Journal of Soft Computing Exploration

Homepage: https://shmpublisher.com/index.php/joscex

p-ISSN: 2746-7686
e-ISSN: 2746-0991

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Flood early warning system at Jakarta dam using internet of things (IoT)-based real-time fishbone method to support industrial revolution 4.0

Muhammad Rizqi Al Farabi[1], Andini Sintawati[2]
[1,2]Faculty of Computer Science, Gunadarma University, Indonesia

Article Info

Article history:

Received March 1, 2024
Revised March 24, 2024
Accepted April 24, 2024

Keywords:

IoT
Raspberry pi
Smart city
Twitter

ABSTRACT

This research aims to develop an effective flood early warning system to provide timely information to the public and support the government in disaster management. The Raspberry Pi mini-computer functions as the central control, collecting data from the Water Level Sensor to measure water height, the Ultrasonic Sensor for further monitoring, the DHT11 Sensor to monitor temperature and humidity, and a Buzzer as an audible warning device. The research method involves review of the literature and data acquisition from related journals. These data are utilized to design an Internet of Things (IoT)-based flood detection tool with the Raspberry Pi minicomputer as the main controller. The system can be implemented in vulnerable locations such as reservoirs, sluice gates, and rivers, as part of the Smart City and Smart Environment concepts. The test results indicate that the developed early warning system, integrating the Raspberry Pi minicomputer, the Water Level Sensor, the the Ultrasonic Sensor DHT11 Sensor, and Buzzer, approaches perfection. Real-time information is transmitted through the Twitter social media platform, which is shown to be more effective than manual notifications. The system can provide accurate early warnings, reduce flood-related damages, and positively contribute to flood prevention and disaster management efforts. This research is expected to make a significant contribution to improving the community and government preparedness for future flood disasters.

Corresponding Author:

Muhammad Rizqi Al Farabi,
Faculty of Computer Science,
Gunadarma University,
Jl. Salemba Raya No.53 9, RT.9/RW.5, Paseban, Kec. Senen, Kota Jakarta Pusat, Daerah Khusus Ibukota Jakarta 10440.
Email: alfarabirizki8@gmail.com
https://doi.org/10.52465/joscex.v5i1.252

1. INTRODUCTION

Flooding is one of the most common natural disasters in many parts of the world, especially in Indonesia, especially in the capital city of Jakarta [1]. As the center of government, economy and culture, Jakarta faces great challenges in managing the risks and impacts caused by floods. This phenomenon is not only caused by high rainfall, but also influenced by various other factors, such as uncontrolled development, inadequate drainage systems, and subsidence of the land [2]. In recent years, the research and development of flood early warning systems has become a major focus in disaster mitigation efforts to reduce losses.

Several recent studies have highlighted flooding problems in Jakarta and efforts to address them. For example, spatial modeling of flood-affected areas around the Krukut River, South Jakarta, which experiences flooding due to high rainfall and massive development along the river, showing the importance of better infrastructure planning and river management to anticipate and mitigate disasters [3]. Meanwhile, explored flood inundation simulations based on GSMaP satellite rainfall data in Jakarta, emphasizing the importance of an accurate flood forecasting system for cities vulnerable to climate-related disasters, including floods, sea level rise, and storm surges [4].

Another study identified the influence of the retreating north latitude on heavy rainfall in Jakarta and its interaction with tropical cyclones, providing information on the meteorological factors that contribute to flood events in Jakarta [5]. Furthermore, the factors that cause flooding in DKI Jakarta Province, with rainfall intensity as the main factor, highlight the importance of understanding and addressing the factors that cause flooding to reduce its risks and impacts [6].

These studies provide an important basis for the development of an IoT-based flood early warning system as part of mitigation and adaptation efforts to flood disasters in Jakarta. Through the application of advanced technology, it is expected to improve the effectiveness of flood early warning and response systems, reduce losses, and support sustainable development in the capital city.

Flooding is a natural disaster event that occurs when excessive water flow submerges land, one of which often occurs in Indonesia, including in the city of Jakarta. Sometimes, flooding of shipments occurs at night, when residents are sleeping, and without early warning in place, can cause material losses and even fatalities. The negative impact of floods can be reduced by setting up an effective early warning system so that people are better prepared and can handle the arrival of floods [7].

