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Research Article

A Fuzzy Expert System for Identifying and Preventing Flood Damage using the Internet of Things

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Abstract

When it comes to managing floods, flood control has proven to be crucial. Installation of rock berms, sandbags, preserving normal slopes with vegetation, and building or enlargement of drainage channels are all methods used for this. Research in this field has begun to concentrate intently on drainage systems following Katrina (2005). Though several researchers have created and erected drainage systems of varying designs, the issue remains unresolved. Therefore, two cellular automata (CA)-based grid structures—a hexagonal one and an octagonal one—are presented in this study. Another solution to the problem of flooding and waterlogging is a method presented for determining the optimal grid design for a drainage system. This study examines and contrasts three distinct grid patterns: a square grid, a hexagon grid, and an octagon grid. The flood plain's linear and bilinear heights have been compared. This analysis led to the recommendation of a grid layout with the tanks located at the four corners of the drainage system. The suggested approach for creating the drainage system has been tested, and shown to be valid, with the use of the Paired T-Test. The researcher has responded to this need by proposing Internet of Things (IoT) and AI-based flood detection methods. Most often, the Internet of Things, wireless sensor networks, and metropolitan area networks are utilised to spot floods. Out of these three, IoT is the most effective technology for communicating and analysing the issue at hand.

Keywords: Cellular automata (CA), Linear and bilinear elevations, Paired T-Test. Internet of Things (IoT), Artificial Intelligence

Introduction

Extreme deaths have been attributed to rain-related calamities. M. Kanda [1] identifies the states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir in the northern area, the northeastern region, which includes West Bengal, and the Western Ghats of Maharashtra, Kerala, Tamil Nadu, and partly Karnataka as the states most at danger for landslides. During the rainy season, when heavy rains are the norm, these landslides are common. The severity of the issue has been highlighted by recent catastrophes such as the Uttarakhand flood [2,3], the J & K flood [2], and the Malin Landslip [4]. Some instances of natural catastrophes brought on by water include waterlogging, floods, landslides, tsunamis, and cloud bursts. When it comes to natural catastrophes, flooding is by far the most common and costly. Rainfall-caused flooding is a common occurrence that paints a bleak picture of life in the affected area. All the calamities caused by rain are examples of global issues that need immediate and significant attention. Landslides have also occurred outside of India, most recently in the southern Chinese province of Fujian [5], where 22 people have been confirmed dead and 17 are still missing. Twenty centimetres of rain in 24 hours was enough to trigger it. Several methods are used to deal with food shortages; together, these methods are referred to as flood control. There is a well-established system in place for dealing with disasters of various flood types. Planning, mitigation, readiness, and response/recovery are the four stages of the disaster management process shown in figure 1 [6]. There are four stages to disaster management, and although each stage is important, no one method can adequately address all four. The author of this material aimed to be of assistance at various points along the process.

Figure 1: Phases of Disaster Management

Flood Management

Unfortunately, no amount of technology or engineering will ever be able to bring floods completely under human control. However, losses may be mitigated via prudent management. A preliminary investigation identifies the following stages of flood control in accordance with disaster management procedures:

