

Early Warning System of Flood Disaster Based on Ultrasonic Sensors and Wireless Technology

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Abstract. A flood disaster provides considerable losses to the people who live around the river. To mitigate losses of material due to flood disaster required an early warning system of flood disaster. For that reason, it necessary to design a system that provide alert to the people prior the flood disaster. And this paper describes development of a device for early detection system of flood disasters. This device consists of two ultrasonic sensors as a water level detector, and a water flow sensor as a water flow velocity sensor. The wireless technology and GSM is used as an information medium. The system is designed based on water level conditions in the Katulampa Dam, Bogor. Characterization of water level detector showed that the device effectively works in a range of water level of 14-250 cm, with a maximum relative error of 4.3%. Meanwhile the wireless works properly as far as 75 m, and the SMS transmission time is 8.20 second.

1. Introduction

Indonesia is an archipelago country that has high rainfall in the world. Many areas in Indonesia are prone to flood disaster. Flood disasters could occur anytime and give adverse impacts to society, especially people who lived around the river. For that reason, it necessary to design a system that provide alert to the people prior the flood disaster. The purpose of the warning system is to mitigate number of victims and material losses suffered by the society.

Nowadays, there are many early warning systems of flood have been developed. Komaludin et al [1] used ultrasonic sensor-based microcontrollers to detect maximum and minimum water levels. Sumarno et al [2] developed a flood early warning system based on microcontroller Atmega16 and buzzer, and used short message service as a flood alert indicator. Other method was also developed to improve the effectiveness of information delivery of alert flood indicator due to geographical and distance factors, such a telemetry method using wireless technology [3], and information broadcasting through social media [4]. An early warning system requires a location as a water level reference, it can be either a water gate or a dam, because each water gate or dam has a standby status with different water levels.

In this paper, we describe the development of a prototype flood early warning system using wireless technology and short message service (SMS) as an information broadcasting medium. Three sensors are used to increase a measurement accuracy, there are two ultrasonic sensors which used to measure water level, and a water flow sensor to measure the flow rate of water. We used a Katulampa Dam as a water level reference.



2. Standby Status of Water Gate

Flood alert status in Jakarta was obtained by information analyzing of the Water-surface level observation stations (TMA) of the rivers that lead to Jakarta (PUSDALOPS BPBD DKI Jakarta, 2016). Each water gate has different warning criteria depend on the depth of the river.

There are four types of warning status: (1) Standby-IV status, there has not been a significant increase in the flow of water, (2) Standby-III status, a condition when the rain causes the water debit increasing at the water gates but the condition is still not critical or dangerous. However, if alert standby III has been officially stated, the public should be alert and prepare everything from the various possibilities of flood disaster, (3) Standby-II status, the condition when the rain causes the flow of water began to expand, (4) Standby-I status, the condition when the water-flow remain at standby II condition more than six hours, or even higher. At Water Monitoring Station of Katulampa-Dam has been defined the water level each status condition: Standby IV-status <79 cm, Standby III-status 80 - 149 cm, Standby II -status 150-199 cm, and Standby I-status ≥ 200 cm.

3. Experimental

The developed prototype was composed of two ultrasonic sensors type of HC-SR04 as a water level detector sensor, a water-flow sensor type of yf-s201 to measure flow rate, a microcontroller as control system, xbee wireless module as transmitter and receiver, a GSM sim900A module as a short message sender, and buzzer as an indicator of water level.

3.1. Characterization of Ultrasonic Sensor

This characterization was conducted to determine the range of the sensors, and to identify resolution of the ultrasonic sensor. The characterization scheme is shown in Figure 1a. From this measurement, the distance range of both sensors is obtained 14-250 cm with a maximum relative error of 4.33%, meanwhile the minimum distance detected by the sensor is 0.5 cm with a maximum relative error of 1.2%. Furthermore, the optimization of the prototype scale to the water level conditions at each standby status was carried out. From the optimization obtained the best ratio result of prototype is 1: 5. This ratio would be used to adjust the distance of the sensor and water surface.

3.2. Hardware Design

Using the ratio of 1:5, water level on standby-I status would be ≥ 40 cm. Thus, a water reservoir of 30 cm x 40 cm x 50 cm was created. Both ultrasonic sensors are mounted on a 60 cm long-stick, 10 cm above the water-maximum surface. The distance of the sensors to the water surface for each Standby-status is shown in Table 1.