In the journal entitled “Flood Detection System Based on Ultrasonic Sensors and Microcontrollers with SMS Gateway Communication Media” [8], also in the journal entitled “Design of Internet of Things-Based Flood Detection Systems” [7], and in the work entitled “SMS Gateway Based Flood Early Warning System and Arduino Uno” microcontroller [9], the focus of research is to solve various problems, although the methods applied are almost similar. The method used involves literature study and problem analysis, which is referred to as the Fish-Bone method, this approach is designed to facilitate effective problem solving. The technology is the Flood Early Warning System (FEWS), which uses various data inputs in real time and forecasts for the next few days [10].

The Internet of Things (IoT) is a concept or scenario where an object has the ability to send data over a network without requiring human-to-human or human-to-computer interaction [11]. The role of IoT in disaster management, from a global perspective, emphasizes a four-stage approach to disaster management: prevention, preparation, response, and recovery. The application of IoT, such as early warning systems, has helped in the management of impending or already occurring disasters. IoT allows real-time data collection and analysis, which is crucial in minimizing the impact of disasters [12]. Various methods that can be implemented after a disaster occurs using IoT. This research provides insight into effective ways to use IoT technology after a disaster. The techniques are excellent in monitoring and have the ability to respond to situations as needed, making a significant contribution to the development of appropriate disaster management blocks [13]. IoT is not only limited to disaster detection and response, but also in post-disaster rehabilitation and recovery. The future direction of the use of IoT in natural disaster management includes the use of IoT for prediction of disaster events and the resulting damage [14]. The integration of IoT with artificial intelligence (AI), big data analysis, cloud computing, and drones is considered essential to improve disaster management. The Internet of Things (IoT) technology cannot prevent disasters, but will be very useful for disaster preparedness, such as prediction and early warning [15]. The standard definition of the term Internet of Things (IoT), which describes the real world in cyberspace with the method used is wireless or automatic control without knowing distance [7]. IoT technology has shown its potential in real-time environmental monitoring, including flood early warning, which can provide important information for evacuation and preparation before a disaster occurs.

For example, a study developed an IoT-based flood detection management system that uses sensors to measure water levels, humidity, and temperature. These data are then sent to the cloud and users can access the data through a mobile app, allowing the necessary precautions before flooding occurs [16]. Another study designed a flood early warning and monitoring system with the implementation of IoT and the Global Positioning System (GPS), which provides information on the current water level in the drainage. When the water level increases to a certain level, the system will send a warning notification to the user, indicating safe, warning and critical water levels [17].

Therefore, the use of IoT in flood early detection offers an innovative solution that can improve preparedness and response to potential flood disasters [18]. Through systems capable of monitoring environmental conditions in real time and providing accurate data to users, communities can be better prepared for flood risks, thus reducing negative impacts on lives and property. This technology, along with Jakarta-focused research, shows significant progress in flood mitigation efforts in the digital age.

The rapid development of technology makes IT developers continue to improve various kinds of innovations in various aspects. One of them is the search for new technologies that can help in the event of natural disasters such as floods. The growing technology made some researchers begin to conduct research on how to anticipate the flood situation. With an early flood warning system, which is one of the supporting tools and is used to be an early warning before floods occur.

In this context, an effective warning and monitoring system is needed for lakes that are not continuously monitored by the community to prevent flooding. One solution is to implement an Internet of Things (IoT)-based flood detection system, which enables real-time monitoring and control of lake water levels [19], [20]. The use of cork-shaped ultrasonic sensors as an indicator of water level allows accurate detection [21]. When the water reaches a certain level, the indicator will automatically activate the early warning system. By creating an early warning detection system tool for flood disasters, it is hoped it can help communities around flood-prone areas provide earlier information when a flood is coming and reduce the impact of the flood disaster [22].

The presence of devices that can be installed in various locations on dams and main waterways provides the ability to provide early warning related to potential flood disasters. The system is designed to effectively anticipate and provide adequate information, with the primary objective of reducing the impact of material losses and potential losses to human life.

