Journal of Advanced Research in Applied Mechanics 119, Issue 1 (2024) 162-173

Journal of Advanced Research in Applied Mechanics

Journal homepage:
https://semarakilmu.com.my/journals/index.php/appl_mech/index
ISSN: 2289-7895

Flood Level Detection System using Ultrasonic Sensor and ESP32 Camera: Preliminary Results

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ARTICLE INFO

Article history:
Received 19 March 2024
Received in revised form 14 May 2024
Accepted 28 May 2024
Available online 30 June 2024

Keywords:
ultrasonic sensor; digital camera; web monitoring; flood image; telegram channel

ABSTRACT

An efficient flood detection system needs to be developed immediately due to the frequency of floods in areas where visitors are concentrated in Malaysia, especially during the monsoon season or when there is heavy rain that makes it difficult for authority to pass on flood information to visitors. Among them is Taman Negara Endau Rompin (Selai) Johor which experiences flooding every monsoon season. However, the method of distributing flood information to visitors still need to be improved in terms of speed, accuracy and systematic. Apart from the factors of location and distance, the main challenge to detect floods is the lack of manpower and real time flood detection system. The conventional method is through patrols or the staff on duty at the counter receiving phone calls from the surrounding residents informing them of flooding is less effective and needs to be improved. Initially, the work of identifying the actual flood area, selecting the installation location of the system and measuring the strength of the telco signal coverage was done with the help of the authority. This article proposes a prototype to detect river water level, temperature, humidity, flood images and send flood notifications to users via smartphones in real time. The device consists of an RTU unit, a sensor arm and IoT system. The work incorporates a Pi microcontroller, a WIFI network equipped with digital camera and industrial sensors. This prototype is able to provide consistent flood data readings to the users. In addition to data readings and flood images displayed in the GUI (web monitoring), flood readings and images are also sent to the authorities via the Telegram channel. TNB electricity supply is used as the source while the authorities and visitors can access the data through their respective smartphones. A prototype has been developed and tested to see the stability, consistency and accuracy of its operation while the data received is stored in the database. This system is expected to help officers channel flood information to visitors at the visitor reception desk in a more organized and systematic manner.

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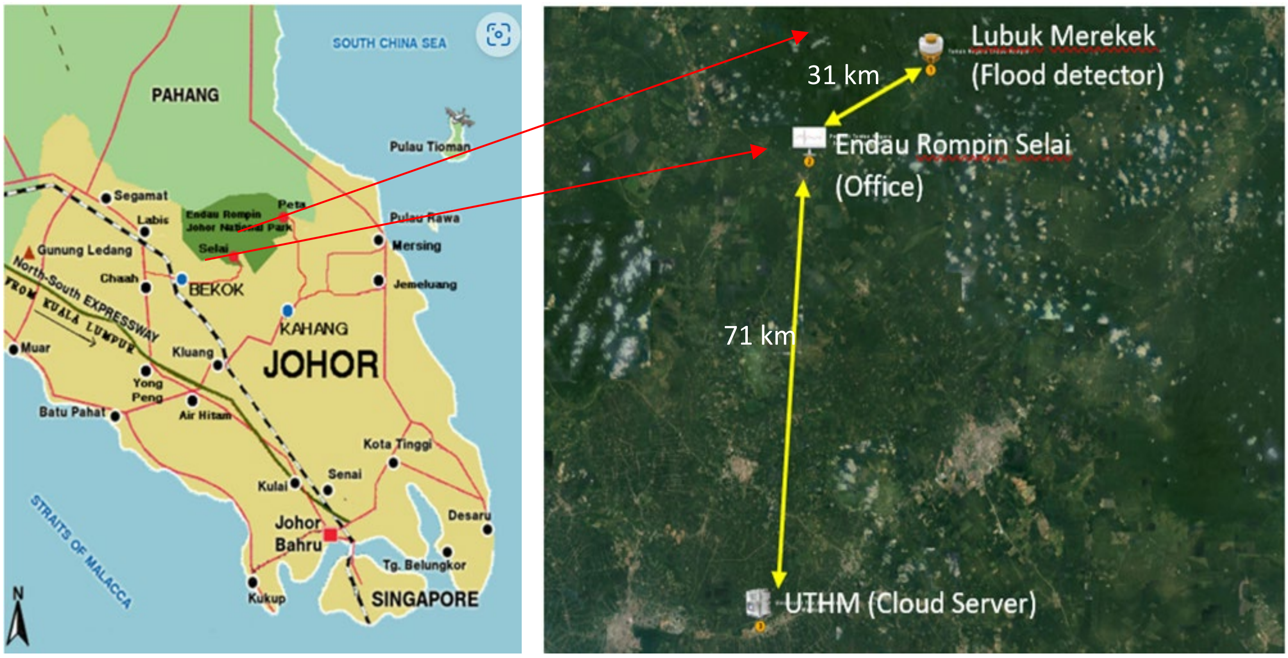
https://doi.org/10.37934/aram.119.1.162173