Table 1. Water level on the Prototype

Status	Sensor to water surface distance (cm)
Normal	≥ 48 cm
Standby-IV	44 cm – 47 cm
Standby-III	43 cm – 30 cm
Standby-II	29 cm – 20 cm
Standby-I	≤ 19 cm

3.3. Designing Software

There are two systems involved in the prototype: monitoring system as a transmitter or data sender system, and a remote warning system as a receiver system. The remote communication uses a pair of module, xbee series 2. For that reason, there are two programs used on this prototype, namely the transmitter program on the monitoring system, and the receiver program on the remote warning system. The flow chart of transmitter and receiver program shown in Figure 1b.

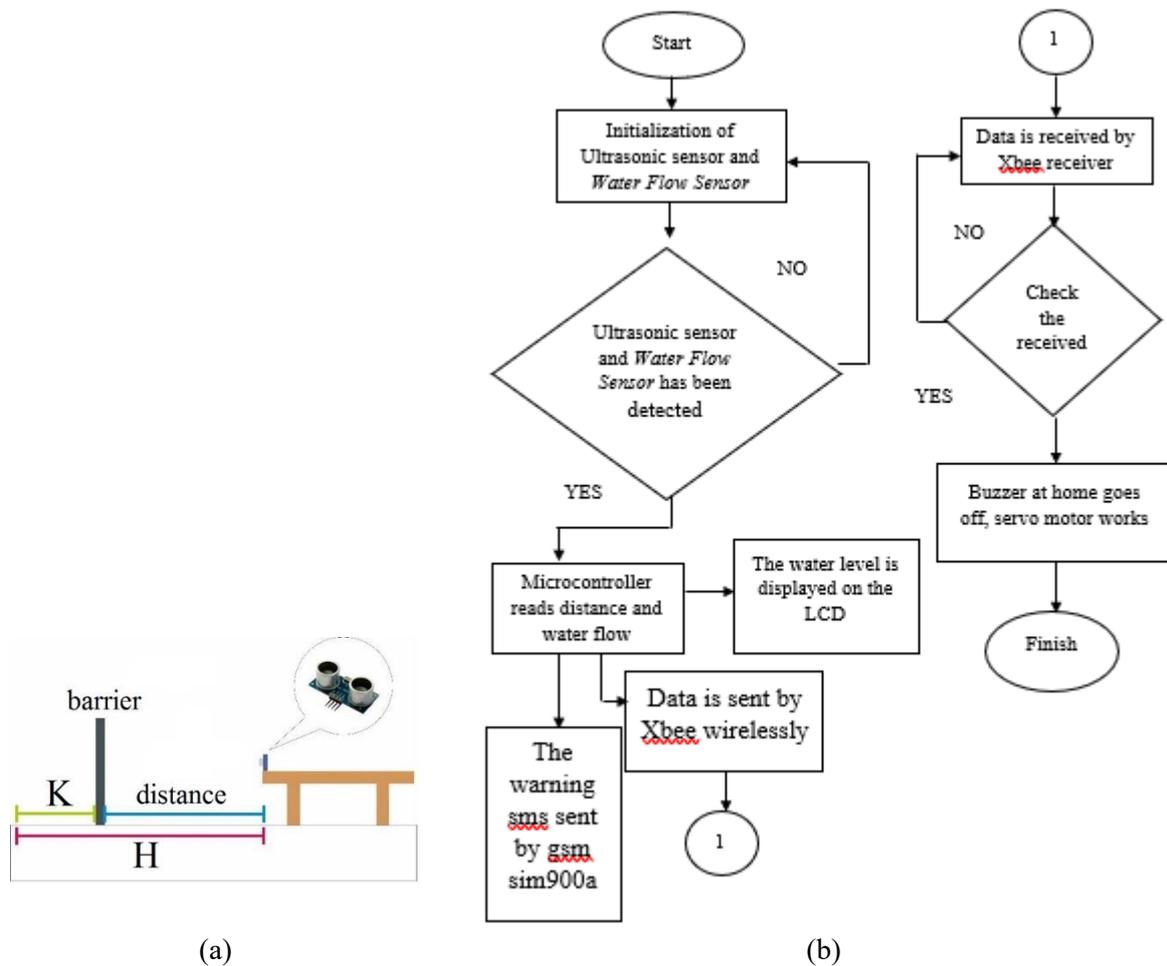
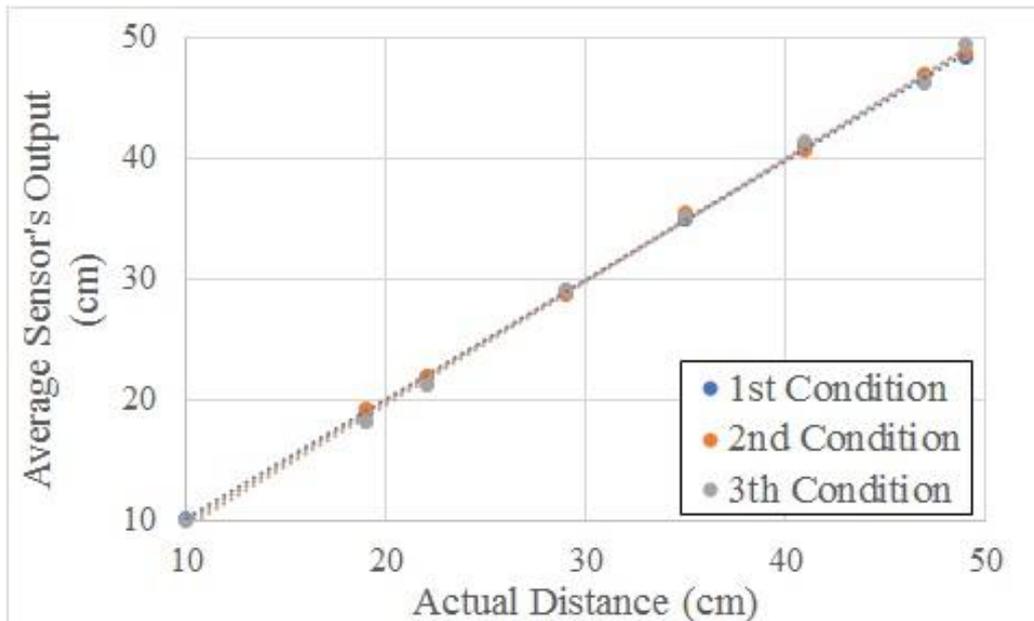


