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Design and Development of a Prototype Water Level Control System for Early Flood Detection Based on The Internet of Things: a Case Study of Kambaniru Dam

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Abstract

Flooding can occur due to overflowing water during the rainy season, therefore early detection of the water level in dams as water runoff processing structures is needed. When heavy rain occurs it can result in flood disasters that are detrimental to communities, dam infrastructure and agricultural land. This research aims to monitor water levels online as initial information about impending flood disasters. Monitoring using Internet of Things (IoT) based technology is intended to obtain water level information in real time. In this device the HC-SR04 ultrasonic sensor is used as a water level reader, a waterflow sensor as a water discharge reader and a servo motor as a sluice gate controller. The results of this research are a prototype of a water level detection device that can provide water level information and can control sluice gates. automatically and can be controlled manually or remotely via the latest notifications in the Blynk application using the MQTT protocol. This research was carried out by taking information based on the results of direct observations and interviews with officers at Kambaniru Dam, Lambanapu Village, Kambera District. In this way, the prototype of this detection tool will be easy to use as initial information about the possibility of flooding.

Keywords: *Control Systems, Dam, Floods, Internet of Things (IoT), Prototype*

1. Introduction

Flooding is a natural phenomenon where there is excess water that is not accommodated by drainage channels in an area so that it can cause detrimental inundations [1]. During the rainy season, many settlements, agricultural land and irrigation canals are flooded. Therefore, it is necessary to build a water treatment system to reduce the impact of flooding. One way to control water runoff is to build a weir. Weirs are used to raise the water level of rivers to the height required so that water flows into irrigation channels and rice fields [2]. One of the main functions of a weir during a flood is to control the flow of water entering the water channel. By closing or adjusting sluice gates or weir gates, the flow of water entering downstream can be reduced or stopped temporarily so as not to cause flooding in residential areas and residents' agricultural land. In the weir there is a sluice gate which is used to regulate the flow of water gradually or continuously, depending on the amount of water in the weir. Weir operating officers must directly monitor the water level to carry out the process of opening and closing the sluice gates. Water from weirs that is sent to rivers and irrigation canals can cause flooding if their capacity increases due to high rainfall.

One of the weirs that is the main thing to watch for the residents of East Sumba is the Kambaniru Dam. In 2021, high intensity rain accompanied by strong winds for several days resulted in the dam overflowing. This weather resulted in damage to weir infrastructure, damage to tools used to measure water levels and flooding in 4 sub-districts, including Kambera, Pandawai, Karera and Wulaweju sub-districts. Many affected residents were displaced due to the flood and it caused significant loss to the community's agricultural land. The development of internet use in this modern era is taking place rapidly and touches various aspects of people's lives. One concept of internet use that is currently developing is the concept of the Internet of things. Internet of Things (IoT) is a design that aims to enable electronic devices to communicate with each other independently, and to receive and transmit data using a network connection [3]. There are many conveniences offered by Internet of Things-based technology to help make it easier for people to obtain information, one of which is providing information about disasters such as floods.Therefore, one of the things that is needed in the current operation of the weir is information that can monitor water levels to detect early floods clearly and directly. It would be better if control of the weir sluice gates could be carried out automatically, because being able to respond to changes in water levels quickly and efficiently would reduce damage to infrastructure and reduce the workload of officers in operating them which is at risk of accidents. Based on the description above, a water level monitoring system is needed as an early detector of flooding at Kambaniru Dam so that it can minimize losses due to flood disasters.

