Utilization of Motion Sensors to Reduce Electricity Consumption in Buildings

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Abstract

Electrical energy use at an agency that results in waste is a severe concern. One of them is in the toilet, which is often a waste of energy due to the lights being on while the toilet is not in use. As a result, energy waste is proportionate to an agency's monthly operating expenses. If waste can be eliminated, additional expenses will also be lowered. This study provides an algorithm that begins with the user pressing the push button to turn on the light and ends with the activated motion sensor. When a user enters the toilet and motion is detected, the toilet light remains on automatically. If, however, the user is not on the toilet after hitting the push button, the toilet light will automatically switch off after 60 seconds.

Similarly, if the user exits the toilet, the toilet light will switch off automatically after roughly 60 seconds. The findings of a test conducted in a toilet for around two weeks using a motion sensor whose algorithm was optimized revealed a 7.08 per cent reduction in electric power usage after utilizing the equipment. Then, the device's test results indicate that the motion sensor detection is 100 per cent successful.

Keywords: Toilet, Automation, Lighting, PLN Electricity, Motion Sensor, Algorithm.

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1 Introduction

Electrical energy is a kind of energy required in daily living, and it's only that its usage is sometimes inefficient, which affects the expenditures spent. If you consider it an office that lacks a control system for the use of electrical energy, the monthly expenditures will undoubtedly be considerable and will continue to rise as the primary power rate grows (Baronetto, 2021).

More precisely, if we analyze the lighting in an office building, mall, or other structure, we will see that the lights are turned on more often than not in the bathroom area. This is done on purpose to meet the demands of its consumers (Grivault, 2017). It is simply that, when evaluated and analyzed economically, how much energy may be saved if the user is prepared to switch off the toilet's lights after usage (Wei, 2020). It is not the case in malls, where restroom illumination is controlled centrally or via a lighting control centre. However, this also reduces the efficiency of electrical energy utilization (saving). If just five toilets use constant 20-watt lights, it is possible to compute how much energy is lost while the toilet is not in use (Magalotti, 2015). This inefficiency in restroom illumination also exists at Bandung's private institutions. In the sense that practically all toilets are turned on during business hours. The pretest data were collected to determine perspectives and knowledge, followed by the self-management education intervention, and finally, the posttest (Setiyowati et al., 2022).

Indeed, the toilet lighting at one of Bandung's private institutions is controlled manually by pushing the On/Off button. Due to the high volume of toilet users (Chakrabarti, 2021). If this continues for an extended period, there will be a waste of electrical energy. This is economically justified based on the Ministry of Energy and Mineral Resources (ESDM) official declaration that the tariff for home customers with 1,300 VA, 2,200 VA, 3,500-5,500 VA, and 6,600 VA and above would be Rp. 1,444,70/KWh as of September 1, 2020. The pricing for 900VA home users is Rp. 1,352/kWh. The rate for medium voltage consumers, such as businesses, industries, and governments, is Rp. 1114.74/kWh. Moreover, for consumers with a power rating of 30,000 kV or above, the cost is Rp. 996.74/KWh (Wang, 2021).

For instance, if someone forgets to switch off the room's 40-watt illumination for five hours, the following amount of electrical energy would be wasted:

$$
\begin{aligned}
E &= P \times t \\
&= 40 \times 5 \\
&= 200 \text{ Wh} \\
&= 0{,}2 \text{ KWh}
\end{aligned}
$$

Suppose the user leaves the light on when the toilet is empty for an extended period (Zheng, 2021). Because users may be unaware that the toilet light they are using has been turned off or may have forgotten to turn it off, this may also result in unnecessary power consumption and raise the cost of paying bills for toilet electricity (Wozniak, 2021). The extension is an active procedure requiring contact between the extension worker and the individual to establish a behavior change process (Sulandjari et al., 2022).

Numerous research has been conducted to try to resolve similar issues. Based on a microcontroller, they designed an autonomous light system with motion sensors, temperature sensors, and sound detection that has a success rate of 56.6 per cent for sound detection, 90 per cent for motion detection, and 93.3 per cent for temperature sensors. Using a timer IC 555, we constructed an automated lighting system based on human body motions, with the lights turning off according to the predetermined time (Ma, 2021). However, the gadget lacks a duration controller, which would allow the lights to switch off while the room is still in use (Bu, 2021).

The study raises many issues, including the following:

a. The sensors placed have not yet achieved a detection rate of 100 per cent.
b. When a timer is used in lighting equipment, the lamp is turned off while still in use.
c. On this basis, researchers will undertake more studies to develop a prototype of a toilet lighting system that utilizes a motion sensor-controlled microcontroller ATMega328 and is predicted to decrease electrical resource waste (Zhao, 2021).

