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Designing an early flood detection system prototype in riverbank settlements

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Abstract: There is still a lot of use of the floodgates in the main hole to drain the residential water into the river is still operated manually by someone in charge of opening and closing the floodgates. It is less efficient and often happens to the operator, so the water overflows and can lead to flooding. In this final task, a prototype of an early flood detection system and the automation of sewerage in a settlement located on the riverbanks. The control of floodgates on the main hole works automatically according to the signal from a sensor that reads the state of the water level. Main hole floodgates will work when the river water enters it at a specific limit that sensors will read and provide information on the level of river water in it to someone via WhatsApp to prevent river water from entering the settlement. When the main hole door is closed automatically, the residential water flow will be directed to a temporary reservoir. When the temporary reservoir is full, the sensor will signal to activate the discharge pump that will be discharged into the river to dispose of the water in the reservoir. The design and testing of flood early detection prototype tools and residential water disposal automation can work well by the design principle.

Keywords: early detection, flooding, settlement, riverside, main hole

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Introduction

Floods are natural disasters that have often occurred. The occurrence of flooding can be caused by natural factors or the condition of a place. One example of a flood-prone place is a settlement close to the river caused by rising river water in the main hole dumping residential water into the river. The main hole is a construction built for sewerage from settlement to the river. When the river water at the main hole increases over the limit, and there is no warning, flooding can occur in the settlement. Therefore, monitoring the floodgates at the main hole needs to be carried out so that the process of discharging water from settlements to rivers runs smoothly. Most of the process of opening the floodgates in the main hole is still done manually by someone. It would be nice if the control of the floodgates on the main hole works automatically and can be monitored because the water level changes are always changing in an uncertain time.

Research has been carried out to solve flood problems, including designing a flood warning and monitoring system to provide early warning to victims in certain flood-prone areas. Implementing Internet of Things technology into the system can help victims get accurate flood status in real-time [1]. Research has also been done to deal with the flooding problem, which impacts the loss of people due to a lack of information and warning. So it is necessary to convey emergency information, monitoring, and warning systems is needed to the public so that they are prepared in case of a flood. The monitoring system can be accessed easily, quickly, anywhere, and anytime by the community. As well as the need for early warning that can inform the public that there is an increase in the water level in the dam, it is hoped that people can prepare themselves for the upcoming floods [2].

Other research to overcome the flooding problem has been conducted by designing a river's water level detection system as an early warning system for floods based on Arduino Nano using the Thingspeak website technology and the Thingsview Android application to provide information for the entire community. With this tool, people who live around the watershed can monitor the river's water level to find out in advance if a disaster occurs [3]. Furthermore, to solve the problem of flooding in dams that have often occurred due to many factors, research has been conducted to produce a dam floodgate that can adjust the water level automatically at a cost that is not as high as the actual plant using the Fuzzy Method Logic Controller. With the Fuzzy control method, to determine each parameter, a plant identification process is carried out to obtain a rule evaluation used as a guide in setting water levels [4].

In addition, other research was being carried out on a water level control system that has an important role in providing convenience in the drainage system, opening and closing the floodgate based on the level of rainfall using Arduino. This design is expected to be a good contribution to the drainage system. With this automatic floodgate, of course, it will minimize the risk of flooding or other risks [5]. The research was carried out to overcome the flood problem by using Arduino as a microcontroller which will thoroughly control the ultrasonic sensor as a water level detector and the buzzer sensor as a sounder or alarm when the water level has reached a certain limit. The SMS will be directly sent by SIM800L sensor to the citizen's mobile number or contact number that has been adjusted by the system [6].

Furthermore, research conducted based on the problems of opening and closing floodgates on rivers or dams in Indonesia has been carried out. The study stated that the problem occurred because the process was still manually based on the water level, so more workers were needed to guard the floodgates. It is inefficient, so an automatic control system for opening and closing the floodgates is made based on tidal water level using Arduino UNO as a processor [7].

Research has also been conducted due to the lack of information on flooded roads to design a GSM-based flood detection and location information system. A GSM-based wireless flood detector has been designed using the HC-SR04 ultrasonic sensor. This tool works based on the height of the water inundated on the highway. The tool consists of an ultrasonic sensor placed at the height of 150 cm on a highway pole. When the water level reaches 40 cm, the Arduino Uno as a data processor using the C language, will control the SIM800L program to send SMS once with an average delivery time of 12:06 s to the registered number [8].

As one of the developing cities in West Papua Province, Sorong City almost always experiences flooding during the rainy season caused by overflowing river water. This problem was overcome by building a prototype system design for this automatic sluice control device using an information delivery system via a microcontroller-based SMS, the GSM Shield media interface between sending SMS and automatic sluice gates [9].

