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Design of water level detection monitoring system using fusion sensor based on Internet of Things (IoT)

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Abstract
River flooding is a condition when the water in a river overflows and exceeds its normal capacity, thereby flooding the surrounding area. This flood disaster has been a known problem for a long time and causes great damage in the affected areas. Flood events in Rivers are influenced by many factors, such as climate change, rapid urbanization, inappropriate land use, ineffective water management patterns, as well as uncontrolled addition of hard soil surfaces. Flood conditions in rivers involve complex processes and are influenced by various factors components, such as rainfall, water flow, topography, vegetation, and many other factors. Therefore, this research is very urgent because it can help reduce the negative impacts of flooding, increase public safety, become a basis for decision making, save costs and resources and make a positive contribution to technological development. This study aims to create a prototype of a flood early warning system. The system is based on a wireless sensor network whose interconnections are connected by a star topology. Every node is a combination of several sensors (sensor fusion) that are related to detecting floods, such as: height sensors, water flow speed sensors and rainfall intensity sensors. Design of hardware (hardware) and software (software) will be done. A classification mechanism based on Fuzzy Logic will be used to estimate flood conditions based on existing data. Flood estimation will determine the time and distance of flood events that will occur. Several experiments in the laboratory will be carried out to determine the performance of the designed system.

Keywords:
Early detection;
Flood;
Fusion Sensors;
Fuzzy Logic;
Wireless Sensor Networks;

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INTRODUCTION

Disasters are a series of events that threaten and disrupt people's lives and livelihoods caused by both natural and/or non-natural factors and human factors, resulting in human casualties, environmental damage, property loss and psychological impacts. Disasters caused by events, or a series of events caused by nature include earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes and landslides [1].

Of the several existing disasters, floods are the most frequent natural disasters in Indonesia. Water discharge flowing in a drainage channel or water absorption pond that exceeds the maximum capacity and absorption capacity will cause flooding. Disturbances in drainage channels can cause puddles of water to appear on land that is usually dry, such as in residential areas or city centers, which later cause the puddles to grow and become floods [2]. Floods can also be caused by river water overflowing into the mainland or caused by rain

[3]. This flood, also called a river flood, occurs when the water in a river overflow and exceeds its normal capacity, thereby flooding the surrounding area [4]. This flood disaster has been a known problem for a long time. and caused great damage in the affected areas. Flood events in rivers are influenced by many factors, such as climate change, rapid urbanization, inappropriate land use, ineffective water management patterns, and the addition of hard ground surfaces. Flood conditions in rivers involve complex processes involving various components such as rainfall, water flow, topography, vegetation, and many other factors [5].

Overall, the flood system in rivers involves many complex and interrelated factors. Apart from that, the losses caused by flooding are quite large, both in terms of material and loss of life/death, therefore the problem of flooding needs serious attention [6]. Therefore, appropriate technology is needed to reduce the risk of flooding and protect communities and the environment from detrimental impacts.

It can be said that there are three problems that must be resolved in river flood disasters, namely: a reliable, accurate and fast river flood control system is needed, a river status classification mechanism is needed at a certain time and optimization of comprehensive river condition measurement.

There are several approaches to solving the problem of flooding in rivers that already exist today. Some of these approaches include Early Warning Systems, River Monitoring Technology, Dams and Sluice Gates, Water Storage Technology and Flood Simulation Modeling in Rivers. This research tries to integrate several problem-solving approaches above, namely: designing a prototype river monitoring system that can estimate flood condition models and provide financial warnings based on the estimation results obtained. The river monitoring system is carried out based on a wireless sensor network. While the estimation process is based on a classification mechanism based on Fuzzy Logic. Finally, the estimation results become the basis for sending out flood early warnings on rivers.

There are several similar studies that have been carried out as state of the art, including the following. First, research using various types of single sensors placed in the river area (on site) [7][8]. Second, research using various types of sensors that utilize remote sensing, GIS and satellites [9, 10, 11]. Third is research that utilizes control system mechanisms and artificial intelligence [12, 13, 14]. And finally there is research that implements (wireless sensor networks) [15, 16, 17]. In general, research on flood detection is based on river monitoring with several measurement variables, such as: water level, water flow velocity, rainfall intensity, satellite data and remote sensing, either as a single system or utilizing a wireless sensor network. Some studies use only one or two sensors on each unit, either a single system or a network. In addition, not many have implemented certain artificial intelligence mechanisms to estimate the probability of flooding in rivers as an early detection system. The system built generally combines mechanisms for measuring, controlling, monitoring and notification of earlier detection results.