2 Literature Review

Numerous earlier research has built automatic lighting systems. Some use motion sensors as their primary sensor, while others employ sensors other than motion or PIR, such as temperature or even sound. For instance, research has resulted in developing an automated lighting system equipped with motion sensors, temperature sensors, and a microcontroller-based sound system (Li, 2021). In this study, a motion sensor in the form of an infrared sensor (PIR) is installed in front of the toilet door; when the PIR sensor detects motion, it sends a signal to the KY038 and MLX9061 sensors that are specifically designed for the toilet; when the KY038 sensor detects sound in the toilet and the MLX9061 sensor detects that the temperature exceeds the set threshold, the system determines that someone is in the toilet and turns on the lights. According to the findings of this investigation, the system's accuracy in recognizing human sounds is 56.6 per cent, motion detection is 90 per cent, and human detection based on temperature sensors is 93.3 per cent (Liu, 2021).

They are using a 555. IC timer, researchers have succeeded in constructing autonomous lighting wakes to depend on human body motions (Ni, 2021). The autonomous lighting system's process flow begins with light readings from the LDR sensor and human readings from the PIR sensor. An AND gate is used to link the LDR and PIR sensors in this setup. When the room is dark, and the PIR sensor detects the presence of people, the system will trigger a timer. The timer output will activate the triac's gate, which will turn on the light (Wang, 2021). The IC 555 acts as a timer, keeping the lights on for a set period. When pin two is tripped, the timer is activated for the specified period. As a result, the researcher proposes that when circumstances are bright and no human movement is detected, the lights may be turned off immediately, without waiting for the timer to expire, and that components be added to enable the timer length to be adjusted appropriately about the need (Chu, 2021). To measure and educate public awareness in implementing health protocols, further research is needed (Cardiah, 2021).

Because the lighting system continues to rely on a motion sensor as its primary sensor, research has succeeded in constructing a structure capable of implementing automated lighting in a room or space (Lin, 2021). When people walk, a differential in temperature between the temperature emitted by the human body and the temperature of the surrounding environment will result, and the PIR sensor detects this temperature change. Along with the PIR sensor, the room has an LDR sensor that measures the room's light intensity(Park, S., 2014). The microcontroller will eventually use this information to determine whether or not to turn on the lights when the PIR sensor detects the presence of someone in the room. However, since the installed power source is a 9 Volt battery, it is strongly advised that you partner with the PLN electrical supply to avoid the high cost of batteries (Ma, 2021). The objective of this study was to determine the determinants between Community-Based Total Sanitation and the incidence of diarrhea in toddler at communities near rivers (Indah et al., 2022).

The Arudino Uno-based automated light prototype has been built. PIR (passive infrared) and RTC (real-time clock) sensors support this instrument. To demonstrate the PIR sensor's sensitivity, tests were conducted at distances of 0 meters, 0.5 meters, 1 meter, 1.5 meters, 2 meters, 2.5 meters, and 3 meters with tilt angles of 0, 30, 45, and 60 degrees using human movement as the source of motion (Jin, 2021).

In this experiment, it was discovered that although the PIR was unable to identify the source of human movement at a distance of 2.5 meters at a 60-degree angle, it was able to detect it at a distance of 0 – 1.5 meters on a level plane at a 60-degree angle.

In this experiment, it was discovered that although the PIR was unable to identify the source of human movement at a distance of 2.5 meters at a 60-degree angle, it was able to detect it at a distance of 0 – 1.5 meters on a level plane at a 60-degree angle (Zhang, 2021). The Autonomous Response Method may control lights remotely through a Bluetooth-connected android smartphone. Because the application in this design is simple to use with an Android smartphone, it enables users to control the lights more efficiently. The Bluetooth HC-05 may be linked to Bluetooth smartphone devices manually or autonomously, and relay 1, relay 2, relay 3, and relay four can be successfully switched on and off using high and low logic. Notification of Bluetooth connection, Bluetooth connection test, and light on/off button testing may all operate independently of one another (Ham, 2021). The results showed that the highest Green Objectives (GO) weight in envi- ronmentally friendly garden management was located on protected forest land used as plantation land by 38.82%, while waste minimization was found in Crude palm oil water content of 48% (Rosyidah et al., 2022). The modern architectural approach to the Transfer Hub building adds value to the area's views and mode of transportation (Andiyan & Cardiah, 2021).

Then the connection time between the smartphone and the device is 3 seconds, the connection time between the tool and the lamp via the button command when the lamp is turned on is 1 second, the connection time between the tool and the lamp via the button command when the lamp is turned off is 1 second, and the connection time between the tool and the lamp via the button command when the lamp is turned off is 1 second. The maximum distance of the Bluetooth connection used is 13 meters (Li, 2021).