Vulnerability is a condition that can reduce the ability of the community to prepare themselves to face a hazard or threat of disaster. The purpose of understanding vulnerability is to reduce the likelihood of adverse impacts caused by disasters. The formulation of the problem in this study is how to compare the Fuzzy Mamdani and Fuzzy Sugeno methods to detect flood-prone areas in Pringsewu District. The construction of a prototype to determine flood-prone areas in the Pringsewu District can reduce the risk of flooding through physical development and awareness and increased capacity to face disasters [10].

The problem that often occurs in the community is the difficulty of early detection of impending flooding so that it has an impact on material losses and casualties. For that, we need a system that can detect floods early so that people can immediately find out early warning information quickly and effectively anticipate early by saving themselves or valuables. Therefore, the researcher designed a flood detection system that automatically monitors water levels and sends early warnings. This water level monitoring system uses the NodeMCU ESP8266 with ultrasonic and IOT-based sensors to provide real-time data to determine the water level created at a certain level. In addition, this system is connected online and displays real-time water level data on the Thingspeak platform and integrated with the Telegram application as an early flood warning [11].

Based on that background, this research builds a control system of early flood detection and automation of water disposal in riverside settlements. The system controls the water door on the main hole. The door on the main hole will work automatically according to the signal from the sensor. When the river water rises and enters the main hole at a certain level, the sensor will signal to send information on the river water level at the main hole to someone. At the same time, the water door will close so that the river water does not enter the reservoir. When the water door to the river is closed, water flow from the reservoir will be diverted to temporary reservoirs. It is hoped that this system can overcome the problem of flooding in the reservoir due to the entry of river water through the main hole.

Methodology

System Design

The design is a prototype system on the main hole of community water disposal to the river based on Raspberry Pi 3 with the on/off system method. Discussion of system design starts from the research stage, diagram block system, hardware design, and software design.

Stages of Research

Figure 1 shows the stages of research. The first thing to do is identify the problem to understand the action that needs to be taken. After identifying the problem, the data collection needed in the implementation of tool creation can be processed. After that, the literature study is conducted to determine what control methods would be used in the tool's design. Next, after obtaining data and there is a step called the manufacture of tools. Once the tool is complete, the tool is then evaluated. If the testing results are not following the desired outcome, then another test is conducted. Finally, after the tool runs smoothly and meets the desired results, the final report is written.

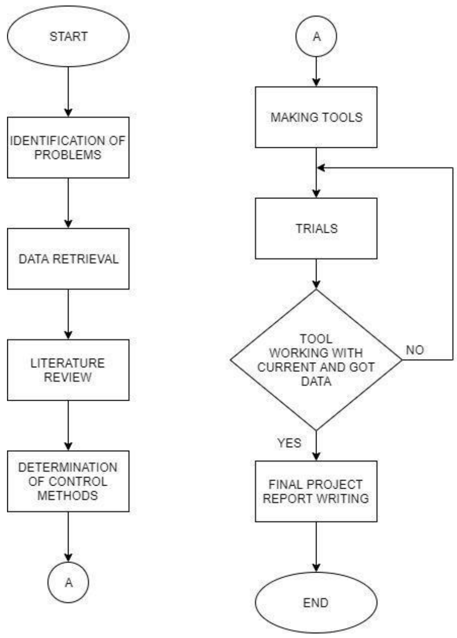


Figure 1. Stages of Research

System Design Diagram

Figure 2 shows the system design diagram. The sensor serves as a river water level detector and provides a signal to the Raspberry Pi 3. The Raspberry Pi 3 serves as a data processor while storing the binary data needed to control the motor drive to open the floodgates, displaying the information on the LCD. The motor drive serves as an automatic floodgate drive that receives it from the sensor to open and close the water doors. LCD serves as a display of circuit activity. The pump serves to discharge water from the settlement if the reservoir is full. The Wi-Fi module connects Raspberry Pi 3 with the internet to access WhatsApp servers and send messages. WhatsApp in this plan serves as a medium to inform the level of river water level.