Basically, IoT devices consist of sensors as a data collection medium, an internet connection as a communication medium and a server as a collector of information received by the sensors and for analysis[4]. A control system or control system is a tool (collection of tools) to control, command and regulate the state of a system. There are several control systems, namely Feed Forward Control Systems (Open loop systems), Feedback Control Systems, Manual Control Systems and Automatic Control Systems[5]. The type of WeMos used is Wemos D1 R1. Wemos can run stand-alone, unlike other WiFi modules which still require a microcontroller as the controller or brain of the circuit, because inside it there is a CPU that can program via a serial port and transfer programs wirelessly[6]. In this research, an ultrasonic sensor was used to measure water level. Ultrasonic Sensor is a sensor for detecting distance. Ultrasonic sensors have 2 transmitting media, namely transmitter and receiver. The way the ultrasonic sensor itself works is that it emits ultrasonic waves which are emitted through a transmitter and reflected by objects with a reader/receiver medium via a receiver[7]. Water Flow Sensor is a sensor that detects the flow of water passing through the sensor. This sensor consists of a plastic pole body, a water rotor, and a hall-effect sensor[8]. A servo motor is a device or rotary actuator (motor) that is designed with a closed loop feedback control system (servo), so that it can be set-up or adjusted to determine and ensure the angular position of the motor output shaft[9]. Blynk is a platform for Mobile OS applications (iOS and Android) which is used to control Arduino, Raspberry Pi, ESP8266 and similar modules via an internet connection. Since its launch in 2014, this application has become a widely used application because it offers convenience and provides the opportunity for users to be creative in creating a graphical interface using the drag and drop widget method provided[10].

2. Research Methods

The Kambaniru Dam was built with the aim of preparing a water supply for irrigation and irrigating the residents' agricultural land. Kambaniru Dam is the largest weir in East Sumba which irrigates almost 1440 Ha of rice fields. Kambaniru Dam has an intake gate as the main water gate, which is one of the main equipment of the weir which functions to divert water from the river to the irrigation canal for community needs. When the water level reaches a critical level or floods, this door is closed to avoid damage to the weir infrastructure.

There are several stages in this research as in Figure 1: Planning is the first step in conducting research which will develop a measuring instrument that can be used to measure water levels and control sluice gates. The analysis stage carried out the data collection process, where the author carried out a literature study to understand the process of monitoring flood gates. The author also conducted interviews with officers to obtain information regarding conditions in the field, starting from the process of monitoring water levels, to flood mitigation efforts if the floodgates enter a dangerous condition. The results of the information search are then packaged as a basis for carrying out system requirements for the Internet of Things-based monitoring process. The design phase aims to design a prototype weir with monitoring and controlling water gates based on the Internet of Things, focusing on intake gates. The next stage is implementation aimed at implementing the system that has been designed.

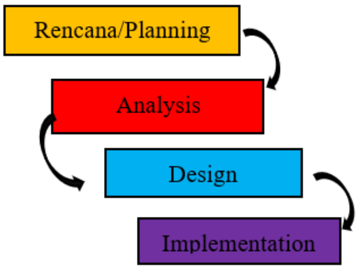

Fig. 1: Research flow

2.1. Block Diagram

Figure 2 is a block diagram of the working stages of the control system. There is an ultrasonic sensor to read the water level and a water flow sensor to read the water flow entering the container. Wemos D1 as a microcontroller will manage the data from sensor readings. Wemos D1 will activate the buzzer to provide an alarm when the air level is at a dangerous level. Next, the Wemos D1 microcontroller sends sensor data to the Blynk application using the MQTT protocol as a communication protocol to be published via the internet. Clients receive information via smartphone using the blynk application as a monitoring system to display water level and discharge data.