Figure 1. (a) The characterization of ultrasonic sensor. (b) The flow chart of transmitter and receiver program

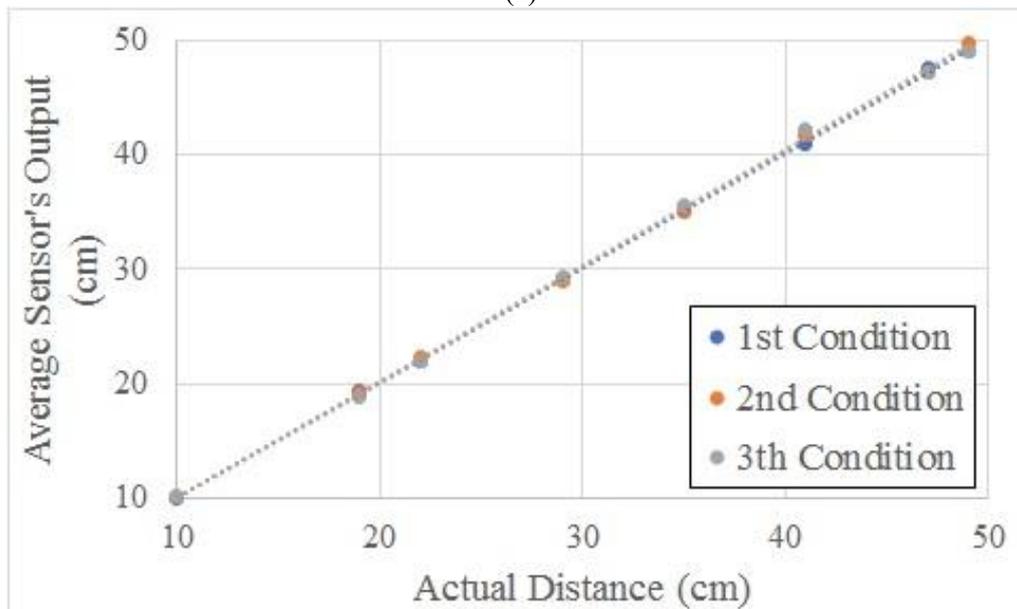
4.Result and Discussion

4.1. Measurement of Ultrasonic Sensor

The measurement of ultrasonic sensor system to the water surface of the reservoir is carried out in three different conditions: condition-1 uses a water source. Condition-2 uses two water sources, and condition-3 uses a water source and a sinkhole (moving surface water). Water surface at condition-1 and condition-2 tend to be stable, meanwhile the water surface at the condition-3 is moving and unstable, thus it more resembles the actual condition. The results of the measurements of sensors 1 and 2 at all three test conditions are shown in Figure 2. The actual distance is measured using a ruler as a standard gauge.



