Simulation and Control of Clean Water Supply on Campus Toilets Using Passive Infrared Receiver Sensor Technology and Flow Liquid Meter

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Abstract. The use of tap water on campus toilets is often problematic due to careless user. The water faucet on campus toilets is often left open, and this leads to wasteful and inefficient use of water. The purpose of this research is as a solution to save and control water usage on campus toilets with automatic faucet so that water usage can be used only when they are necessary or needed. Control of water usage on campus toilets using fluid mechanics and physics kinematics method by using solenoid valve as a valve to open and close the flow of water and flow liquid meter to calculate the water discharge data through it. While, PIR sensor that serve to detect the presence of humans in the toilets so that the solenoid valve can open and let the water flows. While Arduino UNO as microcontroller and Wi-Fi shield used to deliver the water discharge data to application that had been built. The test results show that the method used can work with stable to control water supply on campus toilets with the distance no more than 3 m and large number of users will not affect the performance of the sensor or system built.

1. Introduction
Water is the source of life for every living being. Also, water is one of the main needs in our live. The high level of human needs of water is not proportional to the availability of water on earth, because of all the water that is in the earth, 97% is sea water, while the remaining 3% is fresh water and only 1% is available for human use.

The amount of wasteful use of water causes wasteful use of water. Until now the level of water demand is increasing along with the increasing rate of world population growth. So, it is not exaggeration if UNESCO predicts by 2020 the world will experience a global water crisis.

Monitoring of water usage in toilets is expected to reduce excessive water use. This monitoring is supported by Passive Infrared Receiver (PIR) sensor. Passive Infrared Receiver is an infrared-based sensor. However, it is not as common as most infrared sensors that consist of an IR LED and a phototransistor. PIR does not emit anything like IR LEDs. As the name implies 'passive', this sensor only responds to the energy of the passive infrared beam held by every object detected by it. Objects that can be detected by these sensors are usually the human body.

This is due to an IR filter that filters the wavelength of passive infrared light. IR Filter in a PIR sensor module can filter the wavelength of passive infrared light between 8 to 14 micrometres, so the
wavelength produced from the human body ranging between 9 to 10 micrometres can be detected by the sensor.

Thus, when someone walks through the sensor, the sensor captures the emission of a passive infrared beam emitted by the human body which has a different temperature from the environment causing the pyroelectric material to react and generate an electric current due to the heat energy carried by the passive infrared beam. Then an amplifier circuit amplifies the current which is then compared by the comparator to produce the output.

Based on previous research this series of automatic water faucet is manufactured using microcontroller and the motion sensor is used to activate the automatic switch circuits which serve as input to the washer pump to control the valve to close or open. This will open automatically when the sensor is blocked. When the sensor is obstructed then the series will be active.

2. Previous Research
Several studies have been done to conserve water usage in toilets. In 2010, Gabriel conducted research for automatic faucet control in male toilets using PIR sensors. In his research, Gabriel utilized the PIR sensor as its control centre and object detection in the form of human body. The PIR sensor will give instructions to the relay to move the solenoid that acts as a valve. The results of analysis showed that the PIR sensor in this tool can detect the object within a maximum distance of 1.5 meters [1].

A second study in 2011, Alfarobi undertook research for the manufacture of an automatic faucet system for water savings in ablution using motion sensors. In his research, he made a system of automatic ablution faucet by placing the sensor at a certain point, so that when someone finishes, the faucet will automatically close [2].

In 2014, Subandi conducted a research for automation on water faucet to save water consumption. He used an ultrasonic sensor to detect the presence of a limb that is directed to the faucet and stop the flow of water if no limb is directed to the sensor. Ultrasonic sensor will convert physical quantities into mechanical quantities. He used an Atmega16 microcontroller as the system controller. Test results indicated that there was a difference in the amount of volume of water released using automatic faucet and ordinary faucet [3].

In 2014, Yano et al. conducted a research to measure water consumption and compare savings from tap water usage using Wireless Sensor Network. This research used RFbee Sensor to collect, send, and receive data. Data retrieved by RFbee sensors will be collected and then sent wirelessly to a computer connected directly to the RFbee sensor [4].

In 2017, Rahmat et al conducted a research showed that computation of science, especially fluid mechanics and kinematics physics is implemented on microcontroller. Arduino chip-based ATmega328P can be used to detect the location of leaks in pipes by using a data rate of water flow and the system is able to work stably to determining the location of the leak with a maximum distance of 2 meters and it can determine the location of the leak closest to the actual location of the leak with an average flow rate of 10 litters per minute [5].

3. Methodology
This research consists of several steps begins from data collection which is retrieved automatically through the sensor. For more information about the input and output process of the built system can be seen in Figure 1.
3.1 Hardware Sensor

This section shows the process of data retrieval by the sensor to then be sent to Arduino as well as data transmission by Arduino to the monitoring application system assisted by Wi-Fi shield. This process starts from the water that flows on the pipe and goes through the solenoid valve. Then, it flows through the flow liquid meter sensor that previously installed in the pipe. The sensor will collect data from the water passing through it and will be sent to the Arduino. Flow liquid meter sensor will transmit data to Arduino via digital pin 2. Then, Arduino calculates how much water discharge per second that passes through a flow liquid meter sensor. The water discharge per second that had been obtained is first stored in the server where the water discharge data is collected. Server will then directly send the data to the monitoring application system in real time. Collection of data from Arduino to server using Wi-Fi shield, to connect server with Arduino, Arduino will access the IP address of the server. After it is connected, Arduino will send water discharge data using POST method by accessing web page on server. Wi-Fi shield is mounted with stackable method on Arduino and will connect Arduino with server directly using RJ-45.