The experiments above show that utilizing a motion sensor (PIR) to switch on the lights is highly successful. This researcher created a prototype of a toilet lighting system utilizing a motion sensor and an ATMega328 microcontroller. The system aims to prevent excessive light from being turned on while the toilet is empty, hence minimizing electrical resource loss. Additionally, provide the period the lights will remain off after the user has done using the toilet to prevent rapidly harming the lights when the user enters and exits the toilet (Jeong, 2021). Non-physical adaptation includes changes in time, patterns and methods of learning, behavior, psychology, and the internet network, as well as changes in the internet network itself. In future studies, it is necessary to do more in-depth study on behavioral and psychological adjustments and perspectives (Andiyan et al., 2021).

3 Research Methodology

3.1 Types of Research

Experimental research is employed (non-statistical) (Sugiyono, 2010).This means that a series of experiments have been carried out with comparisons from previous studies, giving 56.6% sound detection results, 90% motion detection, and 93.3% temperature detection, with the main sensor using a motion sensor (Moleong, 2007). The other sensors will corroborate the finding if a motion sensor senses movement. If the motion sensor cannot detect movement, the other sensors become inoperative (off).

This study attempts to re-do research by hypothesizing that decreasing the number of sensors may increase detection accuracy via an analysis of the positioning of motion sensor components in the places being evaluated.

3.2 Needs Analysis

Numerous hardware components are required for this investigation in line with the formulation of the issue, the aims, and the hypotheses of this study. These components include the following:

Arduino Uno

Arduino Uno is a single-board microcontroller based on the ATmega328 (datasheet). It has 14 digital input pins, which may be used as PWM outputs, six analogue input pins, a 16 MHz crystal oscillator, a USB connection, a power connector, an ICSP header, and a reset button. To enable the microcontroller to be utilized, all required is to connect the Arduino Uno Board to a computer using a USB connection, an AC-to-DC converter, or a battery.

PIR Sensor

The PIR sensor is a sensor that detects movement; in this situation, the PIR sensor is often used to assess if there is human activity in an area that the PIR sensor can detect. This sensor is compact, low-cost, consumes minimal power, and is simple to operate. As a result, this sensor is extensively employed on a residential and commercial scale. PIR is an acronym for the "Passive InfraRed" sensor.

Relay

A relay is an electromagnetic device. Relays that operate by moving a series of contactors or an electronic switch that may be controlled by other electronic circuits powered by electricity. The relay employed in this investigation is a four-foot relay that is often used for positive control in single-load electrical circuits.

Push Button

A push-button switch is an essential gadget/switch that operates on a press unlock (not lock) mechanism to connect or disconnect the flow of electric current. When the button is pushed, the switch acts as a connecting device or an electric current breaker; when the button is released, the switch returns to regular operation.

Lamp

A lamp is a light-producing device. The term "lamp" is also used to refer to a light bulb, and Sir Joseph William Swan was the first to discover the light. The lamp is a device that serves as a source of light; it is shaped like a bottle and has a hollow that contains a thin wire that glows when linked to an electrical current.

Cable/Jumper

Jumper wires are electrical lines having a connector pin on either end that connects two Arduino-related components without the requirement for soldering. Jumper cables are used to connect electrical circuits as a conductor. Typically, jumper cables are used on breadboards or other prototype equipment to facilitate circuit manipulation. Jumper cables are electrical cords having a connector pin on either end that connects two Arduino-related components without the requirement for soldering. Jumper cables are used to connect electrical circuits as a conductor. Typically, jumper cables are used on breadboards or other prototype equipment to facilitate circuit manipulation.

Toilet

The toilet is a location for waste disposal, specifically pee and excrement. Despite its distant "rear" position, the toilet plays a significant function in picture production. The toilet is not simply a place to dispose of excrement; it is also a place for creativity to flourish. The toilet must then be clean, pleasant, and compliant with applicable regulations. The following are some common kinds of toilets that might enhance the aesthetic of your bathroom.

3.3 System Design

Figure 1 depicts the design of the tool that will be used later, which includes the following:

a. The device's primary controller is an Arduino.
b. The relay acts as a switch to turn on/off the lamp's electric current.
c. A motion sensor / PIR is a gadget that detects movement.
d. The push-button acts as a toggle switch for the Arduino controller, activating or deactivating the motion sensor (person).
e. The lamp is used to illuminate the toilet.
f. The PIR sensor determines the size of the box containing multiplex material; if the box is made of transparent material, the sensor can detect the material exiting. The box measures 20 cm in length, 25 cm in width, and 20 cm in height.