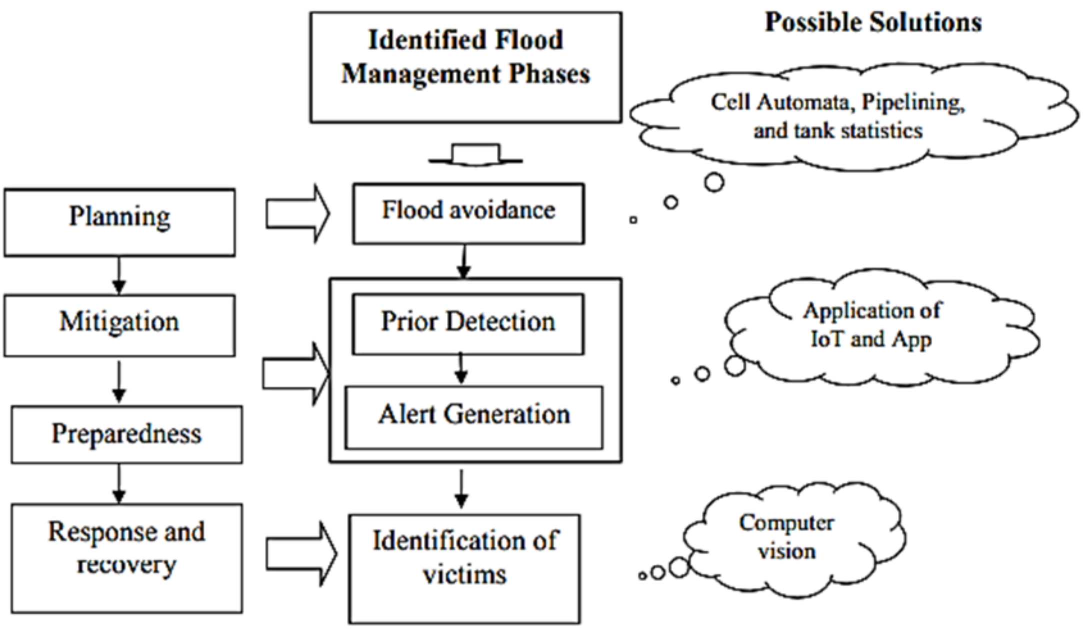

Figure 2: Identified flood management phases and possible solutions

As shown in Figure 2, Cellular Automata (CA) technology and ideas have been used for flood control. These presumptions, if put into action, may play a significant role in reducing the destructive potential of a flood. Existing cities have an extremely difficult time preventing flooding or modelling floods. However, flood modelling seldom makes use of computer science ideas like CA. Modern flood control strategies include the use of rock berms, sandbags, normalising slopes with vegetation, building or widening drainage systems and other similar measures. The process of flood control may be affected by four distinct types of methods, including

The current methods for detecting and avoiding floods are inadequate to prevent or, at the very least, identify the flood in time to save lives and property. Research thus far suggests that avoiding floods is no simple endeavour, but that the damage they might do can be mitigated with careful drainage system design. However, at least for emerging cities, a good drainage system may prevent urban flood. A prompt evaluation of flood risk is feasible with the help of a detection device, which may decrease losses in the event of a drainage system failure. By taking precautions immediately upon flood pre-detection, damages may be minimised. WSN and IoT are two technologies that have been shown to be able to detect early flood warning signs. Since IoT devices may connect to the internet at any time and from any location, they don't have the same network, aggregation, localization, and quality of service problems that plague WSN. The cost of devices is a major factor in the design of a low-cost network, and the design of a low-cost device is time-consuming and complex. The sensing device serves as a network source node, making its design crucial. Without a secondary system to analyse the data, no sensing device can be of any use. IoT sensing devices are no different; nevertheless, they may show you the information they've gathered. They have the ability to calculate with little external programming. The Internet of Things' devices provide a wealth of precise information about gadgets and monitoring stations. Because of this, the method used for data utilisation is a matter of course and changes depending on the need. A sensing and deployment strategy that takes into account how data is used is crucial. Therefore, it is a challenge to figure out how to make smart use of the observed data..

Literature Review

Parkinson [17] drainage management, a tool in flood control, was the topic of discussion. However, they lacked the facilities to put their plan into action. He has spoken about including the community in urban stormwater planning. He said that standard drainage systems occasionally fail because they are ill-suited to the environment. He has proposed a preventative action to take in the case of a flood.

Croke et al. [18] argued about flood risk avoidance strategies. His strategy enhanced techniques for avoiding flood damage by reinterpreting model data. They propose using the free HEC-RAS software made available by the United States government for hydraulic modelling. A flood plain map was generated using this programme.

Spector [19] developed a system for using heavy bags to construct dikes that may be used to contain floodwater. He proposes fibre bags with corner rings and clips for secure storage. It was a strategy for preventing flooding in a specific region.

Ellis et al. [20] have made the assumption that preventing flooding is crucial to urban water sustainability. They improved upon canalization by taking the increasing urbanisation of emerging nations into account..

