Design of Water Level Monitoring using Ultrasonic Sensor

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Abstract. High rainfall intensity is one of the causes of the large volume of water in a water dam. Currently, the water gates of many water dams are still using manual methods to open and close the sluice gates. This design aims to make a device that can monitor the height, discharge of water, and assist in the control of sluice gates. This tool can move the sluice based on the height of the water level, so it does not need to be done manually which also contains human error.

The working principle of the prototype tool is by detecting water level at several stages, and detecting water level by utilizing ultrasonic sensors. The floodgates will move according to the level of water level in the water dam, so that the water in the dam does not exceed the capacity which can cause the dam to become damaged, it can also display water level and water dam status.

Keywords: ultrasonic, servo motor, water level, water level status.

1. Introduction
Measurement of water height is an important aspect in determining water discharge. In relation to water debris, one of the weather factors that influence is the rain factor. High rainfall intensity is one of the causes of large water discharges, and excessive water discharge is one of the causes of flooding. One anticipation of the occurrence of flooding is by knowing the height increase and the water debit and opening the sluice door. Basically the sluice is divided into three types, namely manual, semi-automatic and automatic. During this measurement and opening and closing the sluice gate is done manually, so it needs accuracy and there is often an error in the measurement. Therefore, in addressing these issues a solution is given in the form of designing a sluice gate to monitor water levels based on raspberries. It is expected that with this system, water levels can easily be monitored, and there is no need to bother manually to regulate the dam water door. The measurement of the water discharge is indeed very necessary so as not to exceed the capacity, and if it exceeds the capacity it will have a fatal impact which causes the dam embankment to collapse.

In this tool dam control is done automatically, no need to use commands or manually open the sluice door. The advantage of this tool is that in addition to controlling the water level by automatically opening and closing this tool can also display the water level and the status of the dam on the LCD which can later facilitate the public. In this tool to move the sluice using a standard servo motor. Servo motors are chosen because they have good accuracy compared to other dc motors. The servo motor is driven by the PWM and adjusts to the rotation angle of the motor, besides that the servo motor does not need a motor driver such as a dc motor.
2. Theory

2.1. Water Gate

In existing dams, water gates are used to regulate the amount of water in the dam. The sluice gate is a supporting building in an irrigation dam and flood control dam. Generally sluice gates are used to control the flow of water in the reservoir, river and embankment system. Adjustable doors that are used to regulate water in dams, rivers and river embankments. This tool can also be designed to spillway on a dam, regulate the flow rate in a channel, or it can also be designed to stop water as part of a dike system. For flood control, this building is also used to reduce flood water levels in rivers or in waterways at the time of flooding.

The sluice gate has actually been around since time immemorial, but the shape is very simple. Along with the development of times, the floodgates have also developed rapidly. This can be seen from the many types of sluice gates that exist to regulate the flow of water. Sluice from ancient times to modern times is very useful and cannot be imagined if this modern era is not followed by the development of the use of sluice gates in irrigation dams and flood control dams. In today's modern era, uncontrolled abundance of water as difficult as anything can be easily overcome without having to employ many people.  

Based on the method of operation, the sluice is divided into 3 types, namely:

1. Manual Water Gate
   Manually using the sluice gate is often found in irrigation settings on rice fields and small pressure flows. This manual sluice still requires human power to regulate the flow of water by closing and opening the floodgates.

2. Semi Automatic Water Gate
   The use of semi-automatic sluices is widely used in high-pressure dams.

3. Automatic Water Gate
   Fully automatic sluice gates are used for flood control in overflow buildings on a high-pressure dam. Which works if the water discharge exceeds a certain limit will open itself automatically. Open the automatic sluice lid is a building and installation that functions to open, regulate and close the flow of water that enters the dam or reservoir, based on the level of water in the dam. By seeing the current conditions the weather is unpredictable. Where rain and wind storms often come quickly and simultaneously. As well as the rain that results in a large flow of water, it is very important that there is a tool that can open, regulate and close the flow of water in the dam which can work at any time quickly with the movement to open, regulate and close itself automatically.

