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Arduino Uno-Based Automatic Hand Soap Dispenser Using Ultrasonic Sensors for Hand Hygiene

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ABSTRACT

Hand hygiene is a crucial measure for maintaining health and preventing the spread of germs through direct contact. Manual soap dispensers require users to touch specific parts of the container, thereby increasing the risk of cross-contamination. This study aims to design and build an automatic hand soap dispenser using an Arduino Uno and an ultrasonic sensor to minimize direct contact with the dispenser and enhance convenience and hygiene during use. The research employs the Hardware Development Life Cycle (HDLC) methodology, encompassing planning, requirements analysis, system and device design, development, testing, and implementation and maintenance. An Arduino Uno serves as the microcontroller, processing data from the ultrasonic sensor and controlling a relay connected to a DC pump. The ultrasonic sensor detects the presence of a hand within a preset range, prompting the Arduino Uno to signal the relay to activate the pump and automatically dispense the soap. Test results demonstrate that the device successfully detects hands via the ultrasonic sensor and automatically activates the pump according to the programmed logic. The designed device helps reduce the need for direct contact with the soap dispenser while offering a more practical and hygienic soap-dispensing process. Consequently, this automatic hand soap dispenser serves as a simple solution to support the practice of hand hygiene in daily life.

INTRODUCTION

Advancements in science and technology during the globalization era have brought about changes across various aspects of human life, notably through the implementation of automation systems. Automation technology enables devices to perform specific functions with minimal or no direct human intervention. In the realm of hygiene, this technology can be utilized to create more convenient facilities and minimize direct contact between users and the equipment. Technological progress has also driven the adoption of the Internet of Things (IoT) across various sectors, although automation itself does not always require an internet connection (Syahputra et al, 2021).

Hand hygiene is an essential measure for maintaining health and preventing the transmission of infectious diseases. Handwashing with soap and water is widely recommended as an effective practice for hand hygiene in community settings (MacLeod et al., 2023). However, conventional soap dispensers often require users to touch the dispenser directly, potentially increasing the number of shared contact points. Automated touchless dispensing systems can minimize direct contact with dispenser surfaces and may help reduce the risk of cross-contamination (Das et al., 2021). Therefore, developing an automatic hand soap dispenser using an ultrasonic sensor and an Arduino Uno is a practical approach to improving convenience and supporting better hand hygiene practices.

One technology that can be applied to address this issue is object detection sensing. Sensors can detect the presence of a hand within a certain range, allowing the soap dispensing process to occur automatically. The application of automation technology in hand-washing devices has been explored in several studies. Asrul et al. (2021) designed an automatic hand-washing machine using proximity sensors and a DFPlayer Mini, powered by an Arduino Uno. Their research demonstrated that the Arduino Uno microcontroller could effectively control the automatic operation of the hand-washing device. Additionally, Bait et al. (2023) developed a portable automatic hand-washing machine to reduce direct contact during use.

Other studies have also demonstrated the application of sensors in the development of automatic hand-washing devices. Ananda et al. (2023) developed an automatic hand-washing device based on object-sensor distance using the fuzzy logic method. That study demonstrated that object distance could serve as a parameter for determining the system's response in an automatic hand-washing device. Meanwhile, Permadi et al. (n.d.) developed a portable automatic hand-washing device utilizing fuzzy logic and an Android-based monitoring system. The distinction between that study and the present one lies in the system's focus; this study does not employ an internet- or Android-based monitoring system but instead concentrates on a simple automation mechanism using an Arduino Uno and an ultrasonic sensor.

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Addressing these issues, this research focuses on the "Design and Construction of an Automatic Hand Soap Dispenser Based on Arduino Uno and Ultrasonic Sensors to Reduce Direct Contact with the Soap Container." The study aims to design and build a device capable of detecting the presence of hands via an ultrasonic sensor and automatically dispensing soap using a pump controlled by an Arduino Uno. This device is expected to make the soap-dispensing process more convenient and reduce direct user contact with the soap container, thereby supporting hygiene practices in daily life.