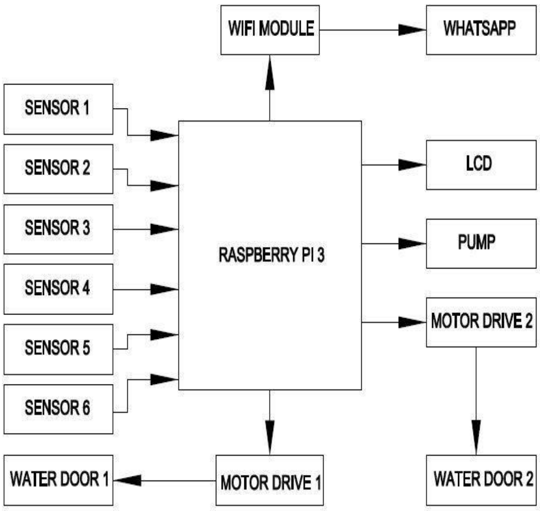


Figure 2. Diagram of system design

System Block Diagram

Figure 3 shows the system block diagram. Raspberry Pi 3 is a component used to process data and feedback from sensors to be passed to motor drives and water doors. A floating water level sensor is a component used to detect water levels. A DC motor drive is a component used to drive the water doors that previously got input from the Raspberry Pi 3. The pump is a component used to drain water in a reservoir. Water doors are components used to set the waterways on the main hole. A water reservoir is a container to hold the wasting water if the river water spills out to the normal limit on the main hole. The main hole is a building that serves to drain water into the river.

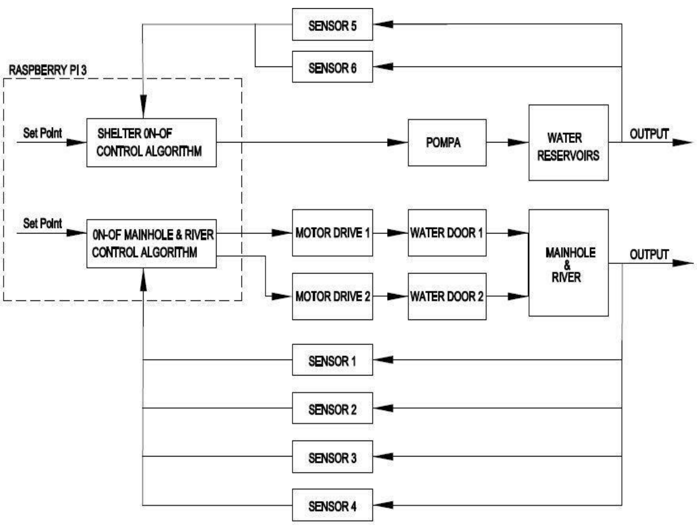


Figure 3. Diagram of system block

Working Principles of the System

This control system is built to control the water doors and exhaust systems automatically. This system works by controlling the water doors in the main hole to be automatically open or closed based on the height of river water flowing in the main hole. The water doors operate automatically, get a signal from the sensor, and are reprocessed by Raspberry Pi 3. The water doors can be open or closed automatically following the activity level of the river water level. When the river water is high and enters the main hole disposal, the sensor will read the water level and signal the Raspberry Pi 3. It drives motor 1 to close water door 1 and drives motor 2 to open water 2 connected from the disposal of the reservoir to the river. The system will send information on the river water level to the settlement residents via WhatsApp. When water door 1 is closed, the disposal from the settlement will be diverted to the reservoir that passes through water door 2. When the reservoir is full of sensors installed in the reservoir will work and will activate the pump to dispose of the water in the reservoir dumped into the river.

The Design of Mechanical Systems

The mechanical system is designed using PCV plate material. This system is mechanically designed with a material thickness of 3mm and dimensions of 0.6m × 0.6cm. The design of the mechanical system shows in Figure 4.

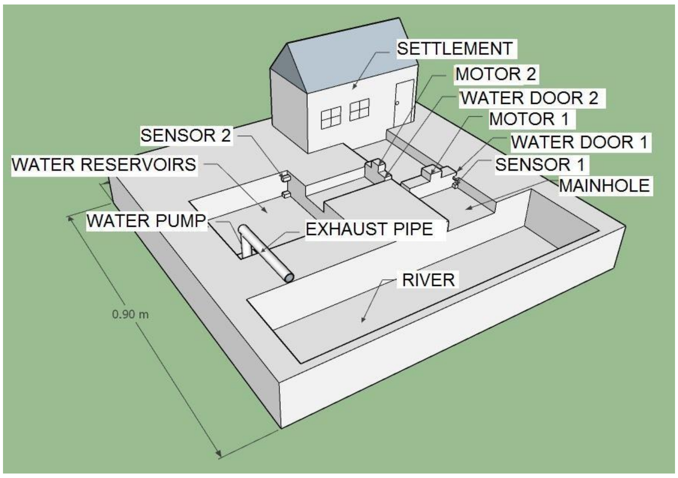


Figure 4. The design of the mechanical system

Software Design

In the software design, early flood detection systems and automation of sewerage systems in riverside settlements use python software to create programs uploaded on Raspberry Pi 3. To facilitate the creation of the program, the main program flowchart and sub-program flowchart are created.