(a)



(b)

Figure 2. Measurement of ultrasonic sensors at condition 1, 2 and 3. (a) Ultrasonic Sensor 1
(b) Ultrasonic Sensor 2

Figure 2 shown that both sensors can work properly to detect the changes of water level in the reservoir. But the measured deviations on condition-3 is greater than the measurement on other conditions. Because basically the sensor does a better reading when the object surface is flat. Ultrasonic sensor will give the best reading at hard and smooth surface. This surface reflects larger signal and produce a strong echo signal than the rough or soft surface. This condition would reduce either the operating distance of ultrasonic sensor and the accuracy of a measurement [5].

The other factor which affects to sensor measurement is the distance of the sensor to the object. The distance enhancement of the sensor to the object, will prolong the response time of sensor to send the reading result, and it makes the echo signal received by the sensor is getting weaker. Otherwise, the

closest distance between sensor and object would produce the stronger echo signal. The relative error of the distance measurement at Standby-I status is described in Table 2. It can be seen that in the Condition-3, the moving water surface, the measurement error of sensors is quite small. The overall, using two ultrasonic sensors would improve effectiveness of the sensor reading, as water level readings are more precise, especially when the water surface conditions are unstable.

Table 2. The relative error of sensors reading

Relative error at Standby-I Status	Condition-1	Condition-2	Condition-3
Sensor 1	3.1 %	2.3 %	2.3 %
Sensor 2	2.4 %	2.7 %	1.0 %

4.2. Measurement of Water-flow Sensor

In this prototype water flow sensor is used to provide information of water flow stability. The result of sensor measurement is shown in Figure 3. In Figure 3a show the current water flow decreases by increasing water level. In the other hand, Figure 3b shows that the current water flow is fixed. It means the sensor output tends to be stable in the 36.3 ml - 37.8 ml range. The decrease or increase of the water flow through the sensor depends on the flow rate of the water source. Water flow sensor YF-S201 works based on the Hall Effect phenomenon [6]. The water flow through the sensor will rotate the impeller in the sensor. The rotation of the impeller will create a magnetic field on the coil in the water flow sensor. The magnetic field will be converted by Hall Effect into pulse signal. The pulses are then converted to water flow rates.

The decreasing or increasing of water flow rate reads by the sensor has no effect on the water level change. Since the rate of water flow has no indication to the change of warning status, it just gives an additional information of the water flow rate. If the flow rate of water suddenly rises drastically, and continuously to be of high value, it can be a warning of flooding.

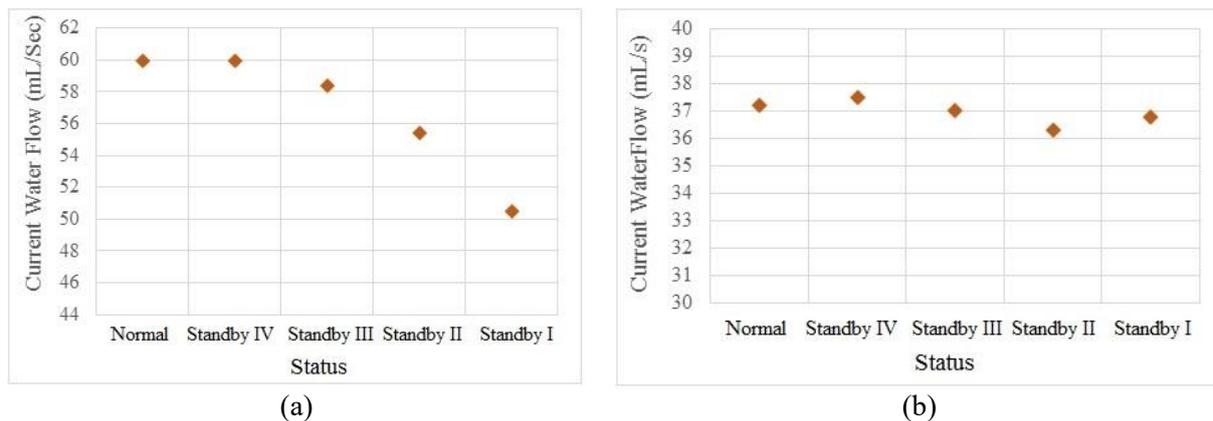


Figure 3. The water flow measurement (a) Unstable water (b) Stable water

4.3. The XBee Module Testing in Receiving Data

The test was done on the two conditions, indoor without barrier and outdoor with a wall barrier. The test results show the wireless capability. The xbee module works well under barrier conditions up to a maximum distance of. As for conditions with a barrier, xbee is only capable of receiving data as far as 24.3 m.