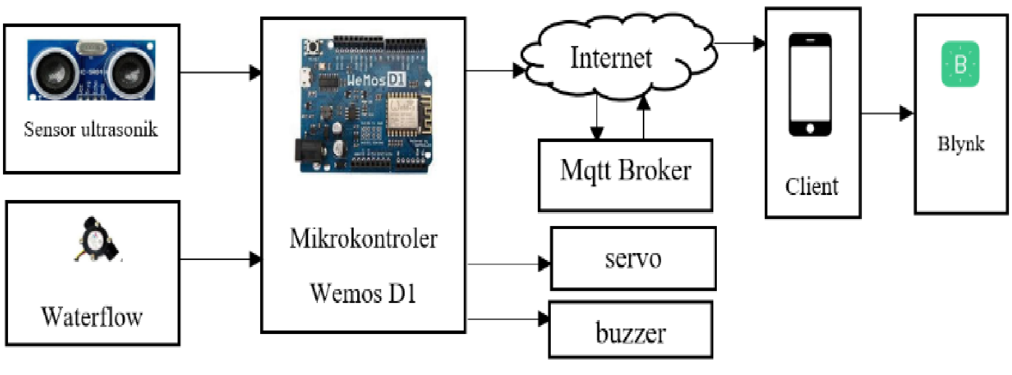

Fig. 2: Block diagram

This weir prototype was made using a container with a reduction scale of 1: 200 to the original size where the original length of the weir = 160 meters, width of the weir = 150 meters and height 30 meters. In the design in figure 3 it is divided into 2 upper and lower containers. The container above is equipped with an ultrasonic sensor to detect the water level in the container which is placed at the top. To distribute water into the container, a water discharge sensor is needed to find out how much water is entering. The container below is symbolized as a channel that functions to accommodate water that comes out through the sluice gate which will continue the water to the next irrigation network. The sluice gate will be raised and lowered by a servo motor as an actuator. Use of a water pump in the recuperation cycle to maintain water availability in the container. The height of the air in the container can be calculated using the distance between the sensor and the air surface. With the following formula:

T = W – J

T = Water height in the container

W = Total height of the container

J = Distance between the sensor and the water surface

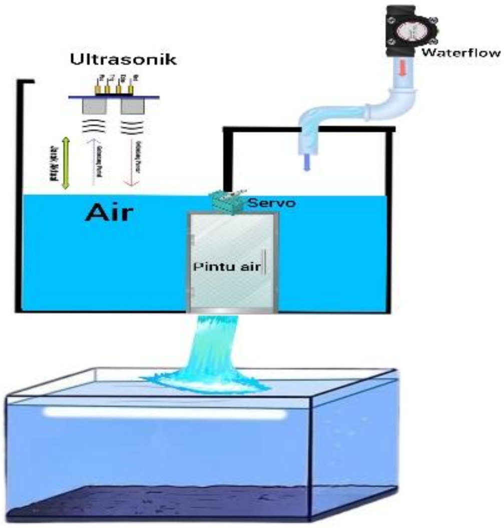

Fig. 3: Prototype Dimensional Modeling

2.2. Sluice Gate Simulation System Workflow

Figure 3 is the Automatic Water Gate Simulation System Workflow. When the ultrasonic sensor detects that the water level has reached or exceeded 8 cm, the system will trigger the servo motor to close the water gate automatically. The aim of closing this door is to prevent further increases which could cause flooding. Conversely, when the water level drops below 8 cm, the system will trigger the servo motor to reopen the water gate, allowing water flow to run normally.

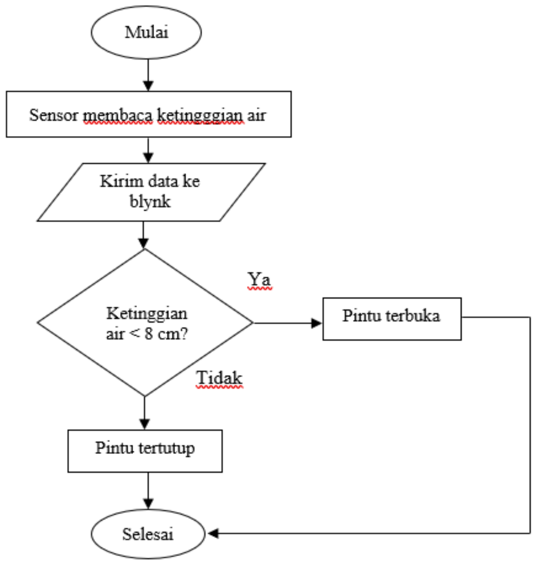

Fig. 4: Sluice Gate Simulation System Workflow

Figure 4 is the manual sluice simulation system workflow.When manual control mode is activated, the user has complete control over the sluice gate regardless of the water level. In this mode, users can open or close the floodgates by pressing the button available in the Blynk application. Even though the sensor detects that the water level reaches or exceeds 8 cm, the sluice gate can still be operated manually.