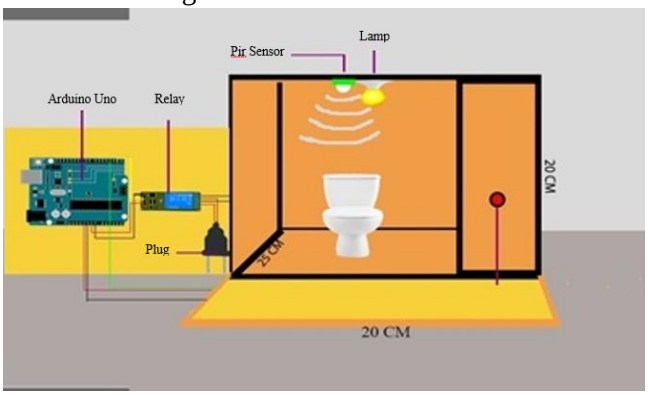

Figure 1: Tool/System Design

The algorithms created in the microcontroller's program are as follows:

Start:

Initialization of the microcontroller's digital port for motion sensor input

Initialization of the microcontroller's digital interface for push-button input

Initialization of the microcontroller's digital port for the indication LED output

Read Button:

Take note of the push button condition.

If the push button is not touched, the label Read Button is returned.

When the push-button is pushed, the toilet light is turned on. Check Motion Sensor 1 Jump to the label

Check Motion Sensor 1:

Determine the condition of the motion sensor 5-second delay

Keep the toilet light on if there is movement. Check Motion Sensor 2 Jump to label

Check Motion Sensor 2:

Determine the condition of the motion sensor 5-second delay

If there is no movement, a 60-second delay is applied. Check Motion Sensor 3 Jump to the label

Check Motion Sensor 3:

Determine the condition of the motion sensor

If there is no movement, a 60-second delay is applied. Switch off

Returning to the label Completed, the read button

3.4 Data and Techniques for Data Analysis

The data analysis approach is a method for segmenting an entire information system. Testing the toilet lighting system based on the ATmega328 microcontroller-controlled motion sensor was evaluated by verifying and re-verifying its accuracy throughout the testing and data collecting processes. Following that, the data from the measurement results are examined for uniqueness, and it is determined if the data has addressed or not addressed the research challenge.

4 Results and Discussion

4.1 The Tool Kit's Overall Appearance on the Original Toilet

Figure 2: Aerial View of the Toilet's Equipment

The gadget shown in Figure 2 is put in the original toilet and will illuminate persons or users underneath the PIR sensor.

4.2 View of the Toolkit as a Whole on the Prototype

Figure 3: Illustration of the Device Created

Figure 3 depicts the devices/tools that have been devised to construct. The gadget is constructed of plywood and serves as an example of a toilet structure. It features a light and a PIR or motion sensor and a push-button on the front. The other supporting components are housed in a separate box positioned above the toilet building and plastic. However, testing may also be conducted realistically by putting the gadget in an actual toilet. The tool's operation is identical to the method previously provided.

When the gadget receives a power source from DC energy, it will operate. The system is then initialized via the Atmega328 Microcontroller's digital interface for motion sensor input, push-button input, and LED indication output. The machine will remain in standby mode and await the user's order to press the push button.

Without pressing the push button, the system will stay in standby mode, waiting for the push button to be pushed. However, pressing the push button activates the toilet light. Then, for five seconds, the motion sensor's state is read. The toilet light will stay on if motion is detected. Next, the system will do a 5-second recheck of the motion sensor's status. If no motion is detected, the system will continue to illuminate the toilet for 60 seconds and then check the motion sensor to determine whether or not a motion was detected. If there is no movement, the system will pause for 60 seconds while keeping the toilet light on and switching off the toilet light. The system will then return to the location to determine whether or not the push button has been pushed.

4.3 Display in the Prototype's Toolbox

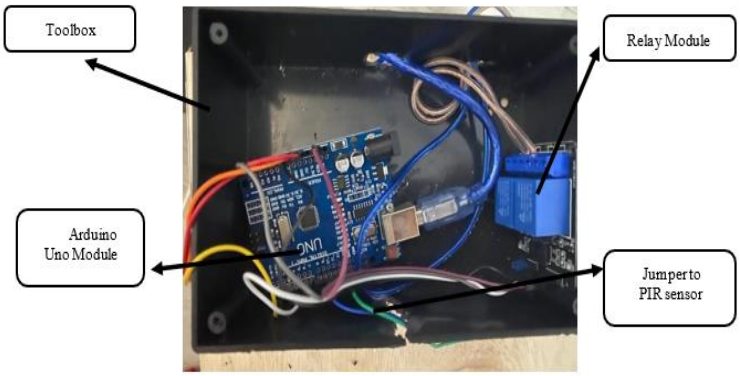

Figure 4: Aerial View of the Toolbox

The instruments contained in the package are shown in Figure 4. The device/tool is made up of multiple tool components, including the following:

a. The device's primary controller is an Arduino.
b. The relay acts as a switch to turn on/off the lamp's electric current.
c. The push-button serves as a toggle switch for the Arduino controller, activating or deactivating the motion sensor and relay.