Miguez et al. [21] water discharge linkages were considered in the integrated network's design. In his study, they have taken runoff rates and volumes into account. The Water Sensitive Urban Design (WSUD) philosophy informed his drainage management scheme. They have accounted for the combination of natural and manmade landscapes in their work. He has proposed a drainage network be kept up with this setup and analysed the discharge.

In this column, a framework provided by Wang et al. [22] for their drainage model may be explored to prevent urban floods. Tanks were proposed in their model to be placed in the water's course.

Mugume [23] explained how to utilise Global Resilience Analysis (GRA) to determine what went wrong with a drainage system. This takes into account the drainage mechanisms and local geography. Cases of pipeline failure due to obstruction have been shown through the provided links. This study shows us how to calculate the odds of achieving maximum water escape while minimising drainage system failure.

Fuzzy Expert System

Data fuzzification is the foundation of this kind of expert system. In this research, we utilise a MATLAB programme to create FES and analyse the effects of various rules. Let's have a look at how a fuzzy expert system is developed:

Defining the issue's parameters by identifying its input and output variables is known as problem specification.

• Fuzzy sets: Shapes of fuzzy sets are decided in this step, and it may be in different shapes such as a triangle or trapezoid to represent the expert knowledge.

• Construct fuzzy rules: Programmers, with the assistance of a subject matter expert, often build fuzzy rules. Choosing the variable is necessary prior to defining the rule. At the time of rule finalisation, however, if a knowledge engineer has not found superior rules elsewhere, he may accept the rule from existing research, papers, and books.

• Encoding: After a fuzzy rule and fuzzy sets have been established, encoding may take place. The design of a physical structure for the fuzzy expert system is crucial. C#, Java, Python, and C are all viable options for encoding, as are tools like Fuzzy Knowledge BuilderTM and MATLAB Fuzzy Logic Toolbox. MATLAB Fuzzy Logic Toolbox was chosen for development in this thesis because of its comprehensive development and testing environment.

Fuzzy Expert System(FES) Architecture and Design for the Internet of Everything (IoET)

This heading, which is shown in more detail in Figure 3, explains the concept behind our IoT-based FES's development on the back end. The data gathering subsystem in an IoET-based FES stores information gleaned from sensors and historical data. Both real-time sensor data and recommended historical data are included here. The information was acquired via telemetry and stored in a database by the Communication Subsystem. Dynamic data integration requires the provision of sensor data, whereas static data integration makes use of past information. Once combined, the database's contents are reserved for use in creating expert system knowledge.

The probabilities of an occurrence are calculated by applying fuzzy logic to the inputs in FES. Expert knowledge may be fed into the system more effectively with the use of fuzzy logic, it has been discovered. The goal is to use information on precipitation and water levels to reliably forecast the likelihood of flooding. After gathering raw data, data integration is undertaken to transform the data into meaningful information suitable for database storage. After this information is transformed into something the Expert System can use, it will be used. Knowledge bases employ this information to feed the inference engine, which is responsible for generating results based on input parameters.