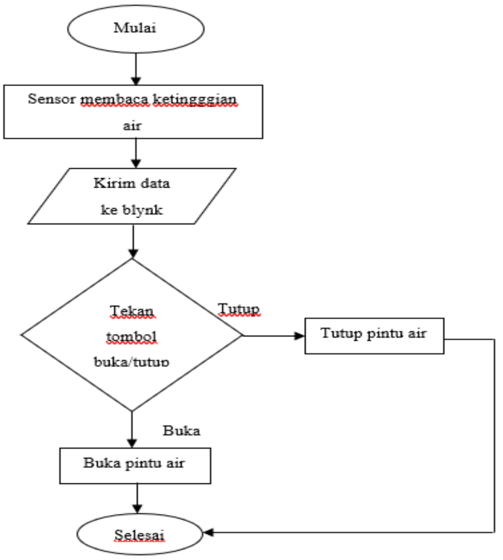

Fig. 5: Sluice Gate Simulation System Workflow

In Figure 4, the manual or remote control sluice system that will be built has the function of opening and closing the sluice gate. Users can control the sluice gate according to a certain water level at the weir based on the results of ultrasonic sensor readings which are monitored via the Blynk application. When you press the open button the door opens, and when you press the close button the door closes, this always works regardless of the water level.

2.3. Schematic Design

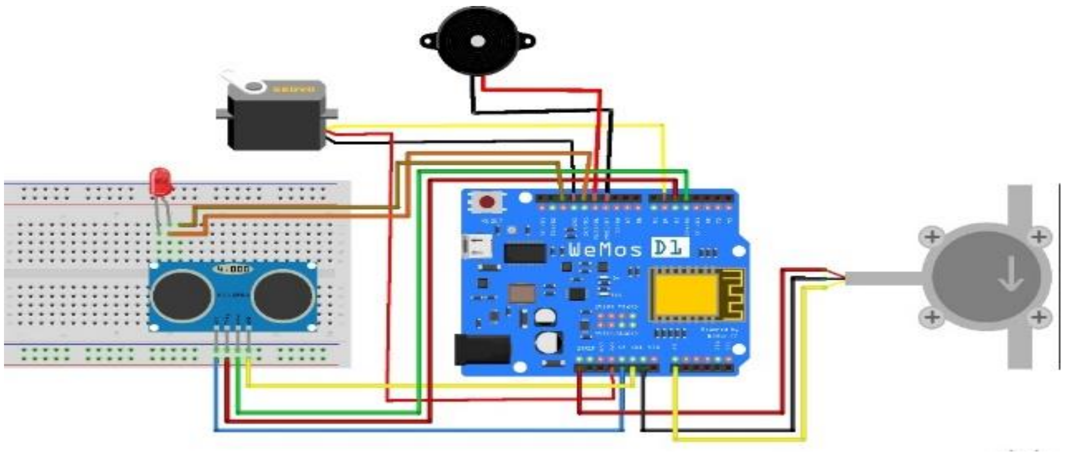

Fig. 6: Schematic Design

Table 1: Set of tools

No	Schematic Design	
	Component	Connection Pins
1	Ultrasonik HC-SR04 VCC GND Trig Echo	 5V GND D5 D6
2	Waterflow VCC GND Signal	 5V GND D7
3	Servo Motor VCC GND Signal	 5V GND D3
4	Buzzer	

+	D4
-	GND

3. Results and Discussion

Fig. 7: Control System Program

Figure 7 shows the programming code for a prototype IoT-based weir water level control system using the Arduino programming language. This code integrates an ultrasonic sensor (HC-SR04) to measure water level, a water flow sensor, a servo motor to control the sluice gate, and a buzzer as an alarm for the Blynk application. This code consists of hardware and software initialization, reading sensor data, sending data to the Blynk application, as well as logic to control the floodgates and buzzers based on the detected water level. The system is designed to provide real-time monitoring and control, as well as allowing manual control via the Blynk app.