Therefore, this research is novel on several fronts. First, the use of a wireless sensor network to obtain data spread across several river flow points. Second, the application of the method of combining several sensors (sensor fusion), to obtain accuracy of the actual river conditions. Third, implementing an artificial intelligence mechanism based on Fuzzy Logic to estimate flood conditions based on existing data. The state of the art and novelty of this research is shown in Figure 1.

This research is included in the field of Control System Applications. Several control system applications have been studied and produced their outputs, such as: vehicle speed control systems based on driver conditions [18, 19, 20, 21], solar light intensity control systems [22, 23, 24], automation systems at LPG terminals [25, 26, 27], as well as a monitoring system for street lighting [28].

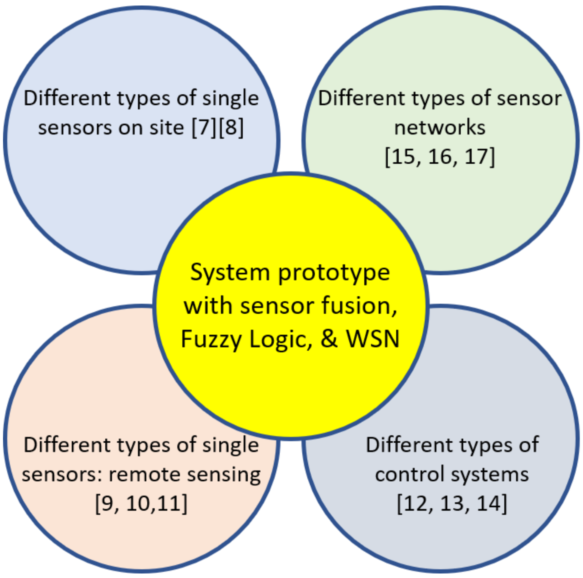

Figure 1. State of the art and Novelty

The research objective for the next five years is to build and implement an intelligent and integrated control system for monitoring and controlling remotely by utilizing telecommunication systems and the Internet of Things (IoT). The big target of this field is to build a smart city that implements an intelligent and integrated control system.

METHOD

The research was conducted based on the principles of system design. Data collection is based on measurements of the system to be designed. Tests and measurements are carried out to test system performance. In general, the research process is shown in Figure 2.

In Figure 2, it can be seen that there are several stages of research. The first stage is preliminary research, to understand the control and monitoring system on a particular system. Every system that will be controlled and monitored must have a system model, sensor devices and actuator devices. Control mechanisms are also generally found in these systems. The second stage is literature review. At this stage, literature will be reviewed regarding river flooding, control systems based on Fuzzy Logic, and wireless sensor network systems and early warning mechanisms.

The third stage is the process of making a prototype. The first prototype designed was a flood control system for a river (single). This process will provide a solution to the first problem.

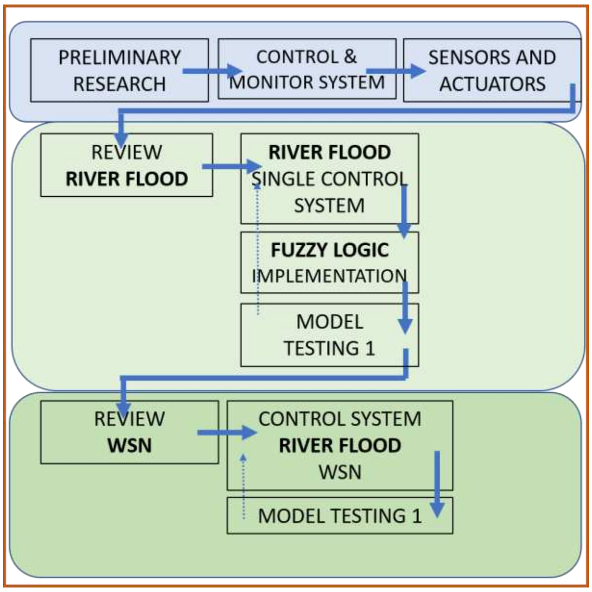

Figure 2. Research Process

Then, a Fuzzy Logic based classification mechanism was designed. This classification determines the status of rivers based on the data produced. This process solves the second problem. Then proceed with the design of a wireless sensor network system from a river flood control system (single node), based on a star topology. With a wireless sensor network, data will be obtained more accurately, integrative and comprehensively. This process solves the third problem. Measurement, testing and design evaluation are carried out in each of the above processes.

The block diagram of the system being designed is shown in Figure 3 and Figure 4. Figure 4 shows the flood control system in a river (single node). This system consists of three sub-systems, namely sensor sub-system, controller sub-system and telecommunications sub-system.