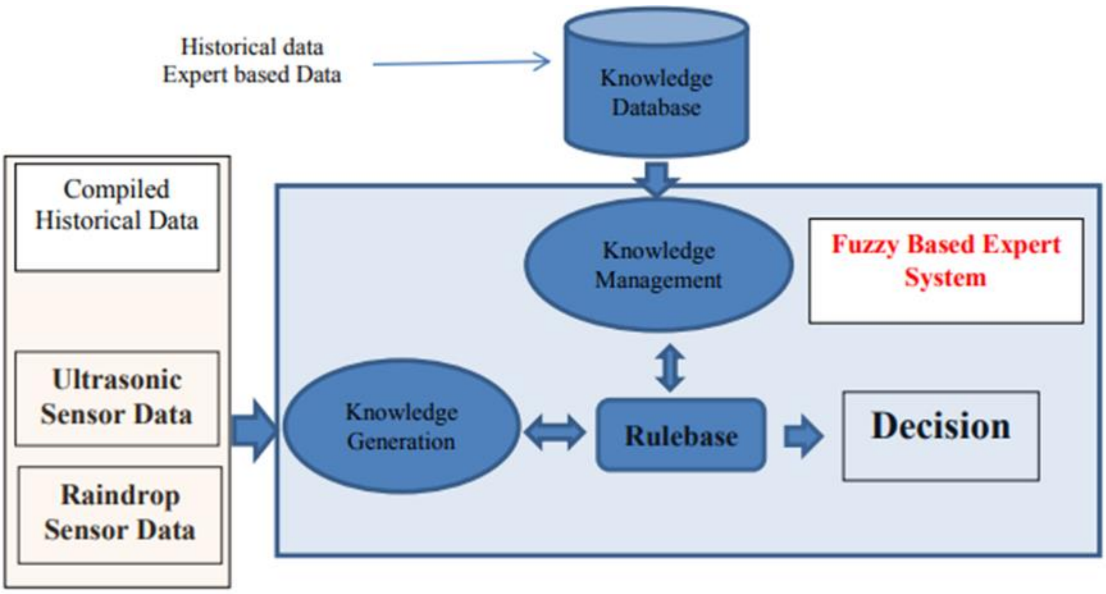

Figure 3: IoT based FES framework for flood risk

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In fuzzy logic, fuzzy sets and fuzzy operators serve as subjects and verbs, respectively. Fuzzy logic is put to use in flood warning by creating maps of water levels and rain activity. Figure 4 depicts the basic mapping method, if-then statements. Rules may be defined in any order, but defining all the words and adjectives is necessary before developing a system that understands the rules. Before we can declare that the water is at a dangerous level, we need to establish what that level really is. Figure 5 is a graphic that may be used as a guide through the fuzzy inference procedure. Before creating an expert system for a certain location, it is crucial to learn about the likelihood of flood episodes in the past. Assumed components directly engaged in risk measurement are the current rainfall and water level.