1. Introduction

The rapid advancement of industrial revolution technology 4.0 (IR 4.0) has resulted in intelligent and expanding flood detection systems around the world. With the maturity of ICT devices including internet networks, people can monitor and control things even at a distance. Thus, the IoT-based system can be widely used such as in the flood level detection system to improve the management efficiency of Taman Negara Endau Rompin (Selai) specially to provide flood data readings to the authorities. This is due to the fact that floods occur every year from the continuous heavy rains in the monsoon season. The lack of a systematic flood monitoring system causes the information of this flood event to be unable to be transmitted to the visitors effectively. The visitors are only informed at the office counter that the national park is closed due to flood. Conventional methods like this are inefficient and need to be replaced with flood monitoring and notification systems using IoT technology in real time. The flood has caused the access road in Kampong Kemidak to the Taman Negara Endau Rompin (Selai) to be cut off and erosion damage has occurred in several areas such as in Lubuk Merekek. Taman Negara Endau Rompin (Selai) is located in the state of Johor, Malaysia with an area of 48,905 hectares, about 100 km from UTHM Parit Raja, Batu Pahat, Johor. It is very interesting to visit and famous for outdoor activities such as camping, tracking to waterfalls and camping activities. Among the factors that cause flooding here include the amount of water that exceeds the limit as a result of continuous rain from Sungai Selai and small tributaries as well as factors of the river becoming shallower. Figure 1 (a)-(b) shows the map of Taman Negara Endau Rompin (Selai) and the study location in Lubuk Merekek.



(a) (b)

Fig. 1. (a) Taman Negara Endau Rompin (Selai) (b) Illustration of the proposed location of flood detector at Lubuk Merekek, Endau Rompin Selai (Office) and UTHM