There are three sensors at each node, namely: water level sensor, rainfall sensor and water flow velocity sensor. These three sensors will integrate their measurement results with a sensor fusion approach. An Arduino Uno-based microcontroller will be used as a control sub-system. And, finally, the data obtained will be sent through a telecommunications sub-system using the LoRa approach.

After that, each flood control system node on the river (single node) will be interconnected with each other with a star topology to form a wireless sensor network. Each node is connected via LoRa. Then, all data from each node is integrated and classified using the Fuzzy Logic approach on a NodeMCU microcontroller. The wireless sensor network section is shown in Figure 4.

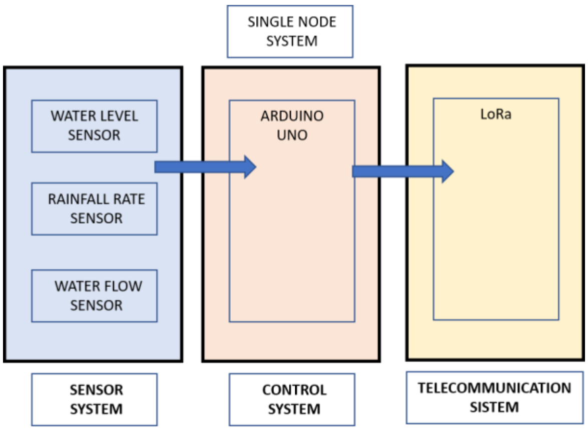

Figure 3. River flood control system (single node)

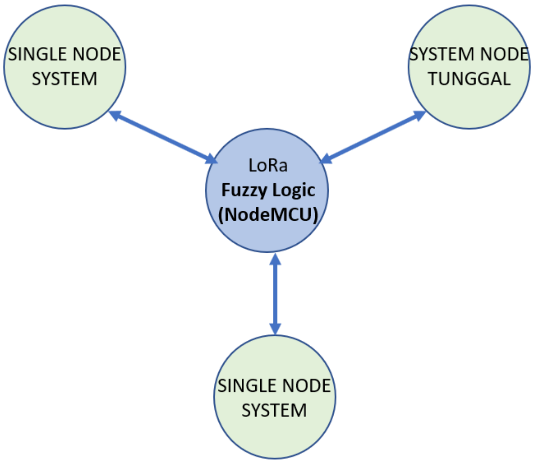

Figure 4. Wireless sensor network with Star Topology. Each node is shown in Figure 3

The flood condition classification process is a critical step in flood risk mitigation efforts. The first step in this process involves collecting data generated by all available sensors, which includes rainfall type, river level, water flow velocity, temperature, humidity, pressure, and area altitude. This information is then analyzed using sensor fusion technology and fuzzy logic algorithms to be classified according to flood potential. The importance of this classification process lies not only in the identification of risk, but also in providing the necessary information for the development of effective flood risk reduction policies and strategies. The flood potential classification system of a place used can be seen in Figure 5 [29][30].

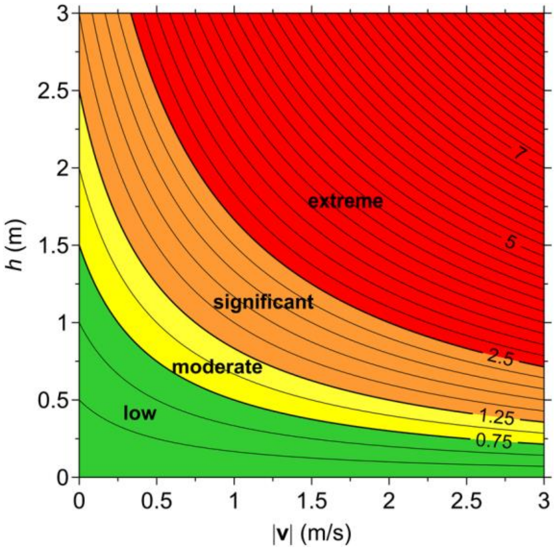

Figure 5. Flood potential classification system

RESULTS AND DISCUSSION

The modular electronics system is shown sequentially in Figure 6-Figure 10.