4.4 Testing and Discussion

Distance Accuracy Test

Table 1: Accuracy Testing of Sensor Distances

No	Trial to-	Distance (cm)	Distance Measurement Detection Status Detected/Undetected	Information	Accuracy (%)
	1	10	Detected	In accordance	
1	2	10	Detected	In accordance	100%.
	3	10	Detected	In accordance	
	1	30	Detected	In accordance	
2	2	30	Detected	In accordance	100%.
	3	30	Detected	In accordance	
	1	60	Detected	In accordance	
3	2	60	Detected	In accordance	100%.
	3	60	Detected	In accordance	
	1	90	Detected	In accordance	
4	2	90	Detected	In accordance	100%.
	3	90	Detected	In accordance	
	1	120	Detected	In accordance	
5	2	120	Detected	In accordance	100%.
	3	120	Detected	In accordance	
	1	150	Detected	In accordance	
6	2	150	Detected	In accordance	100%.
	3	150	Detected	In accordance	
	1	180	Detected	In accordance	
7	2	180	Detected	In accordance	100%.
	3	180	Detected	In accordance	
	1	210	Detected	In accordance	
8	2	210	Detected	In accordance	100%.
	3	210	Detected	In accordance	

Table 1 summarizes the findings of the distance above test, which was conducted directly on a toilet from a distance of 10 cm to 210 cm to individuals around the sensor mounted in the toilet. The test findings are detectable to be 100 per cent accurate. The signal is that if the PIR sensor detects movement, the toilet light will illuminate; however, if the sensor detects no movement, the light will switch off. Because the test was conducted on a toilet measuring 2x2 meters with a toilet room height of 2.1 meters, the most significant distance detectable by the PIR sensor positioned above the toilet is 210 cm.

$$The\ formula\ for\ calculating\ the\ accuracy\ value = \frac{\text{Total Detection Status}}{\text{Total Description Appropriate}} x100$$

Sensor Angle Accuracy Test

Table 2 summarizes the findings of the angle test conducted before, a motion sensor angle accuracy test conducted from 30 degrees to 90 degrees with data identified with a level of 100 per cent accuracy. The signal is that if the PIR sensor detects movement, the toilet light will illuminate; however, if the sensor detects no movement, the light will switch off.

The Formula for Calculating the Accuracy Value

$$The\ formula\ for\ calculating\ the\ accuracy\ value = \frac{\text{Total Detection Status}}{\text{Total Description Appropriate}} x100$$

Table 2: Table for Testing the Accuracy of Sensor

No	Trial to-	PIR Sensor Angle	Distance Measurement Detection Status	Information	Accuracy (%)
			Detected/Undetected		
	1	30o	Detected	In accordance	
1	2	30o	Detected	In accordance	100%
	3	30o	Detected	In accordance	
	1	40o	Detected	In accordance	
2	2	40o	Detected	In accordance	100%
	3	40o	Detected	In accordance	
	1	50o	Detected	In accordance	
3	2	50o	Detected	In accordance	100%
	3	50o	Detected	In accordance	
	1	60o	Detected	In accordance	
4	2	60o	Detected	In accordance	100%
	3	60o	Detected	In accordance	
	1	70o	Detected	In accordance	
5	2	70o	Detected	In accordance	100%
	3	70o	Detected	In accordance	
	1	80o	Detected	In accordance	
6	2	80o	Detected	In accordance	100%
	3	80o	Detected	In accordance	
	1	90o	Detected	In accordance	
7	2	90o	Detected	In accordance	100%
	3	90o	Detected	In accordance	

Sensor Time Lapse Test

This approach is used to determine how long it takes the PIR sensor to detect individuals in the toilet and when they have exited.

Table 3: Time Lapse Test for Sensors

No	Trial to-	PIR Sensor	Process	Test Results (seconds)	Lamp Statue
1	1	Motion Detected	Make sure there is movement	04.26 seconds	Light up
	2			05.78 seconds	
	3			05.33 seconds	
	4			05.33 seconds	
	5			05.27 seconds	
2	1	No Motion Detected	Make sure there is no movement	42.39 seconds	Dead
	2			48.90 seconds	
	3			54.10 seconds	
	4			48.72 seconds	
	5			52.76 seconds	

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2	1	No Motion Detected	Make sure there is no movement	42.39 seconds	Dead
	2			48.90 seconds	
	3			54.10 seconds	
	4			48.72 seconds	
	5			52.76 seconds	

The angle test shown in Table 3 is a time-lapse test of the PIR sensor, which was tested five times for the presence and absence of movement underneath the PIR sensor, with the results produced if the PIR sensor detects movement in roughly 5 seconds. Then the light will come on; after roughly 50 seconds, if the PIR sensor does not detect movement, the light will switch off.