The development of an efficient and practical flood level detection system for monitoring river water levels in this area is an important issue because there is no such system there that can provide flood data to officers and visitors systematically. Reviews of flood level detection methods such as using ultrasonic sensors, water level sensors, cameras, optical remote sensing, and radar systems are reported by Zakaria *et. al.,* [1]. Zekâi [2] mentioned that the flood detection system can be divided into two types, namely the river flood warning system and the road flood warning system. Among the factors that need to be considered are the type of sensor used and the method of displaying the data reading. Apart from the aspects of ICT technology advancement, the route to the location and power supply, and the factor of good mobile phone network coverage also made the IoT-based system installed at the study location a success [3]. Systems equipped with notification messages and alarm sirens become more effective if used. Several examples of flood detection based on IoT systems have been developed and installed at the study location [4-6]. It consists of a remote terminal unit (RTU) box, a sensor arm and a network of IoT systems used as well as a flood reading display. A flood level monitoring system was developed and installed on a bridge crossing a river [4]. This system uses a solar power supply and equipped with three sensor units such as ultrasonic, temperature and humidity. The size and attractive shape with strong and practical structure makes it easy to install, especially in buildings near the river. Conversely, this system is not equipped with security aspects that facilitate theft. A water level monitoring system to detect early flood events is developed by Wannoi *et. al,* [5]. This system uses IoT technology and the changes in river water levels are detected by ultrasonic sensors. It uses an ESP8266 microcontroller and data acquisition NI6008USB module to control and connect data from sensors and Lab view software GUI display. It uses a Wi-Fi network and easy for users to access flood information using smartphones in real time. The RTU box and sensor are placed on a pole. The system is installed on the river bank, tested and consistent readings obtained. However, the security aspect of the system is not given attention. A flood monitoring that uses a radar system is able to detect water level changes effectively [6]. It is equipped with RTU box, sensor arm and installed on the bridge across the river. The system also has notification messages and flood information sent to users when a critical water level is detected. Other articles such as in [7-8] also share information regarding flood detection systems that have been developed and installed in the field. It includes the steps that have been taken such as site visits, identifying flood locations, testing the strength of telco network coverage, design work, system construction, testing and installation on site. Various suggestions by researchers regarding the flood level detection system are reported. These systems can be categorized as being at the proof-of-concept stage including using IoT technology, the water level sensing method, and the application of either flooding in the river or flooding in the city as reported in [8-15]. [8-10] use the ultrasonic sensor, rain sensor, Wi-Fi network, and warning system using a buzzer and LED display while Noar *et. al,* [11] equipped the system with a GPS module that can know the location of the flood. Hadi *et. al,* [12] developed a model that can detect the water level of the Sungai Langat along 34 km. Mohammed *et. al,* [13] proposed a prototype that can detect the water level, measure the speed of the water level increment, and also be equipped with a flood warning when a critical reading is detected. Shah *et. al,* [14] proposed a system that can detect the water level, identify the safe level, and send a message if the situation is dangerous to the user. The optimization of the flood level detection system using AI technology is also proposed by Hashim *et. al,* [15]. Among the objectives of this project is to develop and install a flood detection system that can help staff at Taman Negara Endai Rompin (Selai) to monitor and channel flood information to the public more easily, effectively, and accurately. The developed system is capable of providing river water level readings, flood images, temperature, and humidity. The system is installed in Lubuk Market because preliminary findings from the site visit showed that there is TNB supply, a good network of telecommunication companies such as Celcom GSM, space for system installation, and less risk of monkey interference. The work of monitoring the flood level and detecting the critical level here is a difficult task to do due to the fast and churning movement of the water. A common method used by the authorities to monitor flooding incidents is to patrol when it rains heavily. However, this method is somewhat less efficient due to the factor of labor shortage, and the remote and unsystematic location of the flood area. This is more noticeable if the officer is outside the area and definitely difficult to get flood information at that instance. Therefore, the staff at the counter need a system that can detect flooding at a distance such as monitoring from the office space. Others related article are reported in [16-20].

Illustration of the operation of the flood level detection system in this project is shown in Figure 2. Ultrasonic sensors are chosen because they are practical, contactless, weatherproof and affordable. This system is able to provide water level data, temperature, humidity and flood images to users using a raspberry-pi microcontroller. The 4G network (Celcom GSM) is used to send the flood data to the cloud server. The three important components of the system, namely the RTU unit, sensor arm and cloud server are developed so that sensor data and images from digital camera are sent to the server in real time. This configuration is chosen because it is independent, practical, contactless sensor, effective and its operation has no distance limit suitable to be installed in this location. This project involves the work of developing and installing a flood detection system that can help staff to monitor and channel flood information to visitors more effectively and accurately. In addition, it meets the need of users with a reasonable and practical cost. This prototype is tested and the readings obtained are verified and recorded.