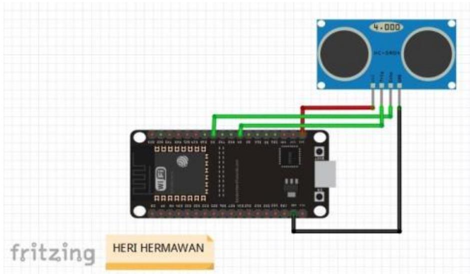

Figure 6. Schematic of the ESP32 Microcontroller and HC-SR04 Ultrasonic Sensor

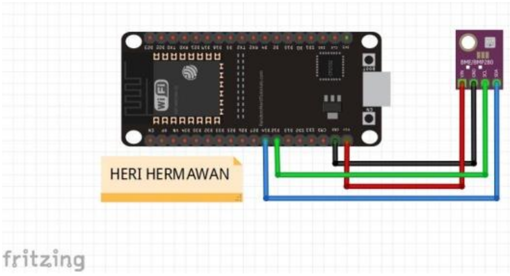

Figure 7. Schematic of the ESP32 Microcontroller and BME280 Temperature, Humidity and Pressure Sensors

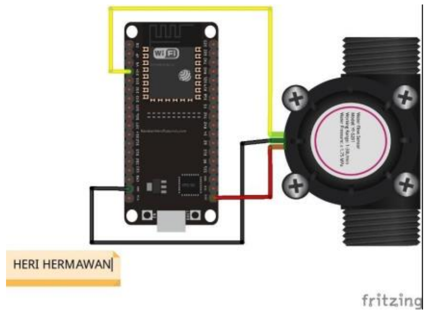

Figure 8. Schematic of the ESP32 Microcontroller and Water Flow Meter Sensor

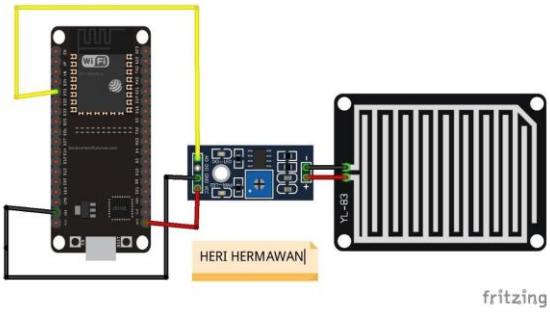

Figure 9. Schematic of the ESP32 Microcontroller and the YL-83 Rain Sensor

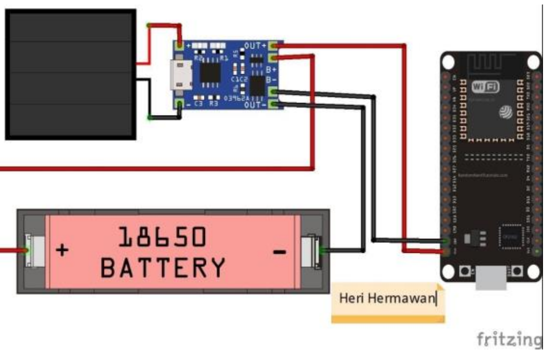

Figure 10. Schematic of the ESP32 microcontroller and solar cell, lithium battery, and TP4056 module

The system is developed by a microcontroller-based electronic circuit approach utilizing the Internet of Things (IoT) mechanism. This circuit is centered on the ESP32 Microcontroller which functions to receive data from several input sensors, process the data and send the processing results to several drives. Some of the input sensors used are HC-SR04 ultrasonic proximity sensor, BME280 temperature, humidity and pressure sensor, water flow meter sensor, and YL-83 rain intensity sensor. The processed data is sent to the IoT system using the web so that it can be monitored online. To power the system, a solar cell-based power source is used. The power generated from the solar cell is stored in a power storage using a lithium battery, and TP4056 module. The overall series of tools and system is depicted in Figure 11.

After that, the research continued with testing and measurement. The process of testing and measuring the ultrasonic sensor is shown in Figure 12. Figure 13 shows the process of testing and measuring the rain sensor. The process of testing and measuring rain and temperature sensors is shown in Figure 13, Figure 14 and Figure 15, respectively. An example of measurement results during heavy rain is shown in Table 1.

Figure 11. Overall series of tools (Front View, Side View and Bottom View)