LITERATUR REVIEW

Advancements in automation technology have spurred research into the implementation of touchless systems for hand-washing devices and soap dispensers. Previous studies indicate that utilizing microcontrollers and sensors enhances convenience and minimizes direct contact when using hygiene facilities. Asrul et al. (2021) developed an automatic hand-washing machine using proximity sensors and an Arduino Uno. Meanwhile, Bait et al. (2023) created a portable automatic hand-washing unit employing infrared sensors, a water pump, and a solenoid valve. Furthermore, Permadi et al. (2021) applied fuzzy logic to a portable automatic hand-washing device featuring an Android-based monitoring system, whereas Juliarta et al. (2022) utilized infrared sensors to automate water and soap dispensing. Ananda et al. (2023) developed an automatic hand-washing device that operates based on object distance, utilizing ultrasonic sensors, infrared sensors, an Arduino Uno, and fuzzy logic. These studies demonstrate that sensors and microcontrollers can effectively create automatic hand-washing systems, though they differ in terms of sensor types, control methods, and system complexity.

Building upon this prior research, the current study distinguishes itself through a simpler system design that focuses specifically on automating soap dispensing. This research utilizes an Arduino Uno and an ultrasonic sensor as the primary components to detect the presence of hands, subsequently controlling a DC pump via a relay to dispense soap automatically. The system does not incorporate internet connectivity, Android-based monitoring, or fuzzy logic methods. Additionally, the pump's operating duration is regulated through the Arduino program to ensure a relatively consistent soap output. The device was developed using the Hardware Development Life Cycle (HDLC) methodology, encompassing planning, requirements analysis, design, development, testing, as well as implementation and maintenance.

METHODS

This study employs the Hardware Development Life Cycle (HDLC) method to develop an automatic hand soap dispenser based on the Arduino Uno and an ultrasonic sensor. This method was selected due to its systematic and sequential hardware development stages: planning, requirements analysis, system and device design, development, testing, and implementation and maintenance (Okpatrioka, 2023). The planning stage involves identifying the problem and defining the objectives for the device's development. The requirements analysis stage entails determining the necessary hardware and software, such as the Arduino Uno, ultrasonic sensor, relay, DC pump, and other supporting components. The design stage focuses on creating the electronic circuitry, operational mechanism, and system workflow. The development stage covers component assembly and programming the Arduino Uno to read the ultrasonic sensor and control the DC pump via the relay. Subsequently, the testing stage evaluates the sensor's hand-detection capability, relay response, and the pump's performance in dispensing soap. The final stage implementation and maintenance involves deploying the device and inspecting component conditions to ensure the system continues to function correctly.

RESULT

This research resulted in a prototype of an automatic hand soap dispenser utilizing an Arduino Uno R3 and an ultrasonic sensor. The device is designed to automatically dispense soap when the sensor detects the presence of a hand within a specific range. The research encompasses system design, hardware design, component integration, device implementation, Arduino Uno programming, as well as testing of the sensor and the device's functionality.

System Design

The system was designed to create an automatic hand soap dispenser capable of detecting the presence of hands and dispensing soap without direct contact. The system utilizes an Arduino Uno R3 as the main controller, an ultrasonic sensor for proximity detection, a relay module as an electronic switch, and a mini DC pump as the actuator for dispensing the soap.

The system comprises both hardware and software components. The hardware includes the Arduino Uno R3, ultrasonic sensor, relay module, mini DC pump, a 9V lithium battery, and other supporting components. Meanwhile, the software consists of an Arduino program used to read distance data from the sensor and control the pump via the relay module.

Prior to physical implementation, the circuitry and program were simulated using the Wokwi platform. This step was taken to ensure that the component interconnections and program logic functioned as intended.