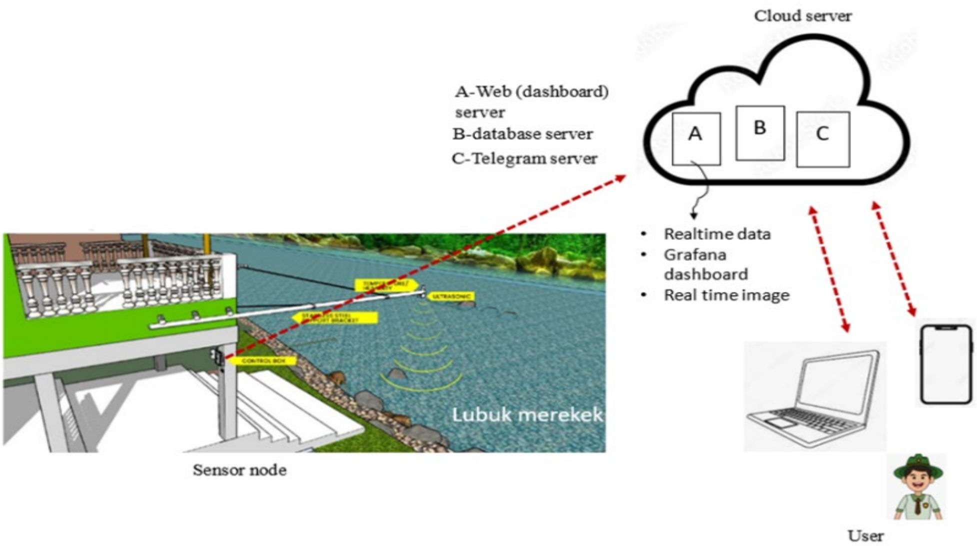


Fig. 2. System operation

2. Proposed System

2.1 Hardware Development

The flood level detector developed in this work consists of hardware, software and IoT. The pi-module is selected as a microcontroller while data transmission to the server uses the Wi-Fi network. Among the advantages of micro-pi controller are large memory and storage, high computing ability, can be used for various OS, support better WIFI network and suitable for complex system. In addition, this system can send sensor data and camera images to the web server consistently and correctly. The camera's digital USB is used and connected directly to the micro-pi controller while the ultrasonic, temperature and humidity sensors are connected to the Modbus unit as an intermediary with the pi-module. These sensors are rainproof type and are often used by the industry. The ultrasonic sensor used is the RS485 type, rainproof and capable of detecting water at a height of 0 - 10 m. It is a contactless type that uses a 12 VDC power supply and is very suitable for detecting river water levels. A digital camera is also used in this project. The RTU unit uses a power supply from 240

VAC supply source. The voltage regulator is used to convert the 240 VAC voltage to 5 VDC and 12 VDC as a power supply for sensors and microcontrollers. The WIFI module will be activated to enable flood data and images to be sent to the cloud. The RTU unit is also equipped with a safety circuit and a UPS system that can break the circuit if there is a short circuit and supply a temporary power supply if the power supply is cut off.

When the critical water level is detected, the system will be activated by sending the critical level status =1 and the server will send a notification to the user through the Telegram channel. Users in the Telegram group will receive this notification. Monitoring of flood parameters can also be done through this channel. Figure 3 and Figure 4 respectively show the block diagram and wiring diagram of the developed system hardware. Figure 3 shows the block diagram of a system that can provide readings of flood level data, temperature, humidity and flood's image. The transmission of data is made through a Wi-Fi network.