3.2 Application Monitoring System

Monitoring application system that will be built is a web-based application system using PHP.

3.3 Web Server

Web server used is a standalone web server. This web server will serve as a place of service and data processing between Arduino, database, and client. Web server will receive the water discharge data sent by the server where the data is collected. This water discharge data will then be stored into the database and ready to be processed and be represented back to the client in the form of graphs. These graphs will be displayed within a certain time interval and will always be updated automatically every second if the Arduino sends the water discharge data.
to the system. The water discharge data will be processed and ready to be represented back to the client either when they access the web server or not.

3.4 Client
The client will access a web page on the web server to perform monitoring and only the specific client who has permission will be able to access this page. This page will display the amount of water discharge used per day or the amount of water discharge that flows on the flow liquid meter. Water discharge will be displayed in the form of graphs and tables. Water usage graphs will be changed when the water flows through the flow liquid meter and updated automatically in the form of graphs and tables.

3.5 Data Used
The data used in this research is data which is obtained directly from the sensor. Then the Arduino will receive data from the sensor. The data is number of turns of the mill inside the sensor caused by the flow of water through the liquid meter flow sensor. The number of turns of the mill is further processed so that water discharge data is obtained through the sensor every second. Then Arduino will send the data assisted by Wi-Fi shield into the server that had been provided. The data transmitted is in the form of volume water discharge data that had been used.

3.6 Design of Solenoid valve Sensor, Relay, PIR Sensor with Arduino
Arduino has several pins that serve as a place of data processing and power. On this system, pins are used for processing data sent from the sensor. The solenoid valve sensor will be connected to the digital pin 6 to receive data from the sensor. To open and close the flow of water, adaptor is used to assist by connecting the relay as a current limiter.

PIR is an infrared-based sensor. However, it is not as common as most infrared sensors that consist of an IR LED and a phototransistor. PIR does not emit anything like IR LEDs. As the name implies 'passive', this sensor only responds to the energy of the passive infrared beam held by every object detected by it. Objects that can be detected by these sensors are usually the human body. PIR sensor detects infrared waves that come from the body heat of living creatures including humans. These waves are emitted as humans move. The PIR sensor will connect to the Arduino via digital pin 8 can be seen in Figure 2.

![Figure 2](image-url) Design of solenoid valve sensor, PIR sensor with Arduino.

3.7 Design of flow liquid meter with Arduino
Arduino has several pins that serve as a place of data processing and power. On this system, pins are used for processing data sent from the sensor. The flow liquid meter sensor will be connected to the digital pin 2 to receive data from the sensor, GND pin and 5V pin as power for the sensor. To design flow liquid meter with Arduino can be seen in Figure 3.
3.8 Design of Wi-Fi Shield and Arduino

Wi-Fi shield is an additional module used on the Arduino to connect to a server using a Wi-Fi network connection. This module will be mounted with stackable method on the Arduino as shown in Figure 4.

4. Results and Discussion

System performance test is performed to determine the performance of the system in monitoring whether the system is running well or not. The test performed will display the graph of the amount of water used only when the tool works. The display of the graph will drop because of the interaction of the PIR sensor detects the presence of humans in the room, this will cause the water in the tube to be reduced. Graph can be seen in Figure 5.
The second phase test will display the test results based on the large number of toilet users. The results of this test will be displayed in tabular form based on testing that have been done. Based on the results of testing the number of toilet users, if there are no toilet users, then the system or tool built will not work. This is due to the PIR sensor does not accept or detect the presence of humans in the toilet. So, the water will not flow because the valve on the solenoid valve is not open. When one person enters the toilet, the built-in sensor or system will work, and that’s because the PIR sensor detects the presence of a human in the toilet. Then the valve on the solenoid valve will open so that water can flow when it’s needed. What is detected by the PIR sensor is the heat wave generated by the human body. Similarly, when 2, 3, and 4 people enter the toilet, the built system or tool can still work well. From the tests conducted based on the number of toilet users can be concluded that the tool can work well. This study shows that the large number of users will not affect the performance of the sensor or system built. The table can be seen in Table 1.

Table 1. PIR Sensor testing based on number of toilet users.

| No | Number of toilet users | Work | Does Not Work |
|----|------------------------|------|---------------|
| 1  | 0                      | -    | Does Not Work |
| 2  | 1                      | Work | -             |
| 3  | 2                      | Work | -             |
| 4  | 3                      | Work | -             |
| 5  | 4                      | Work | -             |

The next test will display the test results ranging from distance that can still be detected by the sensor. The test results performed will be displayed in tabular form. Based on the tests that have been done, the maximum distance that can be detected by the PIR sensor can only work at a distance of 3 meters, but the PIR sensor test with a distance of 3 meters is not as accurate as a distance of 1 meter or 2 meters. Because the heat wave generated by the human body is too far to reach the PIR sensor. If the toilet user is more than 3 meters away, then the PIR sensor will not detect the presence of humans in the toilet and the automatic sensor will not work. It can be seen in Table 2.

Table 2. PIR sensor testing based on distance detectable by sensor.

| Distance / Meter | Detected | Not Detected |
|------------------|----------|--------------|
| 1 m              | Detected | -            |
| 2 m              | Detected | -            |
| 3 m              | Detected | -            |
| 4 m              | -        | Not Detected |

5. Conclusion

The conclusions can be taken based on simulation and control of clean water supply are:
- The built system can reduce the level of human negligence in the use of water on campus toilets.
- The built system can improve the efficiency of water usage in campus toilets to reduce and anticipate the wasteful use of water.
- PIR sensor will not operate if blocked by objects or something thick, such as doors and walls of the toilet room.
- Testing Distance for PIR sensor no more than 3 m.
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