPC outcome benefits of the predictive model controllers. Their research results in a predicted reduction in flood damage costs with a resultant 58% reduction in flood risk in local regions(Marin-Perez et al., 2012).

Ley et al. recommended employing a median absolute estimator to spot outliers in order to obtain correct data on water levels. Also, (Bae & Ji, 2019) study developed a Z-score modification technique for removing outliers from water data/information acquired from sensors. Most sensor-estimated anomalies happen before the sensors' waves reach the stream's outer surface (Dachyar et al., 2019).

Moreover, a waterproof device is necessary to shield sensors from abrasive ambient elements. Six water depth sensor devices underwent an eight-week performance test in a water column in a lab by Shi et al. For approximately a year, the sensor data was collected in the field and measured at six-minute intervals. The research discovered that the initial sensor's improper operation was caused by water getting inside the gadget. No harm was done to the other waterproof sensors (Duncan et al., 2011). The internet of things (IoT) depicts an enhanced character for information commerce and communication for items and incorporates the dynamic connection of hardware and software to the international internet infrastructure organization (Ham, 2013)6]. A perspective on data aggregation methods for extending the lifetime of wireless sensor networks while collecting sensory, audio, or visual data that may need compression. Information accumulation is a technique to improve energy usage by reducing data overlap and redundancy. In order to assess runoff patterns in metropolitan areas, Kim et al. explore real-time flood prediction using hydraulic and probabilistic models. Lizhen used an artificial neural network (ANN) to evaluate hourly water prediction in order to forecast floods.

According to Sung et al. (2017), flood water levels may be predicted in South Korea using hourly rainfall and water level data from six gauging stations along the Han River stream. With the use of statistical data correlation analysis, the researchers created ANN models for water level gauges. The backwater effect and tidal conditions lead the floodwater level at the river to rise. The results showed how various water level data were taken into account to produce precise water level gauges.

In order to gather data for early warning and flood relief in the area, Sunkpho and Ootamakorn set up a wireless flood monitoring network in southern Thailand (Nakhon Si Thammarat). Sensors, data transmission and processing, and database server make up its three components. The STARFLOW ultrasonic sensors, which have a measurement range of 0 to 5 metres, were submerged. They evaluate velocity and water level. Precipitation is estimated by the precipitation sensors, a tipping bucket rain gauge. The GPRS Data Unit received the sensor data and handled it before sending it to the control centre, where the database server processed and displayed the data for the users.

Flood forecasting depends on the timeliness of flood predictions (Leys et al., 2013); a tree-based model predictive control experiment in Turkey demonstrated the current status of flood risk assessment. The study discovered that larger releases within the brief predicted timeframes of six and twelve hours are harmful to the downstream reservoir. The best downstream-timeline flood management is achieved with a prediction horizon of at least 18 hours.

2. Conclusion

Finally, urban flooding happens when there is a surplus of rainwater compared to the capacity of the drainage system during storm events, often when the inflow drains are clogged with debris. In order to warn citizens of impending risks and probable flooding in a specific metropolitan region, sensors network systems are becoming more and more necessary. It is anticipated that adding sensors to the ageing stormwater infrastructure (roads, bridges, rivers, and storm drainage systems) will reduce health problems, traffic disruptions, and economic loss.

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