Testing Conditions in the Toilet

This test is used to identify the circumstances in the toilet, such as whether there are individuals who move and those who do not, and whether the lights are on or will be turned off for two minutes.

Table 4: Testing Conditions in the Toilet

No.	Conditions Inside the Toilet	Toilet Time	Lamp Statue
1	People Who Move Slightly	2 minute	Lights On
2	People Who Do Not Move	2 minute	Lights off

The results of evaluating the circumstances in the toilet for two minutes each demonstrate that if some individuals move, even if just a little, the sensor will identify them, and the light will remain on. Meanwhile, if a person remains quiet in the toilet for more than 60 seconds, the sensor will not identify them, and the light will switch off.

Toolless Lamp Test

Table 5 shows the results of the lamp test without the above equipment, which is a one-week test in which the number of kWh consumed decreases daily, as calculated from 10 a.m. the total kWh consumed is how much and less the total kWh consumed at 10 a.m. the following day, then the number of kWh consumed is reduced by one day. According to the conclusion of the table above, the decreased KWh for one week without the use of a sensor is 44.19 KWh. The amount of kilowatt-hours is calculated as follows: 1 kilowatt-hour = IDR 1,352 x Total kilowatt-hours = 1,352 x 44.19 = IDR 59,744 Per week. Monthly calculation: Rp. 59,744 x 4 weeks = Rp. 238,976 is the cost of power for one month for toilets that need tools.

Table 5: Lamp Testing Without Tools

No	Date	Initial KWh	Final KWh	Total KWh
1	31-Mar-20	14,08	7,33	6,75
2	01-Apr-20	7,33	1,38	5,95
3	02-Apr-20	131,1	126	5,1
4	03-Apr-20	126	118,27	7,73
5	04-Apr-20	118,27	112,61	5,66
6	05-Apr-20	112,61	105,44	7,17
7	06-Apr-20	105,44	99,61	5,83
Total KWh used one week				44,19

Lamp Testing with Tool

Table 6 summarizes the findings of light testing using the instruments above during one week. Here, we check the amount of KWh saved each day, determined by subtracting the total KWh at 10 a.m. from the total KWh at 10 a.m. the next day. This gives us the number of KWh saved by one day. According to the conclusion of the table above, the decreased KWh for one week when a sensor is used is 41.06 KWh. The number of Kwh is calculated using the following formula: 1 Kwh = IDR 1,352 x Total Kwh = 1,352 x 41.06 = IDR 55,513/week. Monthly calculation: Rp. 55,513 x 4 weeks = Rp. 222,052, indicating that the cost of power required for one month for a toilet that utilizes a tool is Rp. 222,052.

Table 6: Lamp Testing with Tools

No	Date	Initial KWh	Final KWh	Total KWh
1	08-Apr-20	99,61	94,44	5,17
2	09-Apr-20	94,44	88,78	5,66
3	10-Apr-20	88,78	83	5,78
4	11-Apr-20	83	76,24	6,76
5	12-Apr-20	76,24	70,28	5,96
6	13-Apr-20	70,28	63,68	6,6
7	14-Apr-20	63,68	58,55	5,13
Total KWh used one week				41,06

5 Conclusion

Conclusions may be reached based on the outcomes of testing and analysis, including the following:

1. The created algorithm has been tested on a motion sensor-based toilet lighting system prototype. By pushing the button/push button first, users may provide commands to switch on the lights. If the initial emphasis is detected, the motion sensor is activated. When a user enters the toilet room, the

motion sensor detects the user's movement and continues to switch on or off the toilet light automatically. If, however, the user is not on the toilet after hitting the push button, the toilet light will automatically switch off after 60 seconds. Similarly, if the user exits the toilet, the toilet light will switch off automatically after roughly 50 seconds.

2. After roughly two weeks of testing, it was determined that the power without this device was 44.19 KWh at the cost of Rp. 238,976 per month. Meanwhile, this equipment consumes 41.06 kWh of electricity every month at the cost of Rp. 222,052. This indicates that the gadget has resulted in a reduction in electrical power consumption. Alternatively, other words, its usage may result in energy savings. The savings percentage gained is roughly 7.08 per cent more than before utilizing the tool.
3. Additionally, this study established that by using only motion sensors that are algorithmically optimized, it is possible to minimize the number of sensors needed to accomplish the same automation objective. As seen by the test results, the effective detection rate is close to 100%.