2. METHOD

The method used in the preparation of this Thesis uses a Fish-Bone with the following details:

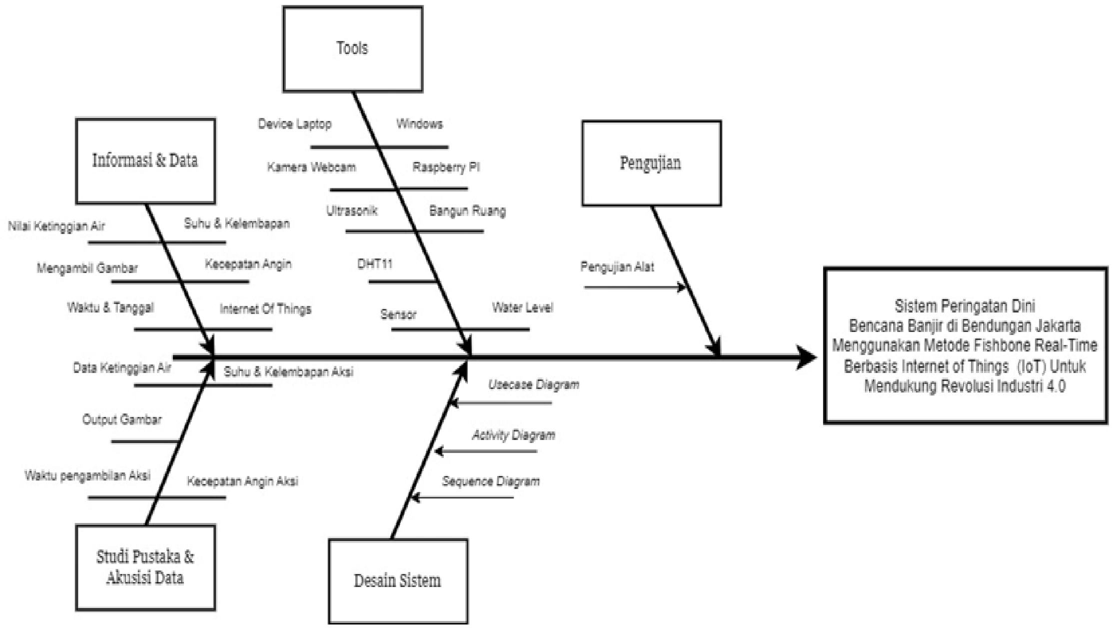

Figure 1. Fishbond method

Figure 1 explains the framework of a project aimed at developing an early warning system for flood disasters at the Jakarta Dam, utilizing Internet of Things (IoT) technology based on the Fishbone Real-Time method, as part of the effort to support the Industry 4.0 revolution. This framework includes the collection of critical data such as water level, temperature, humidity, and wind speed, measured using devices and sensors such as webcams, Raspberry Pi, and the DHT11. This information is then processed and tested using tools such as laptops with the Windows operating system and a system design scheme that includes use case, activity, and sequence diagrams to ensure the system works effectively before being fully implemented as a reliable early warning solution.

Planning Phase

System planning

The system design stage in this phase is very crucial and important because it will be the main foundation for this tool to run properly so that the problems faced can be resolved properly, in this case by using several UML models, namely usecase diagrams and Activity Diagrams.