4. Implementation

This automatic sluice control system uses the Blynk application to monitor water level, water flow and sluice gate status in real-time. In figure 6, the system in the Blynk application shows that the water height is currently recorded at 7 cm, which was measured using the HC-SR04 ultrasonic sensor. The monitored water flow is 2 liters per minute (L/min), which is measured using a water flow sensor. The sluice gate status shows an open condition, which means the sluice gate is in the open position and flowing water. This system is controlled automatically based on the detected water level; When the water level is below 8 cm, as shown in the figure, the sluice gate will remain open.

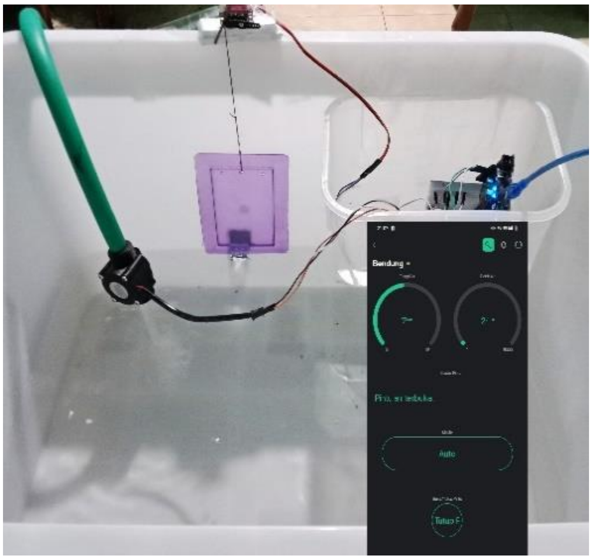

Fig. 8: Automatic Sluice Control System

In Figure 7, the system in the Blynk application for manual control of sluice gates shows that the water level has currently reached 9 cm, as measured using the HC-SR04 ultrasonic sensor. The monitored water flow is 2 liters per minute (L/min), measured via a water flow sensor. The floodgate status shows a closed condition after the "Close" button is pressed in the Blynk application. In this manual mode, users can directly control the floodgate by accessing the Blynk application and pressing the open or close button.

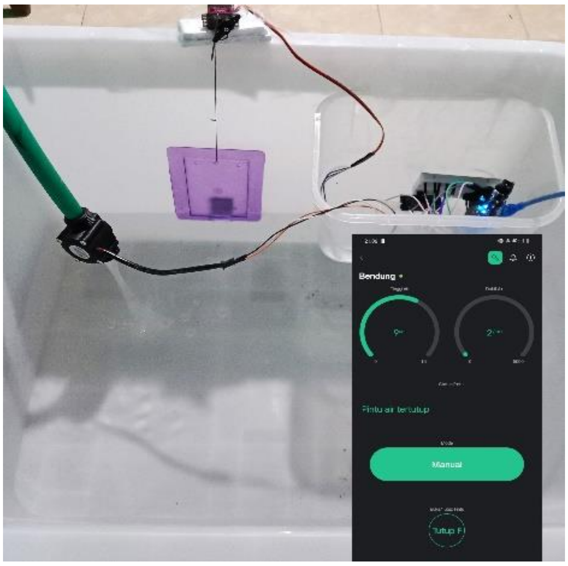

Fig. 9: Sluice Control System Guide

5. Conclusion

In this research, a prototype of a weir water level control system has been successfully designed and built as an early flood detector based on the Internet of Things (IoT). This system consists of several main components, namely an ultrasonic sensor to measure water level, a water flow sensor to measure water flow speed, a servo motor to control the water gate, and a buzzer to provide an alarm when the water level exceeds a specified limit. Testing shows that the prototype system can work well in two modes, namely automatic mode and manual mode. In automatic mode, the sluice gate will close automatically when the water level reaches or exceeds 8 cm, and the buzzer will sound as a warning sign. In manual mode, users can control the sluice gate directly via the Blynk application on their cellphone, enabling more flexible remote control.Apart from that, this system has also successfully integrated the Blynk application to monitor water levels in real-time. This allows the operation of the weir to obtain accurate and fast information regarding the condition of the weir, so that potential losses due to flooding can be minimized.

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