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Hardware Design

The hardware design involves connecting an Arduino Uno R3 with an ultrasonic sensor, a relay module, and a mini DC pump. The ultrasonic sensor is used to detect the presence of a hand, while the Arduino Uno R3 processes the sensor data and issues commands to the relay module. The relay then controls the on/off state of the mini DC pump.

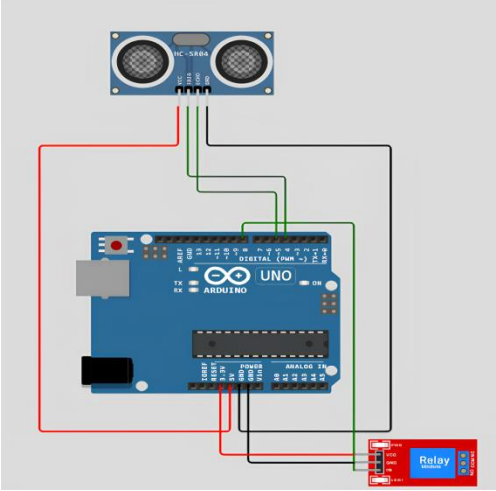


Figure 1. System Circuit Design

Based on the image, the ultrasonic sensor detects the presence of a hand by measuring the object's distance. The Arduino Uno R3 receives data from the ultrasonic sensor and processes it according to the programmed instructions. The relay module receives commands from the Arduino Uno R3 to activate or deactivate the pump. The mini DC pump draws up and dispenses liquid soap when the relay is activated.

Component Integration

Once the design phase was complete, all components were assembled according to the established schematic. Integration involved ensuring that every component was correctly connected so that the device would operate in accordance with the system workflow.

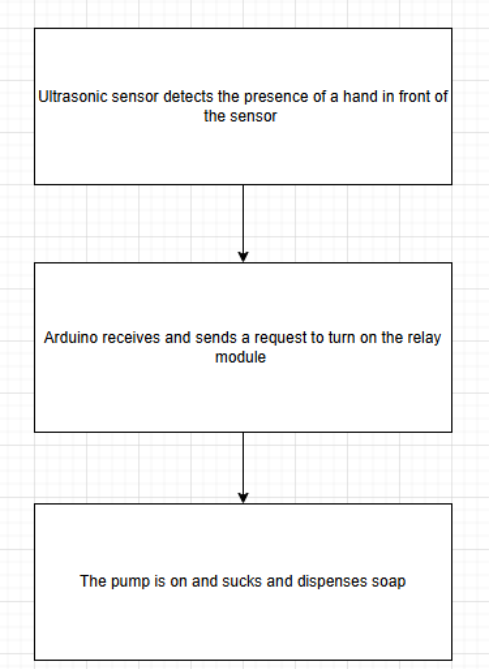


Figure 2. Integration Workflow

The device's workflow consists of several stages. First, an ultrasonic sensor detects the presence of a hand in front of it. Next, the Arduino Uno R3 receives and processes distance data from the sensor. If the hand is within the predetermined range, the Arduino commands the relay module to activate. The relay then connects the power source to the mini DC pump, causing it to operate and dispense soap. Once the dispensing period ends, the relay returns to its inactive state, and the pump stops running.

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Implementation Result

During the implementation phase, all the designed components were assembled into a single, integrated automatic hand soap dispenser unit. The primary components used included an Arduino Uno R3, an ultrasonic sensor, a relay module, a mini DC pump, a 9V lithium battery, a soap reservoir, tubing, and jumper wires.

Assembly was carried out with careful attention to the positioning of the ultrasonic sensor to ensure it could effectively detect the user's hands. The mini DC pump was connected to the soap reservoir via tubing, allowing soap to flow to the outlet. The Arduino Uno R3 served as the main controller, while the relay was used to regulate the pump's operation.