1. Main Program Flowchart

   The flowchart of the program can be seen in Figure 5. When the program works, the program goes through initialization. After that, the program works according to the inputs from the sensor. There are six sensors installed in different places. Four sensors are installed on the main hole and riverbanks to read river water levels, and two sensors are installed in reservoirs to read water levels in the reservoir. After getting input from sensors installed in the main hole and riverbank, the system will automatically send messages via WhatsApp to the residents according to the level changes. After the program runs, the LCD will display the status that the program is completed.

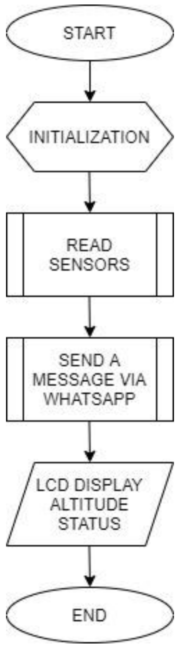


Figure 5. Main program flowchart

2. Flowchart of Sub Program in Reading River's Water Level Sensor
The flowchart for the sub-program in reading the river's water level sensor program shows in Figure 6.

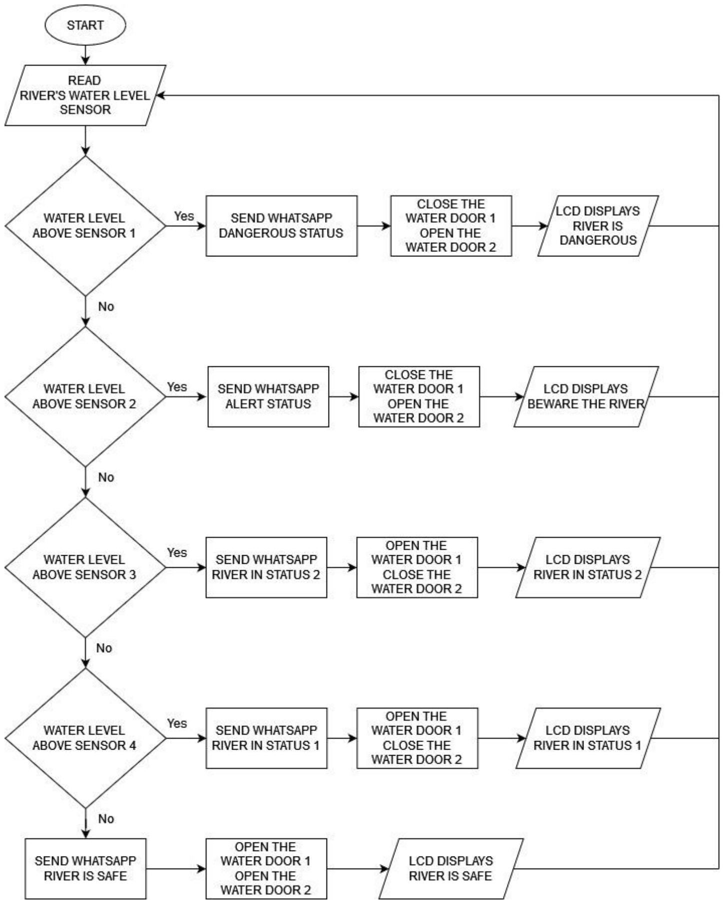


Figure 6. Flowchart of the subprogram in reading river's water level sensor

When the program is working, the sensor will read and provide input on the program. The program works according to inputs from sensor values that have been installed in the main hole and in rivers that serve to detect the level of the river's water level. Once the program receives input from the sensor, it runs according to the values read by the sensor. For example, if the water level is above sensor 1, the system will send a message via WhatsApp dangerous status, and LCD will display the status "river is dangerous". On the other hand, if the water is under sensor 4, the system will send a safe status message, and the LCD will display the "river is safe" status.

3. Flowchart of Sub Program in Reading Reservoir Height Sensor
Figure 7 shows the flowchart of the subprogram in reading the program of the reservoir height sensor.