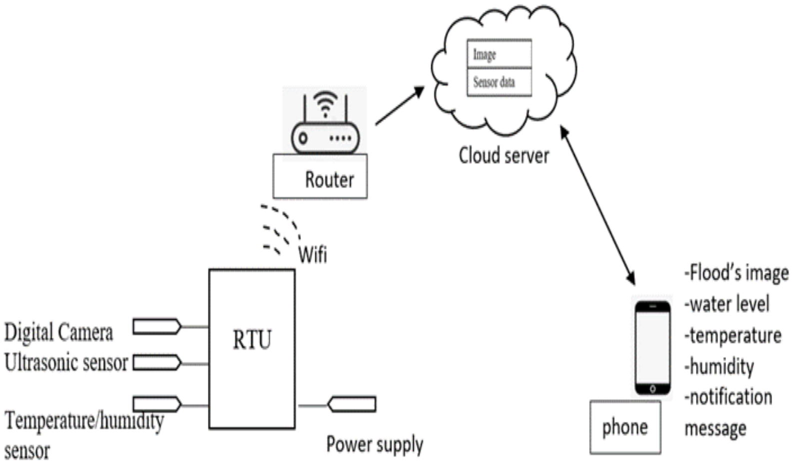


Fig. 3. Block diagram of the proposed system

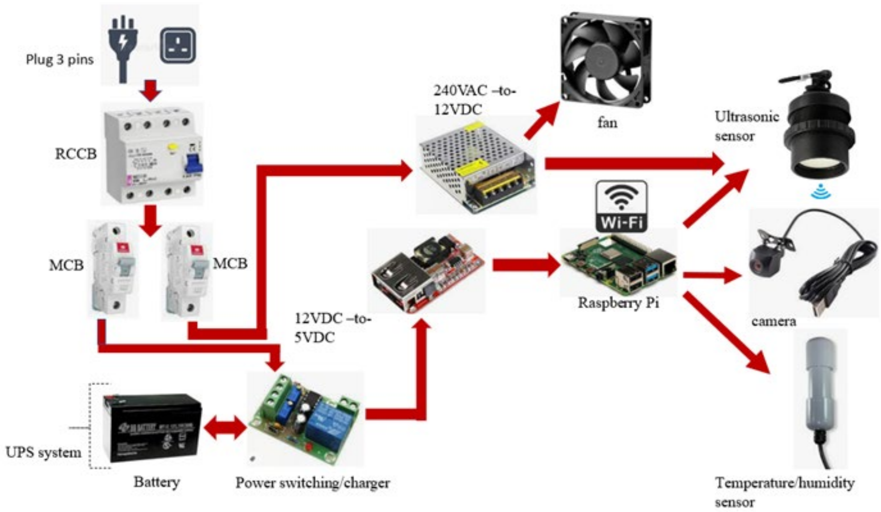


Fig. 4. Wiring diagram of RTU unit

Figure 4 shows the wiring diagram for the RTU unit. Among the important parts are the 240 VAC power supply source, DC 12 V and 5 V power supply, protection/safety system, UPS system and cooling system.

2.2 Software Development

Software development consists of programming in the raspberry-pi board and con-figuration of the cloud server system. Node-Red software is used to store data in the data-base, send critical water level notifications and flood images. For web display, Grafana software is used. Programming code is developed using a pi-board to read the water level, temperature and humidity. The modbus unit is used as an interface between the pi-board and ultrasonic sensors, temperature sensors and humidity sensors. In this case, the development work of the respective programming code involves the operation of sensors, modbus and micro-pi controllers. Next, coding is developed to connect the controller-pi with the Wi-Fi module that will allow the data to be sent to the cloud server. The MQTT protocol is used to send readings of water level, temperature and humidity data while the HTTP protocol is used to send flood images to the server. The data and images are stored in the database. The system will trigger a critical water level by sending a notification message via Telegram channel if a high-water level is detected. Flood images will also be displayed on the display in real time. Users can also monitor flood parameters through Telegram channel. Users need to login to the system using the link http://iot/uthm.edu.my/monitoring along with the username and password.

2.3 Implementation of the Proposed System

The developed system consists of an RTU unit, sensor arm and cloud server. The RTU unit functions as a controller to send river water level data, temperature, humidity and flood images to the cloud server. The sensor arm is used to place the ultrasonic, temperature and humidity sensors to read the water level, temperature and humidity of the environment respectively. Some important parts of the developed prototype such as ultrasonic sensor, camera, power supply are clearly illustrated in Figure 5. Furthermore, the figure shows the position of the sensor, camera and other important parts.

Fig. 5. System set up: (left) ultrasonic sensor, (right) RTU unit and (bottom) display unit

The system will read and monitor water level readings, temperature, humidity and provide water level images to identify the occurrence of floods and weather conditions in the study area. Water level, temperature and humidity data will be sent to the cloud server every 60 seconds while flood images will be sent to the users via Telegram channel if re-quested. A notification message will be sent to the user when the water level reading is at a critical level. This flood data information will be sent to the cloud server through the selected telco network, namely Celcom GSM and will be stored in the developed database. The system operates as a sensor node and gateway that can send sensor data and camera images to the cloud server.

This prototype is able to operate using the GSM network without an intermediary unit because the GSM network has good coverage in this location. The power supply at the study location uses TNB's power supply which also facilitates the development of the system. In this project, the users can monitor data readings from sensors and camera images through an online Graphic User Interface (GUI) display developed using Grafana software, while flood images and notification messages will be obtained through the Telegram channel. This flood level detection system using IoT technology is equipped with GUI that is easy to use and attractive.

The flow chart of the overall operation system is shown in Figure 6. There are two important tasks that have been developed namely typical task and optional task. Firstly, the system will read and send data readings from the sensor to the cloud server every 1 minute and will send a notification message once the critical water level is detected. Secondly, the user can request the system to take a picture of the flood image and send the image to the Telegram channel and Grafana software at any time or after receiving a notification message that the critical water level has been detected.