2.2. Water discharge

Flow debit is the amount of volume of water that flows in a certain time through a water section, river, channel, pipe or faucet. In the SI unit system, the amount of discharge is expressed in a cubic meter per second (m$^3$/second). Measurement is one of the most important things in a water treatment system. One way or method of measuring water discharge in this tool is to know the volume and then measure the time needed to empty the reservoir using the stopwatch.

To determine the water discharge using the equation:

$$ Q = \frac{V}{t} \quad \text{--------------- (1)} $$

where

$Q$: Debit (m$^3$/s) or (liter/second).
$V$: Volume (m$^3$) or (liter).
$t$: Time (second).

To find out the volume of water using the equation:
where

\[ V = p \times l \times t \quad \text{------------------- (2)} \]

\( V \) : Volume (m³).
\( p \) : Length of container (m).
\( l \) : The width of the container (m).
\( t \) : High water (m).

2.3. Ultrasonic sensor HC-SR04

Ultrasonic Sensor is a sensor that can detect ultrasonic waves, namely sound waves that have ultrasonic frequencies or frequencies above the frequency range of human hearing. This sensor consists of an ultrasonic transmitter circuit called an ultrasonic transmitter and receiver called a receiver. Generally ultrasonic sensors are dual, the first characteristic is to detect ultrasonic waves and the second is the opposite, which is to produce ultrasonic waves.

Figure 1. Ultrasonic Sensor HC-SR04.

Figure 2. How the ultrasonic sensor works.
Details of how the ultrasonic sensor works as follows:
1. The signal is emitted by an ultrasonic transmitter with a certain frequency and with a certain duration of time. The signal has a frequency above 20 kHz. To measure the distance of an object (proximity sensor), the commonly used frequency is 40 kHz.
2. The transmitted signal will propagate as a sound wave with a speed of about 340 m/s. When pounding an object, the signal will be reflected by the object.
3. After the reflection wave reaches the receiver, the signal will be processed to calculate the distance of the object. Object distance is calculated based on the formula:

\[ S = \frac{340(t/2)}{} \quad (3) \]

where \( S \) is the distance between the ultrasonic sensor and the object (reflecting plane), and \( t \) is the difference between the transmitting wave time by the transmitter and the time when the reflected wave is received by the receiver.

2.4. Servo motor
A servo motor is a DC motor with a closed feedback system where the rotor position will be informed back to the control circuit that is in the servo motor. This motor consists of a DC motor, a series of gears, a potentiometer, and a control circuit. Potentiometer serves to determine the angle limit of the servo rotation. Whereas the angle of the servo motor axis is arranged based on the width of the pulse sent through the foot of the signal from the servo motor cable.

![Servo motor](image)

Figure 3. Servo motor and elements in them.

2.5. Raspberry Pi-3
Raspberry Pi-3 is a mini computer module that also has a digital input output port like on a microcontroller board. Among the advantages of Raspberry Pi 3 compared to other microcontroller boards is that it has a port/connection to display in the form of a TV or PC monitor and a USB connection for the keyboard and mouse.

Based on the Raspberry Pi-3 data-sheet has specifications, among others:

- **SoC**: Broadcom BCM2837
- **CPU**: 4×ARM Cortex-A53, 1.2 GHz
- **GPU**: Broadcom Video Core IV
- **RAM**: 1GB LPDDR2 (900 MHz)
- **Networking**: 10/100 Ethernet, 2.4 GHz 802.11n wireless
- **Bluetooth**: Bluetooth 4.1 Classic, Bluetooth Low Energy
- **Storage**: micro SD
- **GPIO**: 40-pin header, populated
- **Ports**: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI).
2.6. LCD

LCD (Liquid Crystal Display) is one electronic component that functions as a display of data, both characters, letters or graphics. LCD (Liquid Crystal Display) is one type of electronic display made with CMOS logic technology that works by not producing light but reflecting the light around it to the front-lit or transmitting light from back-lit.\textsuperscript{[11]}
3. Research Methodology

3.1. Experiment method
It is a method of tool design, testing, measurement and analysis of tools made.

3.2. Design method
That is by designing and building a hardware and software.

3.3. Library method
Is a method of collecting data from books related to the tools that are made and searching for data information through the internet as reference material.