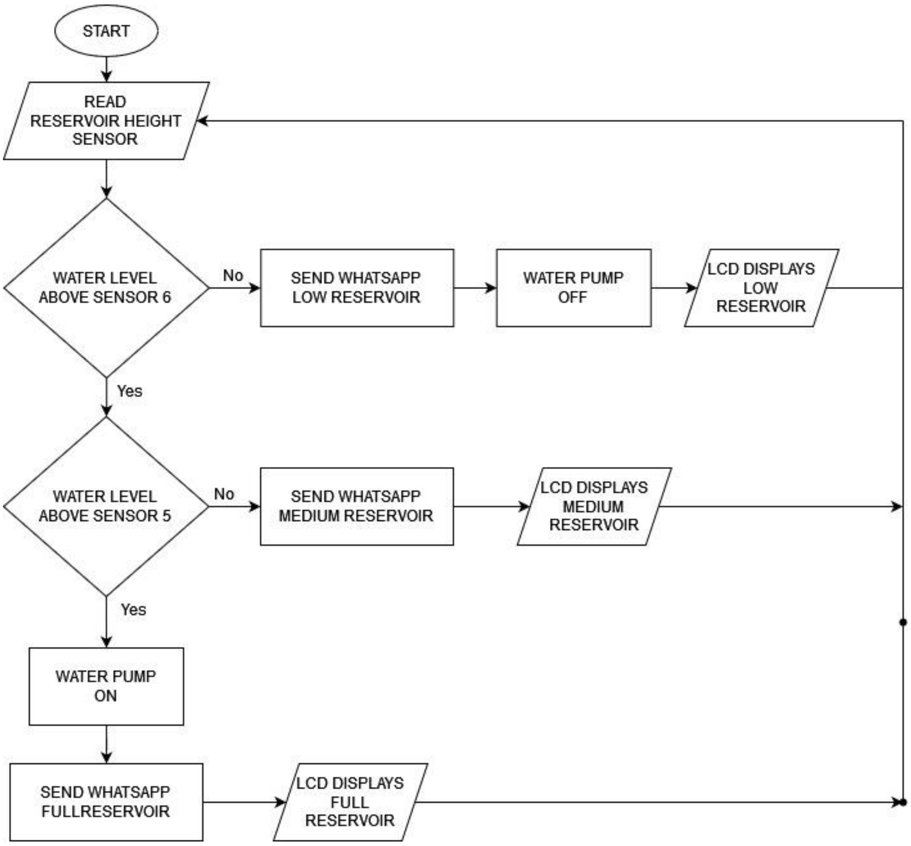


Figure 7. Flowchart of the subprogram in reading reservoir height sensor

When the program starts working, then the sensor will work and provide input on the program. Once the program receives input from the sensor, it runs according to the values read by the sensor. For example, if the reservoir water height is under sensor 6, the pump will not work, and the LCD will display "low reservoir". On the other hand, the pump will work if the water is above sensor 5, and the LCD shows a "high reservoir".

4. Flowchart of sub-program in sending messages via WhatsApp
Figure 8 shows the flowchart of the sub-program in sending messages via WhatsApp. When the program works, sensor 1,2,3,4 will provide input to the Raspberry Pi 3. Once the Raspberry Pi 3 receives input from the sensor, the program works and processes the data. After Raspberry Pi 3 processes the input from the sensor, the raspberry will call the Pywhatkit application to forward the data obtained from the sensor. After the data is loaded in Pywhatkit, the message will be ready to be sent via WhatsApp web with a delay of 30 seconds to 1 minute. After the delay of loading the data and sending the message is

complete, the message is ready to be sent to the WhatsApp number registered, and the program is complete.

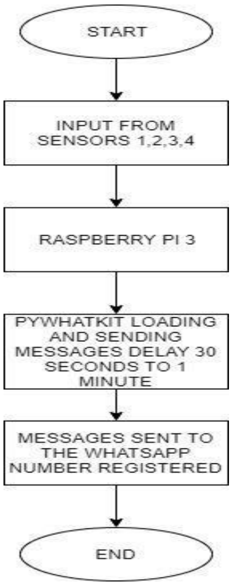


Figure 8. Flowchart of the subprogram in sending messages via WhatsApp

System Testing and Analysis

System testing is divided into testing parts of the system and testing the system as a whole.

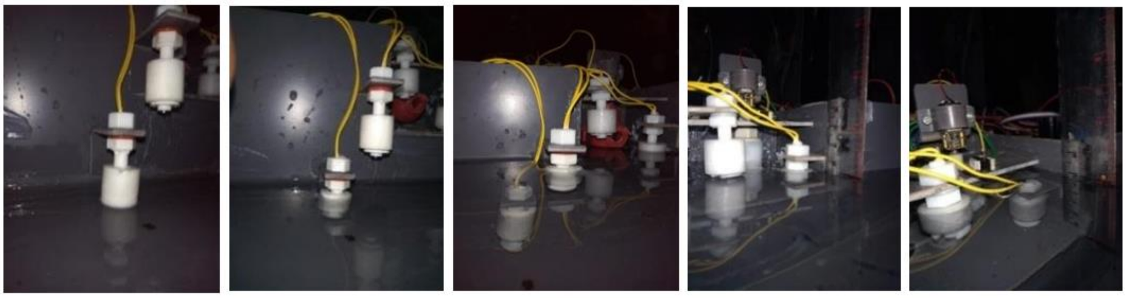
Testing System Parts

The tests performed on the system parts of this final task tool aimed to determine each component's performance by comparing the actual measuring instrument with the program's results. So that when running the overall tool design, it can run by the purpose and minimize the occurrence of system performance errors. The parts tested are water-level float sensor circuit, limit switch sensor testing, LCD circuit testing, relay circuit testing, DC motor circuit testing, and pump testing.