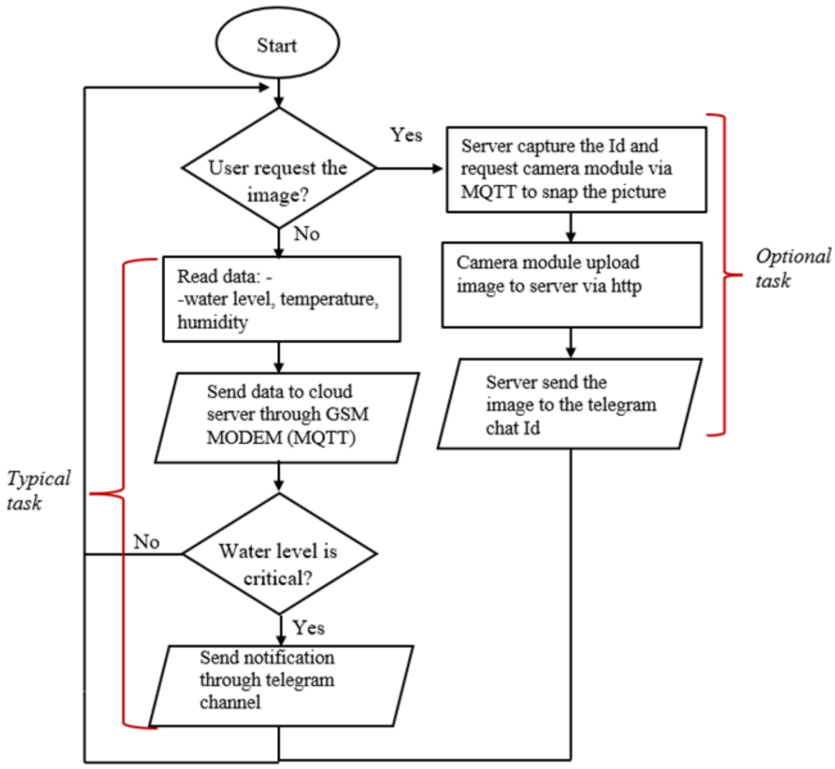


Fig. 6. Flow chart of the overall system

Figure 7 shows the flow-base programming tool using node-red software. The system will send data from the sensor to the cloud server using the MQTT protocol. Node-RED's MQTT system will receive water level, temperature and humidity data and then store these data in the database as shown in Figure 8.

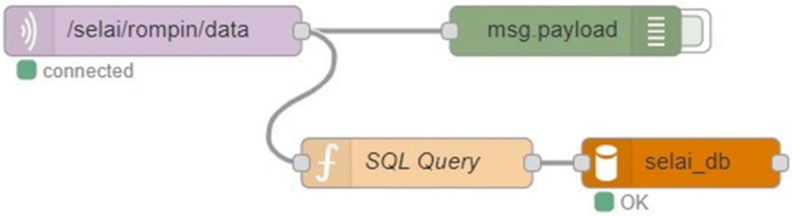


Fig. 7. Flow-base programming tool using node-red software

1 Messages | 2 Table Data | 3 Info

id	nodeid	temperature	humidity	distance	dateadd
1	(NULL)	29.4	70	2.363	2022-12-06 10:32:02
2	(NULL)	29.5	71	2.363	2022-12-06 10:32:55
3	(NULL)	29.1	72	2.362	2022-12-06 10:33:55
4	(NULL)	29.4	72	2.362	2022-12-06 10:34:55
5	(NULL)	29.6	72	2.363	2022-12-06 10:35:55
6	(NULL)	29.3	73	2.362	2022-12-06 10:36:55

Fig. 8. Database

Figure 9 shows how the users can receive notification messages, flood images and system status via Telegram channel. First, when the ultrasonic sensor detects the critical water level, the controller will send data to the MQTT channel /selai/su/notification to be processed by the node function. Then, node Function will send a notification message to the target Telegram group. Second, users need to type the command /cam1 through Tele-gram apps to receive the flood images in the Telegram channel. Command node /cam1 will be triggered to enter node function for MQTT channel to process /selai/su/cam1. At the same time, it will trigger a delay of 10 seconds to allow the camera taking and saving the pictures in the server (loading process). This process takes 10 seconds to complete. After that, the node http request will take the image from the server and node function will then process the picture to be sent to the target Telegram group. Third, to monitor the status of readings such as water level, temperature and humidity, users can type the command /status in Telegram apps. Command nod /status will trigger into the node function. The node function will send the required parameters to the http node. The http request node will then take the flood level reading data, temperature and humidity in the server. Next these data are sent to the targeted Telegram group channel.