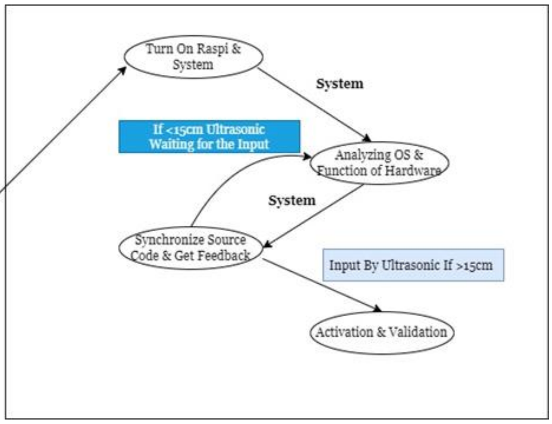

Figure 2. Use case diagram

Figure 2, describes a flow diagram that outlines a programmer's workflow for operating and testing a system integrated with a Raspberry Pi and an ultrasonic sensor. Initially, the programmer powers on the Raspberry Pi and the system. If the ultrasonic sensor detects an object within a distance of less than 15 centimeters, the system awaits further input. Subsequently, the system performs an analysis of the Operating System (OS) and the functions of the associated hardware. Should the ultrasonic sensor detect an object at a distance greater than 15 centimeters, input is then provided to the system, which proceeds to synchronize the source code and gather feedback. Following this, the system undergoes an activation and validation phase to ensure that all processes are running correctly. This diagram likely represents a segment of prototype development or functional testing in a hardware project that involves a proximity sensor.

Usecase diagrams are used to illustrate the interaction between a system and an actor (be it a human or another system) in the context of system functionality.

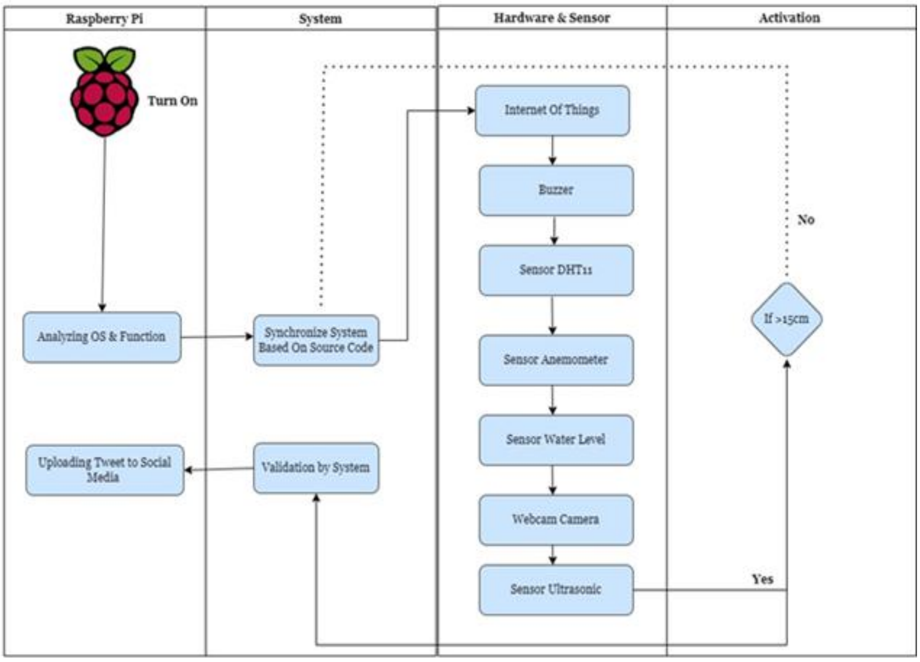

Figure 3. Activity diagram

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Figure 3, explain about the image presents a flowchart detailing the integration and workflow of a Raspberry Pi-based system within the context of the Internet of Things (IoT). The process begins with powering on the Raspberry Pi powering on, followed by the analysis of the operating system and its functions. The system is then synchronized based on the source code, and system validation is carried out. In terms of hardware and sensors, the set-up includes devices such as a buzzer, a DHT11 temperature and humidity sensor, an anemometer to measure wind speed, a water level sensor, a webcam, and an ultrasonic sensor. The system has a conditional activation process that depends on the input from the ultrasonic sensor; if an object is detected within a distance of less than 15cm, the system remains inactive, but if no object is detected below this threshold, the system proceeds to activation. Additionally, there is a feature for uploading tweets to social networks, which likely serves as part of the system's reporting or notification process. This diagram illustrates how various components and sensors collaborate to create an interconnected environmental automation and monitoring system.

Component procurement

In carrying out this process, several main components become a must, both to be operated directly and as supporting elements in the implementation of automation. The main goal is to provide effective early warning.

Tool testing

In testing this tool, there is a purpose and arrangement of the testing system to be carried out. Based on the fish-bone method, this approach allows a structured focus on each objective through a comprehensive analysis of various components. The results are expected to provide relevant and useful output, which in turn will provide the information needed for specific purposes.