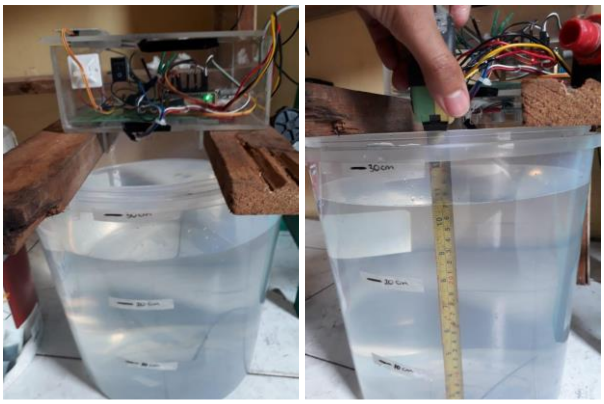

Figure 12. Testing of ultrasonic sensors

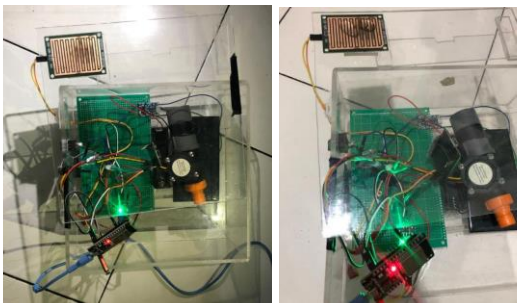

Figure 13. Rain sensor testing

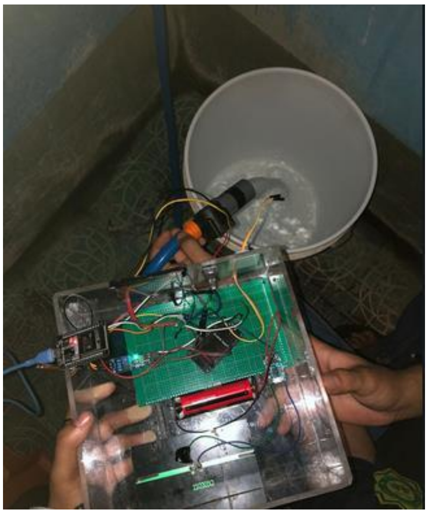

Figure 14. Testing the water flow meter

Figure 15. BME280 sensor testing

Table 1. Result during Heay Rain

Rain Type	Distance (cm)	Flow (L/min)	Temperature (°C)	Humidity (%)	Pressure (hPa)	Altitude (m)	Time	Situation Class
Moderate	24	10	31	66	101159	14	2023-07-18 10:22:09	moderate
Moderate	24	15	31	64	101159	14	2023-07-18 10:22:51	moderate
Moderate	24	19	31	60	101158	14	2023-07-18 10:18:32	moderate
Heavy	25	19	30	61	101161	14	2023-07-18 10:18:14	significant
Heavy	25	18	31	62	101162	14	2023-07-18 10:14:56	moderate
Heavy	25	18	31	64	101165	13	2023-07-18 10:14:38	moderate
Heavy	24	14	31	70	101168	13	2023-07-18 10:09:20	moderate
Heavy	24	10	31	68	101166	13	2023-07-18 10:09:02	moderate

One of the direct and on line measurement processes results are shown in Table 1. The table shows several parameters measured, such as river height, river flow rate, temperature, humidity, air pressure, altitude and time of measurement. Based on the table, it can be seen that there is a corresponding change between the type of rain that occurs and several other parameters along with changes in time. Some of the parameters that change according to the type of rain that occurs are: river height, river flow velocity, temperature, humidity, air pressure, and altitude. The changes that occur are directly proportional to the changes in rain that occur.

In addition, there are parameters that are the result of the classification of the measurement data obtained. The parameters that are the result of the classification of the measurement data obtained are Rain Type and Situation Class. The Rain Type parameter is the result of classification from rain intensity measurements obtained through simple type division. From the testing of the tools that have been carried out, this series has succeeded in monitoring the water level with 3 levels, namely normal, alert and standby and can monitor rainfall from light rain, moderate rain, and heavy rain. The classification of the readings of the rain stress numbers is set as follows: 0–2000 = heavy rain, 2000-3100 = moderate rain, 3100-3800 = light rain, and above 3800 = no rain. While the Situation Class is obtained from the sensor fussion process from all existing sensors [29][30].

CONCLUSION

From the test results of all the tools that have been implemented, it can be concluded that the tools made work as expected. All the sensors can read temperature, humidity, barometric pressure and altitude, and can monitor flow rates all tests can be viewed in real time on the web. In testing the ultrasonic sensor which is used to determine the distance between the height of the sensor and water objects starting from a height of 5cm, 15cm, 20cm and 27cm it has succeeded in giving notifications on the web at normal, alert and alert levels. In testing the rain sensor, the sensor is able to provide notifications from light, moderate to heavy rainfall levels. The test is carried out by comparison on the serial monitor when the rain sensor voltage reads the voltage number 4095 which indicates the condition of the dry rain board. In testing the BME280 sensor, the sensor can read temperature, humidity, air pressure and altitude. In the tests that have been carried out the water flow meter can read the water discharge when given water and can display it in real time on the web, when the water is not flowing, the web will display a reading of 0 L/min. Sending sensor reading notifications to the web requires a delay of approximately 20 seconds.

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