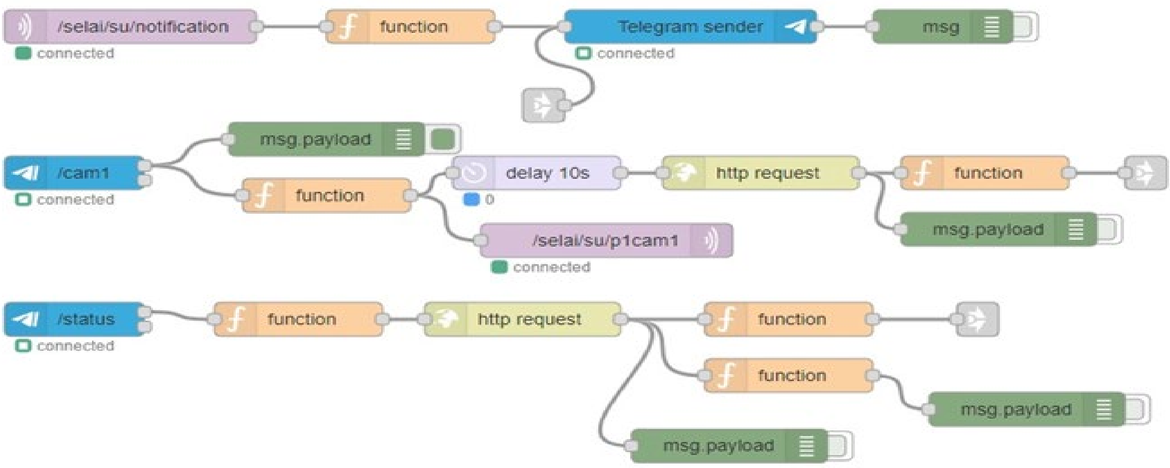


Fig. 9. Flow-based programming tool for image capture and notification message using Node-RED software

The notification message will receive through the Telegram channel. Users need to type command /help to get a complete reading of flood data such as flood level, temperature and humidity. This information can be obtained by typing command /status. The Graphical GUI Grafana software is discussed in the next section.

Figure 10 depicts the diagram of the entire system installed in right side view, front view and left side view. The actual location where the system will be installed is Lubuk Merekek, Taman Negara Selai Bekok. Its location is 30 km from the Taman Negara Selai Bekok office. The proposed system has a height of 3.0 meter, 7.6-meter-long and is tied using wire firmly. It is will be mounted on a chalet pole in Lubuk Merekek.

Fig. 10. 3D drawing

3. Results

Users can log into this system via iot.uthm.edu.my/monitoring and access the flood data information using a smartphone. Water level readings, flood images, temperature, humidity and notification messages from sensors and digital cameras are stored in the cloud server database. The developed system can work well by providing flood data readings to users in real time. At the initial stage, the system is installed and tested in the laboratory at the Faculty of Electrical and Electronic Engineering (FKEE), UTHM. Figure 11 shows a picture from a VGA camera. Users can request the system to turn on the camera to take a picture and this image will be sent to the web display and Telegram channel. Water level readings and images from VGA cameras are the most significant flood data readings for the authorities. The developed system uses a pi-controller that can provide current readings for water level, temperature and humidity in addition to continuous data readings in real time to the users. In Figure 12, the readings of water level, temperature and humidity are 2.38 m, 29.4 °C and 87.4% respectively. The continuous water level reading is also displayed in the diagram with a mini-mum value of 2.36 m and a maximum value of 2.38 m. Figure 13 shows the graph of the continuous data temperature and humidity. The maximum and minimum values for the temperature are 32 °C and 24 °C while the humidity is 100% and 80%. The changes in value shows that the sensor is operating well by measuring the actual level of water height, heat and dryness of the surrounding areas. To monitor the system using Telegram, the user needs to be in the official Endau Rompin Selai

Telegram group as shown in Figure 14. By typing the command /reading, the status of the flood data will be displayed in the Telegram channel. The current readings obtained are water level (2.376 m), temperature (30.37 °C) and humidity (86.17 %). By typing the command /cam, a clear picture will be obtained in the channel as shown in the figure.