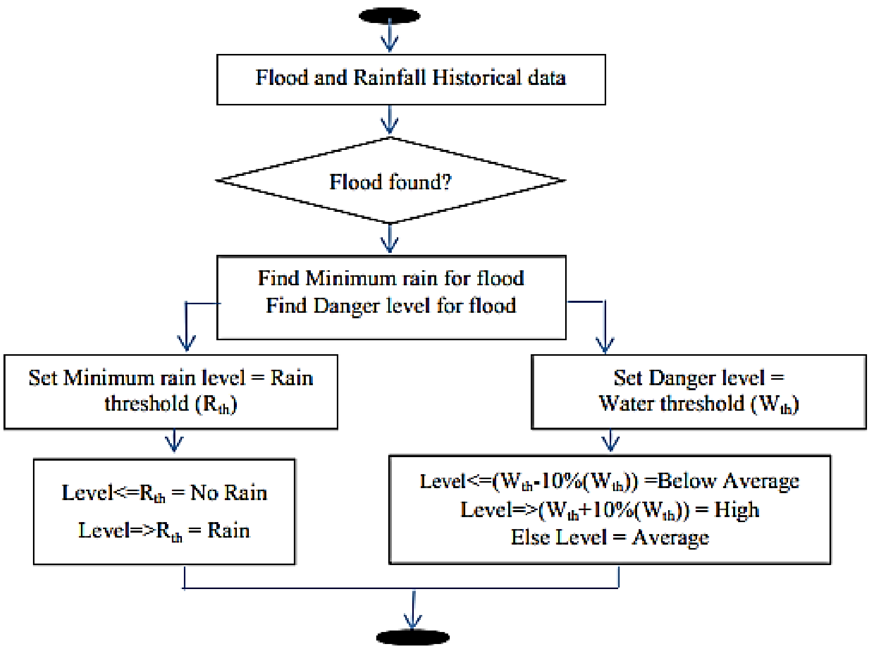

Figure 4 : Antecedent and consequent generation mechanism

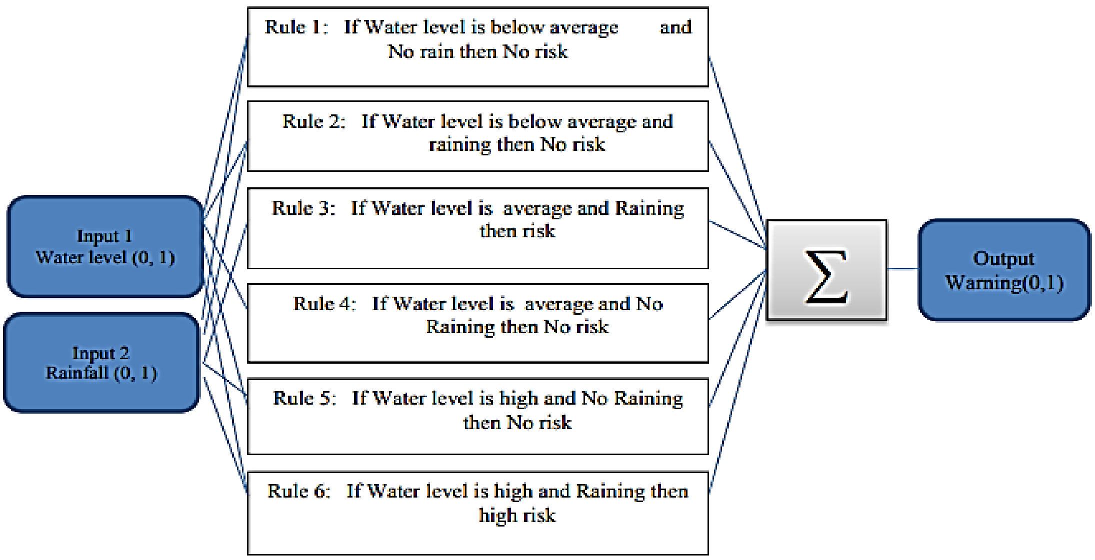

Figure 5. Fuzzy Inference diagram

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Fuzzy Logic Designer

This is a tool to handle high-level issues of deciding input and output variable and their names as:

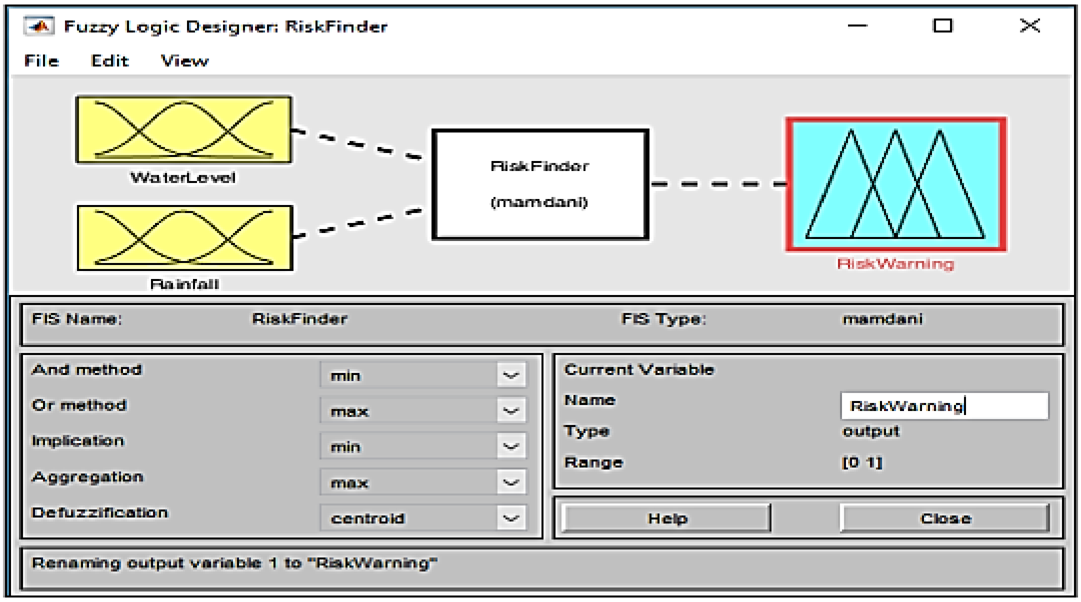

Figure 7 : Fuzzy Logic Designer for FES.