Overall Tool Testing

1. Testing the Process of Water Level Check

   Testing the process of water level check aims to determine the level of river water and whether the reservoir is working as expected. The river water level parameter in this prototype is 13 cm and is divided into five height levels for the status of river water level. Figure 9 shows the test using float water level sensors. In Figure 9, four sensors are attached to the device that serves as a river water level sensor. In Figure 9 points (1), it is seen that the river water is still under sensor 4, then the sensor reads the level of river water in the river in a safe state. At point (2), the buoy of sensor 4 has been lifted upwards, and then the sensor reads the river water level in standby state 1. At point (3), it looks like the buoy sensor 3 lifted upwards, then the sensor reads the river water level in alert state 2. At point (4), the buoy of sensor 2 is already lifted, then the sensor will read that the level of river water is in a state of alert. Finally, at point 5, where all the buoys of all sensors have already lifted, the sensor will read the river water level in danger. Table 1 shows the test results of checking the river water level.



(1) (2) (3) (4) (5)

Figure 9. The test using float water level sensors

Table 1. Result of testing river water level

No.	River water level (cm)	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Output
1	1-2	Off	Off	Off	Off	Safe
2	3-5	Off	Off	Off	On	Standby 1
3	6-8	Off	Off	On	On	Standby 2
4	9-11	Off	On	On	On	Alert
5	12-13	On	On	On	On	Danger

Table 1 shows the test results of checking the river water level. In Table 1, it can be seen that the water level will make the sensor work according to the height level that has been set at a certain water level and will produce output according to the height read by the sensor. The process of altitude check testing using a float water level sensor in the reservoir can be seen in Figure 10.

(1) (2) (3)

Figure 10. The process of altitude check testing using a float water level sensor

In Figure 10, two sensors are mounted on a tool that serves to sensor the water level in the reservoir. Point (1) shows that the water in the reservoir is still below the lower limit of the sensor, then the sensor reads that the reservoir's water level under normal circumstances. Point (2) indicates that the water is already on the lower limit sensor and lifted. Therefore, the sensor reads that the reservoir water level is in a moderate state. Point (3) indicates that the lower and upper limit sensors have been submerged in water, and the upper and lower limit sensor buoys have been lifted, so the sensor reads that the reservoir's water level is in a high state. Table 2 shows the results of the sensor testing in the reservoir. In table 2, it can be seen that the water level will make the sensor work under the altitude level that has been fixed at a certain water level and will produce output according to the height read by the sensor.

Table 2. Result of testing river water level

No	Storage water level (cm)	Lower limit sensor	Upper limit sensor	Output
1	<5	Off	Off	Normal water level
2	5-9	On	Off	Medium water level
3	10	On	On	Full water level

2. Testing the Process of Sending Messages via WhatsApp

Testing the delivery process via WhatsApp aims to determine if Raspberry Pi 3 can send messages via WhatsApp. Figure 11 shows a message informing a high river water level warning via WhatsApp in the Indonesian Language. The process of sending WhatsApp messages using the WhatsApp web with the Pywhatkit application requires login. Figure 12 shows that the response speed of sending messages via WhatsApp takes a time lag of about 30 seconds to 1 minute to process data and send messages. It is because the application takes time to process and send the data. If the speed is set quickly, the message will collide with the data, which cannot be sent.