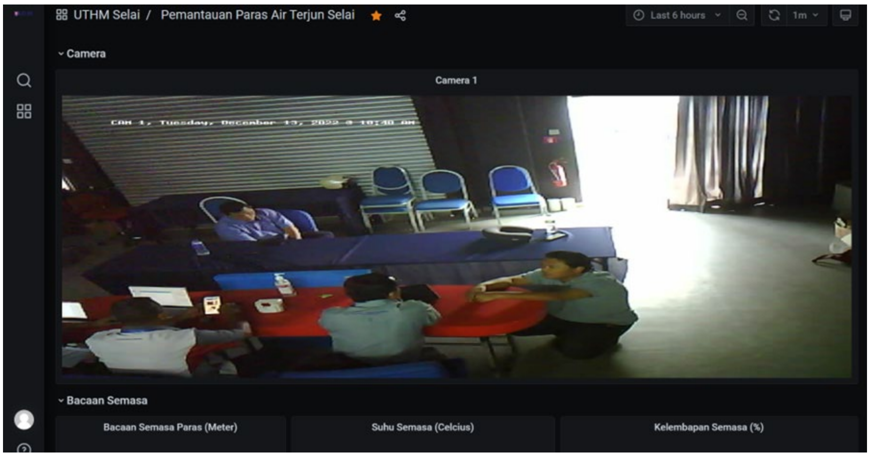


Fig. 11. Image from VGA camera

Fig. 12. Water level distribution

Fig. 13. Temperature and humidity distribution

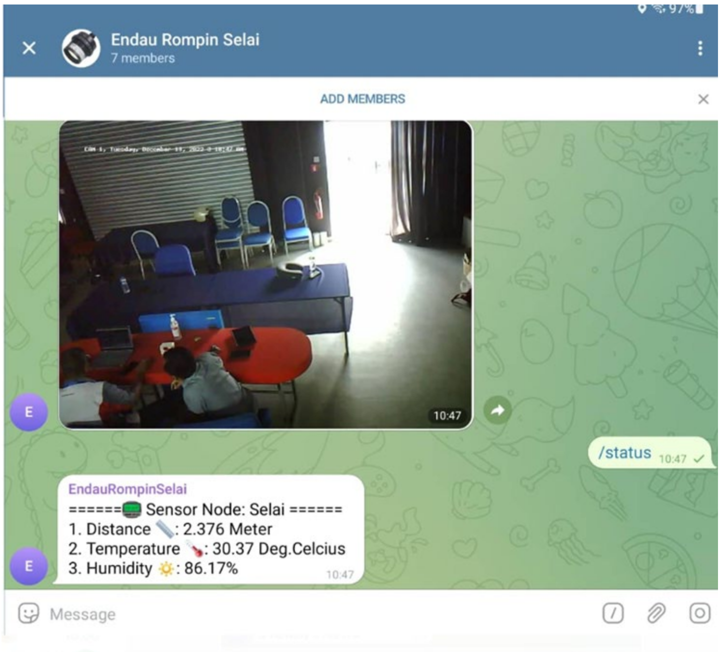


Fig. 14. Flood monitoring via Telegram channel

4. Conclusions

The system in this work was developed since November 2022 and tested until today. It is able to provide flood data readings to users systematically and successfully transmit data consistently. It can also detect the critical water level and send a notification message to the user through a Telegram channel using an IoT system that meets the objective of the study that produce a flood level detection system. Users can also monitor using the Telegram channel and request the system to take a picture of the flood and send through it. The proposed intelligent flood detection system is expected to work efficiently and safely to provide flood data readings to the users. This system can help users to monitor river water level readings, flood images, temperature and humidity readings.

Acknowledgement
This research is supported by University Tun Hussein Onn Malaysia (UTHM) under the GERAN TIER 1 Vot Q356, Geran Kontrak UTHM Q005 and the Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme (FRGS/1/2019/TK04/UTHM/02/8) and Johor National Park Corporation. The authors would like to thank to Mr Zulkifli Ani and Mr Bob from Endau Rompin National Park (Selai) who contributed to making this research successful.

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