Reference

[1] Andiyan, A., & Cardiah, T. (2021). Application of contemporary architecture in the transfer hub high land borobudur building. *Civil Engineering and Architecture*, *9*(7), 2353-2361.

[2] Andiyan, A., Rusmana, D., Hari, Y., Sitorus, M., Trinova, Z., & Surur, M. (2021). Disruption of IoT in Adapting Online Learning during the Covid-19 Pandemic. *International Journal of Early Childhood Special Education*, *13*(2), 1331–1341.

[3] Baronetto, A., Wassermann, D., & Amft, O. (2021). Deep 3D Body Landmarks Estimation for Smart Garments Design. *In IEEE 17th International Conference on Wearable and Implantable Body Sensor Networks (BSN)*, 1-5.

[4] Bu, Y., Shen, T., Yang, W., Yang, S., Zhao, Y., Liu, H., & Shen, C. (2021). Ultrasensitive strain sensor based on superhydrophobic microcracked conductive Ti3C2Tx MXene/paper for human-motion monitoring and E-skin. *Science Bulletin*, *66*(18), 1849-1857.

[5] Cardiah, T., Andiyan, A., & Rahma, A. (2021). Implementation of Health Protocols at Mosques during the Covid-19 Pandemic in the city of Bukittinggi. *Review of International Geographical Education Online*, *11*(5), 3765–3771.

[6] Chakrabarti, K., Obaidat, M.S., Mostufa, S., & Paul, A.K. (2021). Design and analysis of a multi-core whispering gallery mode bio-sensor for detecting cancer cells and diabetes tear cells. *OSA Continuum*, *4*(8), 2294-2307.

[7] Chu, Z., Jiao, W., Huang, Y., Zheng, Y., Wang, R., & He, X. (2021). Superhydrophobic gradient wrinkle strain sensor with ultra-high sensitivity and broad strain range for motion monitoring. *Journal of Materials Chemistry A*, *9*(15), 9634-9643.

[8] Grivault, L., El Fallah-Seghrouchn, A., & Girard-Claudon, R. (2017). Next generation of airborne platforms from architecture design to sensors scheduling. *In IEEE International Conference on Agents (ICA)*, 60-65.

[9] Ham, S.S., Lee, G.J., Hyeon, D.Y., Kim, Y.G., Lim, Y.W., Lee, M.K., & Park, K.I. (2021). Kinetic motion sensors based on flexible and lead-free hybrid piezoelectric composite energy harvesters with nanowires-embedded electrodes for detecting articular movements. *Composites Part B: Engineering*, *212*.

[10] Indah, F.P.S., Cardiah, T., Rahmat, A., Sulandjari, K., Andiyan, A., & Hendayani, N. (2022). Effect of Community-Based Total sanitation Program with diarrhea Incidents in toddler at communities near rivers. *Materials Today: Proceedings*, *63*, S349-S353.

[11] Jeong, S.Y., Lee, J.U., Hong, S.M., Lee, C.W., Hwang, S.H., Cho, S.C., & Shin, B.S. (2021). Highly skin-conformal laser-induced graphene-based human motion monitoring sensor. *Nanomaterials*, *11*(4), 1-15.