4.4. The GSM SIM900A Testing

The tests were performed on 5 different cell phone numbers with different operators, the message reception speed was calculated from the time the system issued the "A" character on the monitor serial which meant Standby-I.

Phone Number	Status	Time of SMS delivery (1 st delivery)	Time of SMS delivery (2 nd delivery)
+6285710619759	Sent	8.2 s	33.3 s
+6281314546611	Sent	14.1 s	9.5 s
+6287785579476	Sent	22.1 s	24.6 s
+6289604192268	Sent	8.5 s	10.2 s
+6285881000626	Sent	17.3 s	16.9 s

The fastest time of receiving SMS based on the test is 8.2 s and the longest time is 33.3 s. The duration of sending SMS was not always constant. It changes any time depending on the speed of the GSM communication line at the time of sending SMS. The phone number receiving the standby message will get an SMS containing the Standby-I status as well as a water level height report when the SMS is sent from a water level monitoring system (Figure 4).

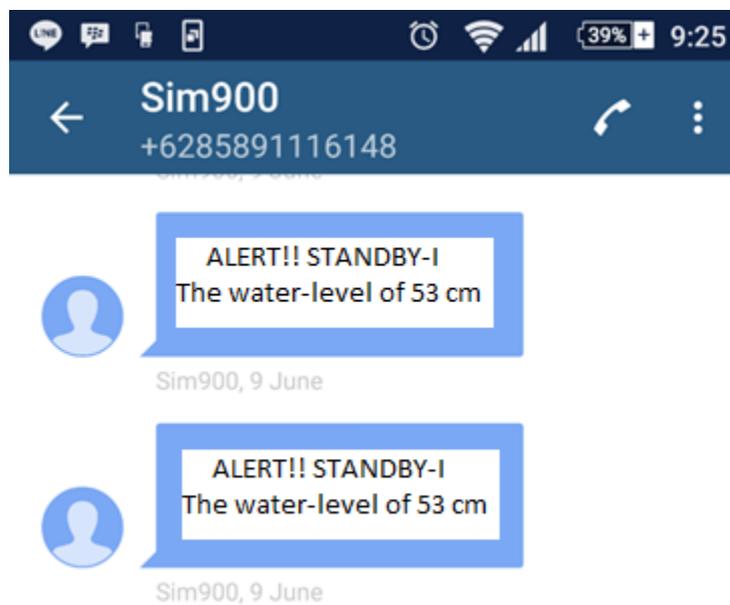


Figure 4. The contents of the received warning SMS

4.5. The Overall System Test Result

The test was performed to determine the overall system performance in accordance with the design software created. Every distance change specified according to the standby status was seen to be appropriately run in accordance with the design of the software. Table 4 shows that the tests performed have been in accordance with the design of the software.

This prototype has high capability work on unstable water level conditions with the Ultrasonic sensor-1 accuracy of 97.6%, and the Ultrasonic sensor-2 accuracy of 97.2%. The using of multiple sensors can improve the accuracy of this prototype, especially at moving water-surface conditions. The incorporation of wireless technology, using xbee and GSM modules, increase the efficiency of warning-message delivery.

Table 4. The Overall System Test Result

Character sent/received	SMS status	LED	LCD	Buzzer	Automatic gate
A	Sent	Red	Standby-I	On	Closed
B	-	Yellow	Standby-II	On	Open
C	-	Green	Standby-III	Off	Open
D	-	Off	Standby-IV	Off	Open
E/N	-	Off	Normal	Off	Open

5. Summary

Development of early warning system of flood disaster that utilizes the wireless technology, using xbee and GSM modules, as a long-distance warning has been carried out successfully. The ultrasonic sensor can work effectively in measure the moving water surface conditions. Meanwhile, the measurement of water flow sensor can be used as additional information, changes in water flow velocity in early warning system of flood disaster.

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