Implementation Phase

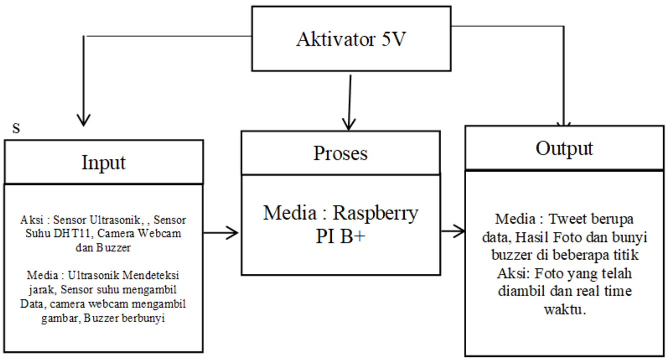

Figure 4. Blok diagram

Figure 4 explains an automation system segmented into three parts: Input, Process, and Output. The input section involves actions from an ultrasonic sensor detecting distance, a DHT11 temperature sensor gathering temperature data, and a buzzer sounding as an indicator. The Process part is managed by a Raspberry Pi B+ which processes the incoming data. The Output section produces two types of outcomes: the media, which includes tweets containing data and the sound of the buzzer at various points, and images that have been captured; and the action, which involves these images that have been taken along with a real-time timestamp. The system appears to be designed to monitor and report environmental conditions in real time, with notifications accessible to the public via social media.

Network and Equipment Planning

After the initial stage of system design is complete, enter to design a series of providing all the components needed without missing a single thing such as Microcomputers, ultrasonic sensors, webcam cameras, DHT11 temperature sensors, and also buzzers. After the provision of all components is complete, we enter with the creation of source code which will later be executed by Microcomputer, there are 6 source codes made, namely, for Ultrasonic Sensors, DHT11 Temperature Sensors, Buzzer Sensors, Camera Webcams, Water Level Sensors and sending the final results to the Twitter platform.

Stages of Application

Direct testing how the tool works, then collecting data and compiling it as an analysis and design tool is a critical stage in the preparation of scientific writing reports. At this stage, the application of this flood warning tool is carried out. This tool is placed on a water gate which usually functions as a regulator of water movement from one area to another, regulating water waste, and as a barrier for water so that it does not flow upstream or rivers in other areas.

In this stage, direct testing of the functionality of the tool is carried out by observing its response to changes in ambient conditions. The data obtained during this test is then collected and analyzed to support design and functionality.

3. RESULTS AND DISCUSSIONS

The following is explained about the results and discussion of the Flood Early Warning System at the Jakarta Dam using the Internet of Things (IoT)-Based Real-Time Fishbone Method to Support the Industrial Revolution 4.0.

Tool Condition and Build Space When the Water Level is Normal

In this phase, several sensors have been installed at certain points to get the information needed later. At this stage the Ultrasonic Sensor is continuously on the run with a delay of 10 seconds to fire Ultrasonic Waves to wait for variable input that will trigger all sensors and other components.

Figure 5. Tools and build overall space

Figure 5 explains the phase of the system setup, we have strategically positioned multiple sensors across designated points to acquire essential information for the monitoring process. The key component in this configuration is the Ultrasonic Sensor, which is programmed to emit ultrasonic waves at regular intervals, specifically with a 10-second delay. This consistent emission serves as a preparatory step, allowing the system to be in a constant state of readiness to receive input variables. The ultrasonic sensor plays a crucial role as the initial activator in the sensor network. When it detects a variation in water level indicating that the distance between the sensor and the water surface has changed, it captures this critical data point and relays it to the central system. This action then serves as a catalyst, initiating a sequence in which all connected sensors and additional components are triggered to perform their respective functions.