[12] Jin, R., Xu, J., Duan, L., & Gao, G. (2021). Chitosan-driven skin-attachable hydrogel sensors toward human motion and physiological signal monitoring. *Carbohydrate Polymers*, *268*.
[13] Li, S., Li, R., González, O.G., Chen, T., & Xiao, X. (2021). Highly sensitive and flexible piezoresistive sensor based on c-MWCNTs decorated TPU electrospun fibrous network for human motion detection. *Composites Science and Technology*, *203*.
[14] Li, W., Zhou, Y., Wang, Y., Jiang, L., Ma, J., Chen, S., & Zhou, F. L. (2021). Core–sheath fiber-based wearable strain sensor with high stretchability and sensitivity for detecting human motion. *Advanced Electronic Materials*, *7*(1), 1-24.
[15] Lin, L., Choi, Y., Chen, T., Kim, H., Lee, K.S., Kang, J., & Piao, Y. (2021). Superhydrophobic and wearable TPU based nanofiber strain sensor with outstanding sensitivity for high-quality body motion monitoring. *Chemical Engineering Journal*, *419*.
[16] Liu, X., Ren, Z., Liu, F., Zhao, L., Ling, Q., & Gu, H. (2021). Multifunctional self-healing dual network hydrogels constructed via host–guest interaction and dynamic covalent bond as wearable strain sensors for monitoring human and organ motions. *ACS Applied Materials & Interfaces*, *13*(12), 14612-14622.
[17] Ma, Z., Wei, A., Li, Y., Shao, L., Zhang, H., Xiang, X., & Zhang, G. (2021). Lightweight, flexible and highly sensitive segregated microcellular nanocomposite piezoresistive sensors for human motion detection. *Composites Science and Technology*, *203*.
[18] Ma, Y., Ouyang, J., Raza, T., Li, P., Jian, A., Li, Z., & Tao, G. (2021). Flexible all-textile dual tactile-tension sensors for monitoring athletic motion during taekwondo. *Nano Energy*, *85*.
[19] Magalotti, D., Placidi, P., Conti, E., De Biagi, M., Fabiani, S., Bissi, L., & Servoli, L. (2015). Design and implementation of a wireless intelligent personal sensor node for the dosimetry of interventional radiology operators. *In IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings*, 1159-1164.
[20] Moleong, L.J. (2007). *Qualitative Research Methodology*. Yogyakarta: Gadjah Mada University Press.
[21] Ni, Y., Huang, J., Li, S., Wang, X., Liu, L., Wang, M., & Lai, Y. (2020). Underwater, multifunctional superhydrophobic sensor for human motion detection. *ACS Applied Materials & Interfaces*, *13*(3), 4740-4749.
[22] Park, S., Bang, J., Ahn, M., Lee, W., & Kwon, T. (2014). A Method for Hiding Link Layer Addresses Using Bloom Filter in Wireless Sensor Networks. *Journal of Internet Services and Information Security (JISIS)*, *4*(4), 71-81.
[23] Rosyidah, M., Khoirunnisa, N., Rofiatin, U., Asnah, A., Andiyan, A., & Sari, D. (2022). Measurement of key performance indicator Green Supply Chain Management (GSCM) in palm industry with green SCOR model. *Materials Today: Proceedings*, *63*, S326-S332.
[24] Setiyowati, E., Agustina, A.N., Yuddha, A.S., Muchtar, M., Fatmawati, E., & Andiyan, A. (2022). Self-Management to Change of Perception and Clinical and Pharmacological Knowledge of COVID-19. *Journal of Pharmaceutical Negative Results*, *13*(2), 1-6.
[25] Sugiyono, S. (2010). *Qualitative Quantitative Research Methods and R&B*. Alf. Bandung.
[26] Sulandjari, K., Putra, A., Sulaminingsih, S., Adi Cakranegara, P., Yusroni, N., & Andiyan, A. (2022). Agricultural extension in the context of the Covid-19 pandemic: Issues and challenges in the field. *Caspian Journal of Environmental Sciences*, *20*(1), 137-143.
[27] Wang, S., Fang, Y., He, H., Zhang, L., Li, C.A., & Ouyang, J. (2021). Wearable stretchable dry and self-adhesive strain sensors with conformal contact to skin for high-quality motion monitoring. *Advanced Functional Materials*, *31*(5).
[28] Wang, H., Li, J., Yu, X., Yan, G., Tang, X., Sun, Y., & Lin, L. (2021). Cellulose nanocrystalline hydrogel based on a choline chloride deep eutectic solvent as wearable strain sensor for human motion. *Carbohydrate Polymers*, *255*.
[29] Wei, L., Guo, X., & Wang, Q. (2020). Design of integrated fire alarm system for integrated pipe gallery based on multi-environmental sensors. *International Journal of Wireless and Mobile Computing*, *19*(2), 178-187.

[30] Woźniak, M., Wieczorek, M., Siłka, J., & Połap, D. (2020). Body pose prediction based on motion sensor data and recurrent neural network. *IEEE Transactions on Industrial Informatics*, *17*(3), 2101-2111.
[31] Zhang, Z., Gui, X., Hu, Q., Yang, L., Yang, R., Huang, B., & Tang, Z. (2021). Highly sensitive capacitive pressure sensor based on a micropyramid array for health and motion monitoring. *Advanced Electronic Materials*, *7*(7).
[32] Zhao, J., Li, F., Wang, Z., Dong, P., Xia, G., & Wang, K. (2021). Flexible PVDF nanogenerator-driven motion sensors for human body motion energy tracking and monitoring. *Journal of Materials Science: Materials in Electronics*, *32*(11), 14715-14727.
[33] Zheng, Y., Yin, R., Zhao, Y., Liu, H., Zhang, D., Shi, X., & Shen, C. (2021). Conductive MXene/cotton fabric based pressure sensor with both high sensitivity and wide sensing range for human motion detection and E-skin. *Chemical Engineering Journal*, *420*.

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