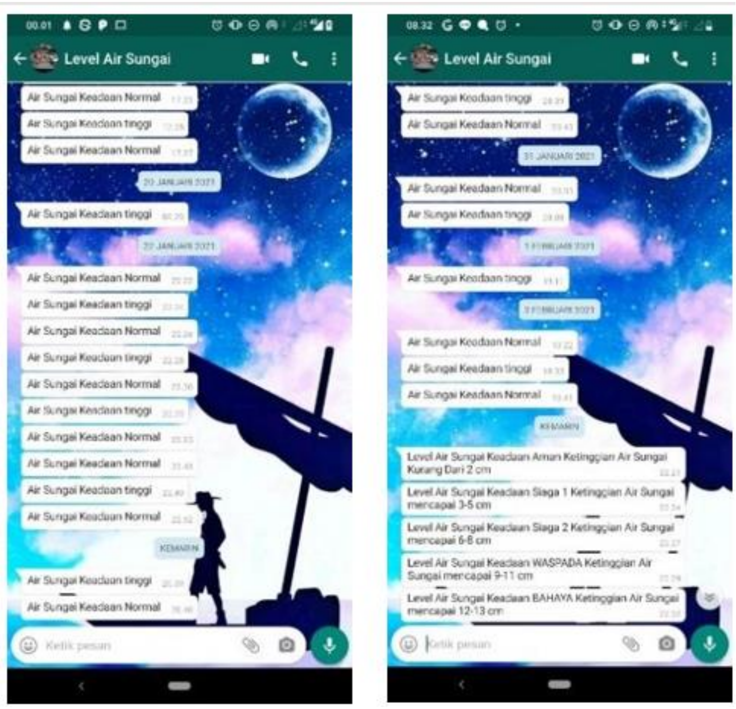


Figure 11. Message informing a high river water level warning via WhatsApp

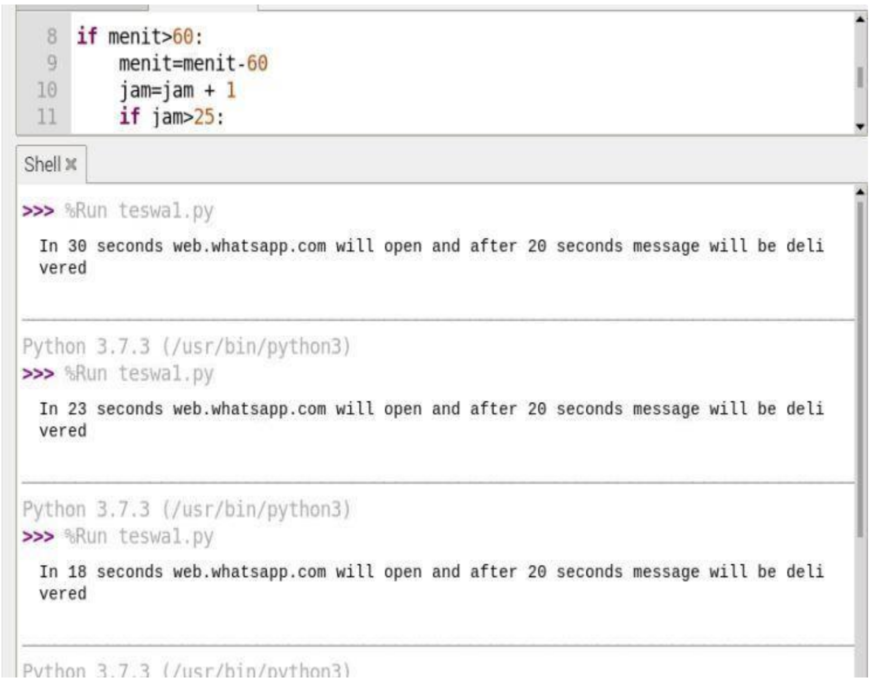


Figure 12. Result of speed response in sending a message via WhatsApp

3. Python Application Testing
   Python application testing aims to find out whether the application that has been designed can run as expected.