Figure 3. Appearance of the Automatic Hand Soap Dispenser

Based on the implementation results, all components were successfully integrated, and the device operates automatically. When a hand is placed within the detection area, the ultrasonic sensor measures the distance, and the Arduino Uno R3 issues a command to activate the pump via a relay. Consequently, users can dispense soap without directly touching the container.

Arduino Uno R3 Program

Programming is performed using the Arduino IDE. The program is designed to manage the ultrasonic sensor readings and control a mini DC pump via a relay module. It utilizes a specific distance threshold as the condition for activating the pump.

In this system, the ultrasonic sensor is configured to detect a hand at a distance of 10 cm or less. The distance data obtained is processed by an Arduino Uno R3. When the distance meets the specified condition, the Arduino activates the relay, causing the mini DC pump to dispense soap. Once the dispensing duration concludes, the pump is turned off.



Figure 4. Arduino Uno R3 Program

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Once the program is created, it is uploaded to the Arduino Uno R3 using the Arduino IDE. The successfully uploaded program is then tested with the hardware circuitry to ensure that the sensors, relays, and pumps operate according to the designed logic.

Ultrasonic Sensor Test Results

Ultrasonic sensor testing was conducted to evaluate the sensor's ability to detect the presence of a hand based on distance. Sensor readings were displayed via the Serial Monitor in the Arduino IDE, allowing the object's distance to be monitored throughout the testing process.

The test results demonstrated that the ultrasonic sensor could measure changes in object distance in centimeters. When a hand was positioned at a distance of 10 cm or less, the Arduino triggered the relay, activating the mini DC pump. Conversely, when no hand was present in the detection area or the distance exceeded 10 cm, the relay remained inactive, and the pump did not operate.

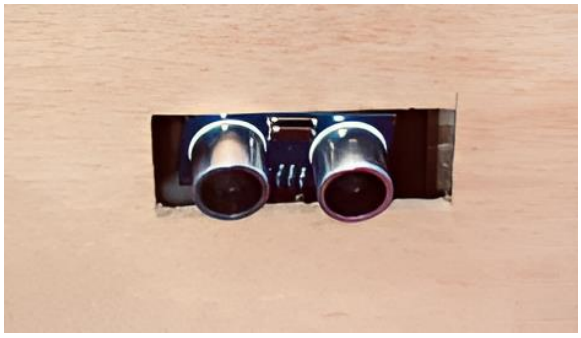


Figure 5. Ultrasonic Sensor Testing

Test results indicate that the ultrasonic sensor can be used to detect the presence of a hand in an automatic hand-washing device. The sensor's response to changes in distance can also serve as a basis for automatic pump control.

Table 1. Ultrasonic Sensor Detection Test

No.	Distance (cm)	Sensor Condition	Status
1.	3	Normal	Detected
2.	4	Normal	Detected
3.	6	Normal	Detected
4.	8	Normal	Detected
5.	10	Normal	Detected
6.	>12	Normal	Not Detected

Based on the test results, the sensor is capable of detecting the presence of a hand at distances of 3, 4, 6, 8, and 10 cm. However, at distances greater than 12 cm, the sensor no longer detects the object. Thus, the sensor has an effective detection range of 3–10 cm under the tested conditions.

Device Testing Results

Testing was conducted to determine whether all components functioned in an integrated manner according to the design. The tests evaluated the sensor's ability to detect a hand, the Arduino Uno R3's response, the operation of the relay module, and the mini DC pump's ability to dispense soap.

The test results showed that when a hand was positioned within the predetermined range, the ultrasonic sensor transmitted data to the Arduino Uno R3. The Arduino then activated the relay, causing the mini DC pump to turn on and dispense soap. Once the programmed duration elapsed, the pump stopped, ensuring that soap dispensing did not continue indefinitely.

Based on these tests, the device successfully performed its intended primary functions: detecting the presence of a hand and automatically dispensing soap. The system also eliminates the need for users to touch the soap container directly, making the device more practical and hygienic to use.