During normal water-level conditions, the Ultrasonic Sensor's readings are expected to remain fairly consistent. However, the deviation from these readings is most telling, prompting the system to move from a passive monitoring state to an active alert phase. This can include activating alarms, sending notifications to relevant personnel, and engaging any linked automated response systems. The objective of this continuous monitoring is not just to record the current state of the water level, but also to enable a swift and proactive response to any potential changes that could signify a risk of flooding or other water-related issues. Data collected from this and other sensors, such as temperature, humidity, and water clarity, are fed into a comprehensive dashboard that provides a real-time overview of environmental conditions. This allows immediate analysis and decision-making, ensuring that any necessary maintenance or preventative measures can be deployed efficiently and effectively, maintaining the integrity and safety of the environment being monitored.

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Condition of the Tool and Build Space When the Water Level is High Enough

In this phase, the water level has already reached a level that it should not have, and some sensors have prepared to take action. The system will immediately send an early warning to the public via Twitter as a social media. Also, the Buzzer will sound in some densely populated flood-prone locations.

Figure 6. Output in twitter

Figure 6 explains that during this critical phase, the water level has escalated to a threshold that warrants immediate attention. The system's sensors, now in a heightened state of alert due to elevated water levels, are programmed to initiate preemptive measures. As soon as the sensors, such as the ultrasonic sensor, detect water levels that exceed safe parameters, they trigger the system's response protocols. Firstly, the system is designed to communicate urgent warnings to the public. It does so by leveraging its integrated social media capabilities, immediately sending an automated tweet that alerts followers to the high-water level situation. This tweet will contain essential information about the increase in water level, safety precautions, and possibly, recommended evacuation routes or shelter locations. The goal is to quickly and widely disseminate this information to ensure maximum reach.

Gleichzeitig, the system activates local alarms to provide immediate auditory warnings to residents in the vicinity, particularly in areas known for high population density and vulnerability to flooding. This is accomplished through a network of Buzzers that emit a loud and clear sound designed to be heard over a wide area, thereby alerting people to the potential danger and the need for prompt action. The system can also interface with other emergency services and platforms to ensure a complete response. For example, it could integrate with local government alert systems, emergency response networks, or flood mitigation control systems to coordinate a holistic response to the high-water level event. In addition, the system dashboard will reflect the urgency of the situation, providing real-time updates, visual alerts, and detailed information to system operators, emergency management personnel, and decision-makers, who may need to coordinate additional actions based on the severity of the situation. The sophistication of the system lies in its ability not only detect and react to high water levels, but also to communicate effectively across various channels to ensure that all stakeholders, from the general public to emergency responders, are informed and prepared to take the necessary steps to mitigate risks and protect lives and property.

Result Trial

Table 1. Observations

No.	Sensor Ultrasonic	Water Level Sensor	Buzzer	Sensor DHT11	Camera Webcam	Raspberry PI B+
1.	< 15 cm	Retrieving Data	Turn on	Retrieving Data	Taking Pictures	Process images, extract data, and send Images to the Platform
2.	> 15 cm	No Action	No action	No Action	No action	The initial condition is only for the ultrasonic sensor to fire waves and wait for input.

Table l 1 explains how various sensors and devices in the system interact based on the distance detected by the ultrasonic sensor. When the ultrasonic sensor detects an object within a distance of less than 15 cm, the water level sensor begins to retrieve data, the buzzer is activated, the DHT11 sensor also starts to retrieve data, and the webcam captures images. All this information, including the images and data from the sensors, is then processed by the Raspberry Pi B+, which processes the images, extracts the data, and sends them to the designated platform. On the contrary, if the ultrasonic sensor detects a distance greater than 15 cm, then no action is taken by the water level sensor, buzzer, DHT11 sensor, and webcam, with the Raspberry Pi B+ remaining in an initial state where only the ultrasonic sensor is emitting waves and waiting for the next input. This illustrates a responsive system that can adjust its actions based on the conditions gleaned from its environment.

4. CONCLUSION

Based on the results of trials conducted by the author on the design and implementation of flood detection tools using Raspberry Pi with a number of sensors, it can be concluded that the flood early warning system at the Jakarta Dam uses the Internet of Things (IoT)-based Real-Time Fishbone method to support Industrial Revolution 4.0 almost close to the level of perfection. Thorough testing has shown that this system is quite effective in providing early information to the community regarding potential flooding.

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