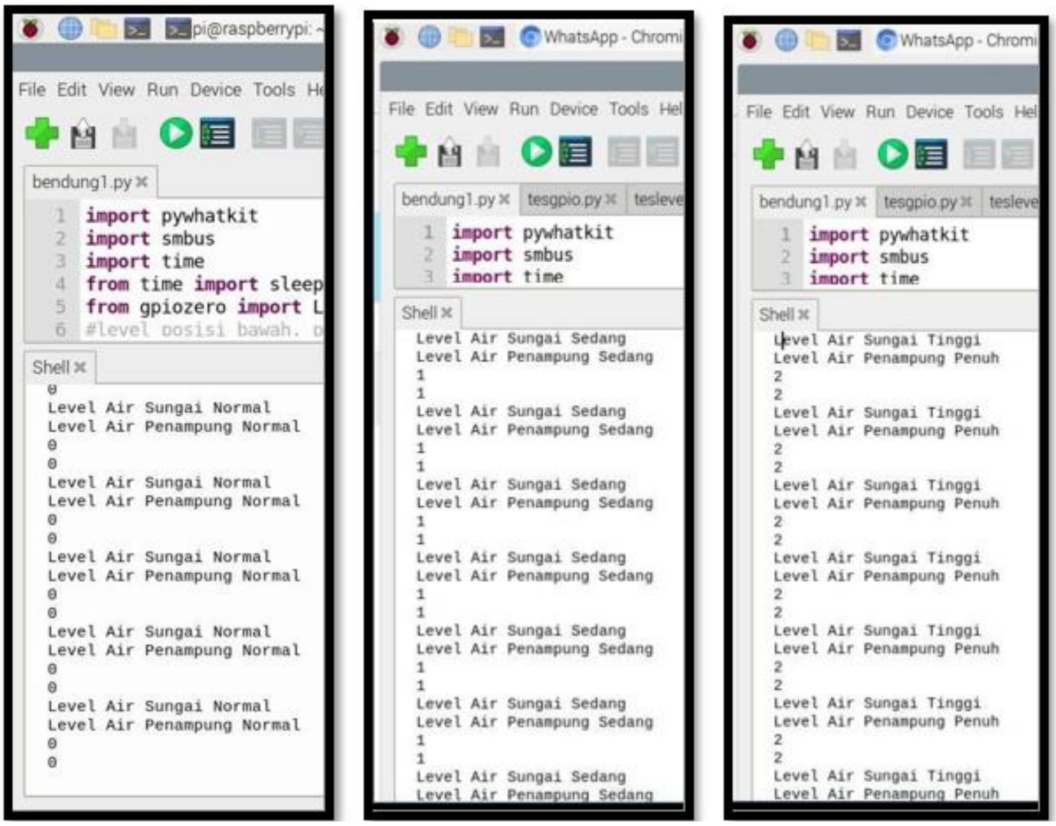


Figure 13. Python Application Testing

Figure 13 illustrates the reading of the float water level sensor installed in the main hole and reservoir in Indonesia Language. The left figure shows that the water level in the main hole and the reservoir are normal. The center figure shows that the water level in the main hole is moderate, and the right figure illustrates that the water level is high and full.

Whole System Analysis

From the steps of testing the parts of the system that have been carried out, it can be analyzed that each component has a different work system. So that the process of testing each component is very necessary to do, aiming to determine the characteristics and work system of each component. After testing and knowing the characteristics of the work system from each component, the components can be placed in the right parts so that the tools created can work as expected.

Testing the whole system covers testing the float water level sensor installed in the main hole and the reservoir. Testing the float water level sensor in the main hole is done by flowing water into the river until it enters the main hole, and the sensor will read the water level and provide input to the raspberry pi 3. Thus, the water level read by the sensor will be processed by the raspberry and displayed on the LCD. When the sensor in a high state reads the river water level in the main hole, the main hole water door closes, and the reservoir water gate opens, and the system sends a high river water message via WhatsApp. Sending messages via WhatsApp requires a time lag because the application used in sending messages via WhatsApp takes time to process data. After the data process is complete, the message is sent via WhatsApp automatically. Testing the automation of the drain pump is done by entering the water into the reservoir with the full water level limit, then it is read by the float water level sensor installed in the reservoir. After the sensor reads the full reservoir water level, the drain pump automatically works. After the water in the reservoir is drained and the sensor reads the normal reservoir water level, the drain pump stops. From the overall system testing that has been done, it can be analyzed that the system can work as expected. Results after testing the whole system can be elaborated as follows:

1. The test results of checking the river's water level with float water level sensor installed in the main hole and the river show that the process can work well, and the sensor can read the water level when the condition is safe, standby 1, standby 2, alert, and danger.
2. The test results of checking the water level in the reservoir with a float water level sensor show that the process can be done well, and the sensor can read the water level at normal, medium, and full time.
3. The process of opening the floodgates can work according to the input of the water level sensor. When the high river water level of the main hole door is closed, the reservoir water door is open.
4. The exhaust of the pump automation system process can work automatically with the input ofthe float water level sensor installed in the reservoir.
5. Raspberry Pi 3 can run an early flood detection system program and exhaust automation system and a message delivery process via WhatsApp with a Python application.
6. The process of sending messages via WhatsApp is still delayed due to the default application that takes time in the process of loading data. In addition, sending WhatsApp is done using the WhatsApp web.

From the Python application testing that has been done, it can be analyzed that the programmed system can run well as expected. Testing the system is done by running the water level float sensor manually so that the Raspberry receives the sensor input, and the results will be displayed on the LCD. The results on the LCD are the same as the input from sensors that have been programmed with Python.

Conclusion

Evaluating the parts of the system is very necessary as it aims to determine the performance of each component and can determine whether the condition of each component is good or damaged so that it can minimize errors and damage to system performance. Thus, system errors can be avoided to work under what has been designed when we run the entire system.

After the whole test is carried out, the tool can work properly according to the design. However, there are still weaknesses in sending WhatsApp messages. The process of sending the message can only be done with one number that has been registered as a recipient, and there is still a delay during the sending process. The application used in this tool cannot send messages simultaneously to different numbers and can only send messages to one number. If the messages are forced to be sent to several numbers, the message to the following number will be sent after sending the message to the first number is completed. It can create delays, and data collisions can occur so that errors will occur on the system. The delay in sending messages happened because it takes time to load data. The message sending process is done via the WhatsApp web, so it requires a WhatsApp number that is always active.

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