Table 2. Automatic Hand Soap Dispenser Function Test

No	System Condition	Sensor Response	Pump Status	Description
1.	Hand kept in place	Detected	On	Normal
2.	Hand removed	Not detected	Off	Normal
3.	There is no hand	Not detected	Off	Normal

Based on the functional test results, the pump activates when the sensor detects the presence of a hand within the detection range. When the hand is moved away from the area, the sensor no longer detects an object, causing the pump to stop operating. In the absence of an object, the pump remains off. These test results demonstrate that the sensor and

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pump are functioning according to the programmed system logic.

DISCUSSION

The test results demonstrate that the automatic hand soap dispenser prototype can detect the presence of a hand and control the soap dispensing mechanism according to the programmed conditions. The ultrasonic sensor detected the hand at distances of 3, 4, 6, 8, and 10 cm, whereas the object was not detected at distances greater than 12 cm. These findings indicate that the sensor operated within the intended detection range under the tested conditions. The results are comparable to those reported by Syahputra et al. (2021), who developed an automatic hand sanitizer dispenser using an ultrasonic sensor, an Arduino Uno, and a mini DC pump. Their system activated the pump when a hand was detected within the specified distance, demonstrating the applicability of ultrasonic sensing for contactless liquid dispensing.

The functional testing also demonstrated that the integration of the ultrasonic sensor, Arduino Uno R3, relay module, and mini DC pump operated according to the designed control logic. When a hand was detected within the predefined range, the Arduino Uno R3 processed the sensor readings and activated the relay, allowing electrical power to reach the pump. Consequently, the pump dispensed liquid soap. When the hand was removed from the detection area or no hand was present, the pump remained inactive. This operating mechanism is consistent with the automatic handwashing system developed by Purba and Roza (2022), which used an Arduino Uno R3, proximity sensors, relays, and DC pumps to control liquid dispensing automatically. These similarities demonstrate that sensor-based microcontroller systems can be applied to automate the dispensing process using different types of liquid.

The sensor testing further indicates that the selected detection threshold of 10 cm was appropriate for activating the dispenser within the intended operating area. By defining a specific distance threshold in the Arduino program, the system can distinguish between the presence and absence of a hand within its detection range. However, the test results do not establish the sensor's accuracy percentage or its performance under all environmental conditions. Further testing involving repeated measurements at each distance would be required to evaluate detection accuracy and response consistency more comprehensively.

The prototype's operation also demonstrates the practical application of an automated dispensing mechanism to reduce the need for direct physical contact with the soap container. Users can obtain soap by positioning their hands in front of the sensor without manually pressing or touching the dispenser. A similar objective was reported by Agustanti et al. (2021), who developed a touchless hand sanitizer dispenser using an Arduino Uno and an HC-SR04 ultrasonic sensor, with a reported maximum detection distance of 10 cm. Although their device dispensed hand sanitizer rather than liquid soap, the underlying principle of detecting a nearby object and activating a dispensing mechanism is comparable to that of the present study.

Overall, the results show that the prototype successfully performed its primary functions: detecting the presence of a hand and activating or deactivating the soap pump according to the programmed conditions. The use of an Arduino Uno R3 as the main controller, an ultrasonic sensor as the input component, a relay module as the switching mechanism, and a mini DC pump as the actuator provided a straightforward approach to developing an automatic hand soap dispenser. Nevertheless, the current evaluation was limited to sensor detection and functional operation. Further research could examine the volume of soap dispensed per activation, the repeatability of dispensing, the response time, and the system's reliability during extended use. Such evaluations would provide a more comprehensive assessment of the prototype's performance and practical suitability for hand hygiene applications.

CONCLUSION

Based on the research conducted, it can be concluded that an automatic hand soap dispenser utilizing an Arduino Uno R3 and an ultrasonic sensor has been successfully designed and implemented. The device is capable of detecting the presence of a hand within a predetermined range and automatically activating a mini DC pump via a relay module, thereby reducing direct contact and facilitating the soap dispensing process.

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