4. Result and Discussion

4.1. System flow chart
Automatic sluice gates are designed with the aim that the sluice opening process is carried out automatically. Tool design starts from making a system flow diagram. The following design of automatic sluice based on water level can be seen in Figure 6.
In the system flow diagram there are several steps, at the initial stage the ultrasonic sensor detects the object, in this case what is meant is the height of the water. The ultrasonic sensor detects water level at a distance of 0 cm to 15 cm and sends data in the form of an analog signal to Raspberry Pi-3. The data sent will be processed into digital data which is forwarded to drive the servo motor as a sluice drive. The servo motor in this tool can move according to the water level. The higher the water will affect the servo motor movement. In addition, data can also be displayed by the LCD. Later the water level can be monitored or monitored through the LCD, so there is no need to manually measure the water level. Because this automatic system can reduce measurement errors.

4.2. Ultrasonic sensor testing

Testing is done on ultrasonic sensors. The data taken is the time of the pulse from logic ‘1’ on the Trig pin until this pulse will logic ika 0 ”when the reflected sound wave is detected by the sensor. The length of travel time of ultrasonic waves which can then indicate the distance between the ping sensor and the object. In testing the ultrasonic sensor is carried out by measuring the distance of the object using a measuring instrument which is then calculated the distance of the ultrasonic sensor to reflect the signal from the transmitter back to the ultrasonic sensor receiver. This time is displayed in the command created by the Python in raspberry program.

![Graph 1. Response Time of Ultrasonic Sensors.](image)

Based on graph 1, it can be seen that the sensor processing time shows a value close to linear. The sensor processing time is obtained from the formula. The measurement is done in a mathematical way. The purpose of this test is to determine the accuracy or accuracy of the ultrasonic sensor in measuring distance, and whether the sensor can work properly. The distance measured is the distance in the range of 9.5 cm - 21.5 cm. The test is done by connecting the ultrasonic sensor with Raspberry Pi-3 which has been programmed to read the distance. The detected distance results will be displayed through an LCD display. The results of this distance will be compared with a distance measuring device. The test results include data distance comparison between actual distance and distance measurement with ultrasonic sensors. The following are the results of ultrasonic sensor testing and analysis.
Based on the results of the measurement of the ultrasonic sensor on graph 2, it is known that the performance of the ultrasonic sensor used is good enough but still not accurate the distance detected. This test was carried out 5 times. This test is done to ensure that the sensor works properly. This method of testing is done by placing objects (in this case water) at different distances in order to determine the sensor's performance.

![Graph 2. Comparison of Average Ultrasonic Sensors.](image)

4.3. Servo motor testing

Tests on servo motors are carried out by varying input of Pulse With Modulation (PWM). The following is a table of test results from servo motors with ranges ranging from 1100 micro seconds to 1600 micro seconds:

| No. | PWM value provided (micro seconds) | Motorbike Round |
|-----|-----------------------------------|-----------------|
| 1.  | 1100                              | Reverse         |
| 2.  | 1150                              | Reverse         |
| 3.  | 1200                              | Reverse         |
| 4.  | 1250                              | Stop            |
| 5.  | 1300                              | Stop            |
| 6.  | 1350                              | Stop            |
| 7.  | 1400                              | Stop            |
| 8.  | 1450                              | Stop            |
| 9.  | 1500                              | Forward         |
| 10. | 1550                              | Forward         |
| 11. | 1600                              | Forward         |
In table 1, it can be seen that when the servo motor is given a pulse width or PWM from 1100 micro seconds to 1200 micro seconds, the Reverse motor rotation or reverse. If the servo motor is given pulses from 1250 micro seconds to 1450 micro seconds, then the Stop motor or not rotates. Whereas if the servo motor is given pulses from 1500 micro seconds to 1600 micro seconds then the motor rotation turns into Forward or forward.

4.4. Testing open and close the water gate
This automatic sluice open and close test aims to find out whether the ultrasonic sensor can read the water level according to the stage or level of water level and the servo motor can work well to open the floodgates in several stages according to the water level. In addition, this test is also carried out to ensure that the entire equipment runs well without any interference or obstacles. In this tool there are two sluice gates to control one dam. At the first sluice, it functions as an input for water which enters the two reservoirs. The sluice gate is intended to keep the two dams continuously holding water. If the second dam exceeds the capacity, the first sluice will be closed to prevent overflowing water and the second sluice will open in accordance with the existing water level. If the water in the second dam is dry, the first sluice will open to drain water.