Membership Function Editor

It is used to define the shapes of the membership function associated with each variable.

1) An input membership function defined for water level using a membership function editor.

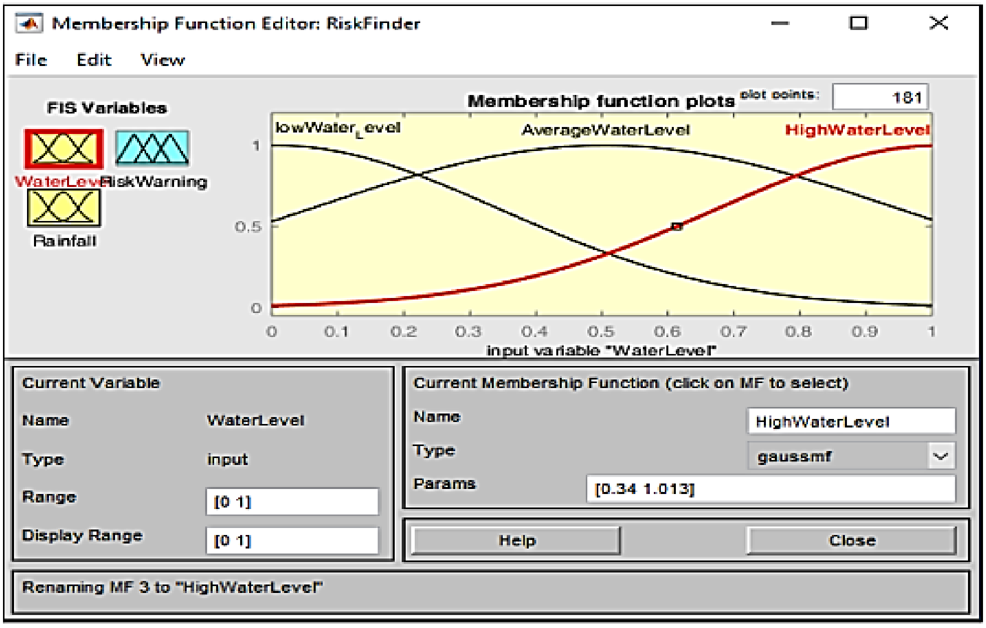

Figure 8: Input membership function to define the water level for FES

Rule Editor

The rule is edited using a rule editor. Rule edited using rule editor as:

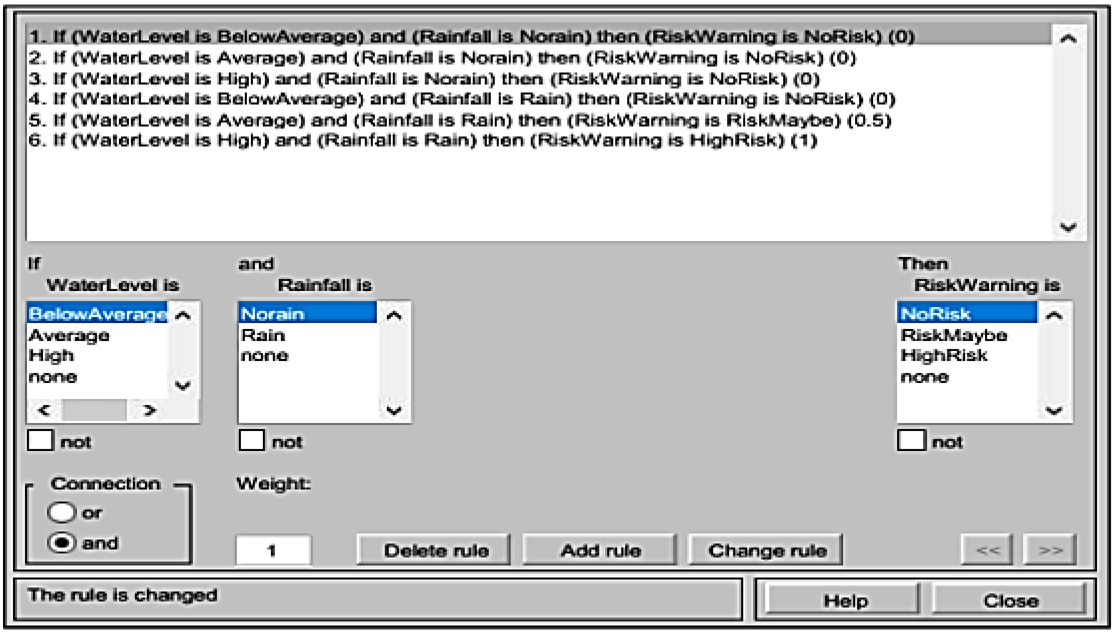

Figure 7: Rule editor of FES to define flood risk

An ES prototype has been successfully created under these strict constraints. As seen in Figure 8, there is a page dedicated to managing the user's sensor deployments.

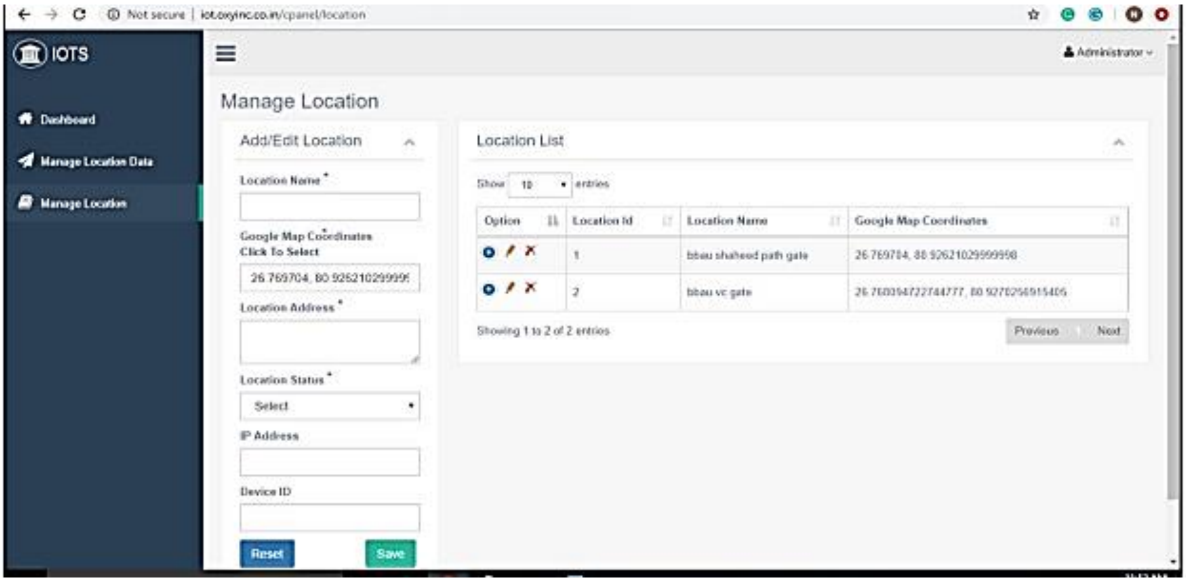

Figure 8: Location entry for deployed IoT devices

Conclusion

Fuzzy logic's major strength lies in its capacity to accommodate for uncertainties and nonlinearities. The outcomes generated by fuzzy logic are comparable to those generated by humans. As a result, this process takes less time and is simpler. Since a number of factors might trigger a flood, it makes sense to harness the intelligence of the internet of things (IoT) and an array of sensors. Many methods exist for effectively implementing an early flood warning or detection system. Various algorithms may be applied to information gathered by various sensors. In addition to machine learning and embedded systems, algorithms like decision tree, random forest, and fuzzly logic system may be employed. A flood detection system needs sensors, a microprocessor, and an appropriate algorithm at its core. As a result, one may anticipate flood situations with the aid of various algorithms and Internet-of-Things-sensors.

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