Table 2. Results of Water Gate Testing.

| No. | High Water (cm) | Sluice gate | High Open the Water Gate (cm) |
|-----|----------------|-------------|-------------------------------|
|     | I | II | I | II |
| 1.  | 0,5 | Open | Close | 3 | - |
| 2.  | 2,5 | Open | Open | 3 | 0,5 |
| 3.  | 4  | Open | Open | 3 | 2 |
| 4.  | 5,5 | Close | Open | - | 2,5 |
| 5.  | 15 | Close | Open | - | 3 |

4.5. Testing of water discharge monitor
Monitoring of water discharge monitoring is done by calculating how long it takes to empty the dam. This water discharge aims to find out how much volume of water can be collected by the dam and released by the water gate, in a certain time unit.

Graph 3. Water Discharge Testing Results.

5. Conclusion
From the results of the testing and analysis that has been done on the design of the automatic sluice gate to monitor water level, conclusions can be drawn, namely:
a. A water gate has been designed to monitor water level. The sluice gate in this final project works based on the existing water level. After testing the device, the servo motor and ultrasonic sensor work well. The LCD can display the height and volume of the water. This tool works automatically to control the opening of the sluice by moving the servo motor by giving a cycle to the program. Duty cycle or PWM given to servo motors based on water level detected by ultrasonic.

b. With the ultrasonic sensor HC-SR04, can detect water level which can then calculate the amount of water discharge in the dam. The signal emitted by the ultrasonic sensor transmitter is a pulse or an analog signal, which then bounces when it hits an object in front of it. The signal will be received again by receiver of the ultrasonic sensor and processed into a digital signal.

c. In testing the HC-SR04 ultrasonic sensor, there is a difference in the distance between the measuring instrument and the ultrasonic sensor. The difference is considered an error. In the test results it can be concluded that the HC-SR04 ultrasonic system is quite accurate but has an error value when compared to the calibration measuring instrument.

d. If this paper is developed and applied for the use of energy conversion, then the writing is expected to be useful in determining the water level in water dams, as a water resource for hydroelectric power plants.

References
[1] Gustave., 11 Januari 2017., Jenis – Jenis Pintu Pengendali Banjir (Flood Gate)., https://gustavesp.wordpress.com/2009/02/17/jenis-jenis-pintu-pengendali-banjir-flood-gate/.
[2] Kurniawan. Dayat., 2016., Membangun Aplikasi Elektronika dengan Raspberry., Jakarta: Elex Media Komputindo.
[3] Saftari. Firmansyah., 2015., Proyek Robotik Keren dengan Arduino., Jakarta: Elex Media Komputindo.
[4] Suranata, Aditya., 27 Januari 2017., Interfacing Sensor Ultrasonic Pinger HC-SR04 di Raspberry Pi & Python3., https://tutorkeren.com/artikel/interfacing-sensor-ultrasonic-pinger-hc-sr04-di-raspberry-pi-python-3.htm.
[5] … ., 5 Desember 2016 ., Raspberry., http://www.raspberrypi.org/downloads.
[6] … ., 23 Desember 2016., LCD., http://elektronika-dasar.web.id/lcd - liquid - cristal - display/.
[7] … ., 2 Januari 2017 ., Motor Servo., http://elektronika-dasar.web.id/motor-servo/.
[8] … ., 2 Januari 2017 ., Elektronika Dasar ., http://elektronika-dasar.web.id.
[9] … ., 4 Januari 2017., Sensor Ultrasonik., http://www.elangsakti.com/2015/05/sensor - ultrasonik.html.
[10] … ., 28 Januari 2017 ., 16 x 2 LCD Module Control Using Python., http://www.raspberrypi-spy.co.uk/2012/07/16x2-lcd-module-control-using-python/.
[11] … ., 28 Januari 2017., Controlling a Servo on Raspberry Pi with Python., http://www.toptechboy.com/raspberry-pi/raspberry-pi-lesson-28-controlling-a-servo-on-raspberry-pi-with-python/.