Design and Development of a Smart Ultrasonic-Based Touchless Alcohol Dispenser

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ABSTRACT

This study presents the design and development of a Smart Ultrasonic Alcohol Dispenser that provides a touchless and automated solution for hand sanitation. The system utilizes an ultrasonic sensor integrated with an Arduino UNO microcontroller and a pump mechanism to detect the presence of a user's hand and dispense a controlled amount of alcohol without physical contact. The ultrasonic sensor operates based on distance measurement, allowing accurate hand detection within a predefined range and triggering the dispensing process only when necessary.

A descriptive and experimental research design was employed in the development of the system. The prototype was assembled and tested through multiple trials to evaluate hand detection accuracy, response time, consistency of alcohol dispensing, and occurrence of false triggers. Results showed that the dispenser responded quickly upon hand detection and consistently released a fixed volume of alcohol per activation. The ultrasonic sensor performed reliably under different lighting conditions, and the controlled dispensing logic effectively prevented over dispensing and minimized sanitizer waste.

The study demonstrates that sensor based automation can significantly improve hygiene practices by reducing cross contamination and ensuring consistent sanitizer use. The Smart Ultrasonic Alcohol Dispenser offers a practical, low cost, and hygienic alternative to manual dispensers and is suitable for use in homes, schools, offices, and other public areas. Future enhancements may include adding a low alcohol level indicator, improving enclosure design, and conducting long term testing in real world environments.

Keywords: Smart Ultrasonic Alcohol Dispenser, Ultrasonic Sensor, Touchless System, Arduino UNO, Automated Sanitizer, Sensor Based Automation

INTRODUCTION

Maintaining proper hand hygiene has become increasingly important, especially in public areas where people frequently interact with shared surfaces. Traditional manual alcohol dispensers often require users to press a pump, which can lead to the accumulation of germs and increase the risk of cross-contamination. As awareness of cleanliness and disease prevention grows, there is a strong need for touch-free technologies that help promote safer and more efficient hygiene practices.

Advancements in sensor technology have allowed everyday devices to become smarter and more convenient. Among these technologies, ultrasonic sensors are widely used for detecting the presence of objects by emitting sound waves and measuring their reflection. This makes them highly effective for hands-free systems such as automatic dispensers. By integrating an ultrasonic sensor with a microcontroller and a pumping mechanism, an alcohol dispenser can automatically release sanitizer when a hand is detected, eliminating the need for physical contact.

The Smart Ultrasonic Alcohol Dispenser aims to provide a safe, accessible, and cost-effective solution that encourages regular sanitization. Through its touchless operation, the device reduces contamination risks, promotes proper hygiene, and dispenses a consistent amount of sanitizer to avoid waste. Its simple yet functional

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design allows it to be used in various settings such as schools, offices, and community facilities. By offering a practical hygiene tool, the project contributes to creating safer environments and supporting good health practices.

Background Of the Study

In recent years, especially with global public health concerns such as those arising from pandemics, maintaining hand hygiene has become critically important to reduce the transmission of viruses and bacteria. Traditional hand sanitizer bottles, which require manual pressing or squeezing, carry the risk of cross-contamination: users must touch the dispenser, possibly transferring germs from prior users' hands.

To address this, automatic (touchless) dispenser systems have been developed. Among different sensing technologies, the Ultrasonic sensor commonly using modules like HC-SR04 Ultrasonic Sensor is widely used to detect the presence of a hand under the dispenser by measuring the distance between the sensor and the object (hand) via sound waves.

In an ultrasonic-based design, the sensor continuously emits high-frequency acoustic waves; when a hand (or object) is placed within a defined range, the waves reflect back and the sensor calculates the time-of-flight to determine distance. Once the distance is below a threshold, the system triggers a pump to dispense sanitizer.

Automatic sanitizing devices not only eliminate the need to physically press a dispenser (reducing contact and potential contamination), but they also help ensure a consistent amount of sanitizer is dispensed, which can improve hygiene practices and optimize sanitizer usage.

REVIEW OF RELEVANT THEORY, STUDIES, AND LITERATURE

This chapter presents a review of related theories, studies, and literature that support the design and development of the Smart Ultrasonic-Based Touchless Alcohol Dispenser. The review is organized into three sections: relevant theories, related local and foreign studies, and related literature. These provide the theoretical foundation and contextual background for the proposed system.

Relevant Theories

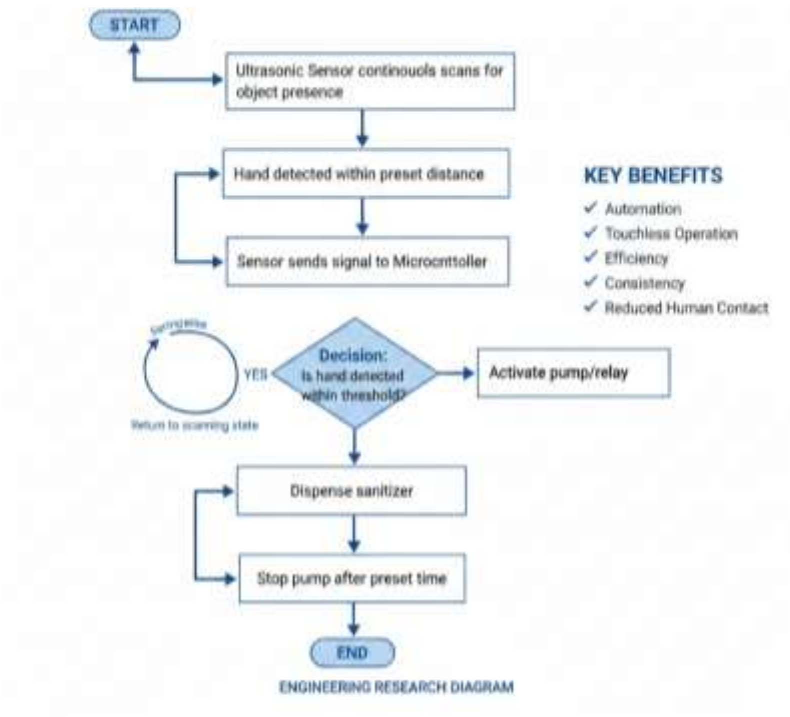

Figure 1. Sensor-Based Automation Theory

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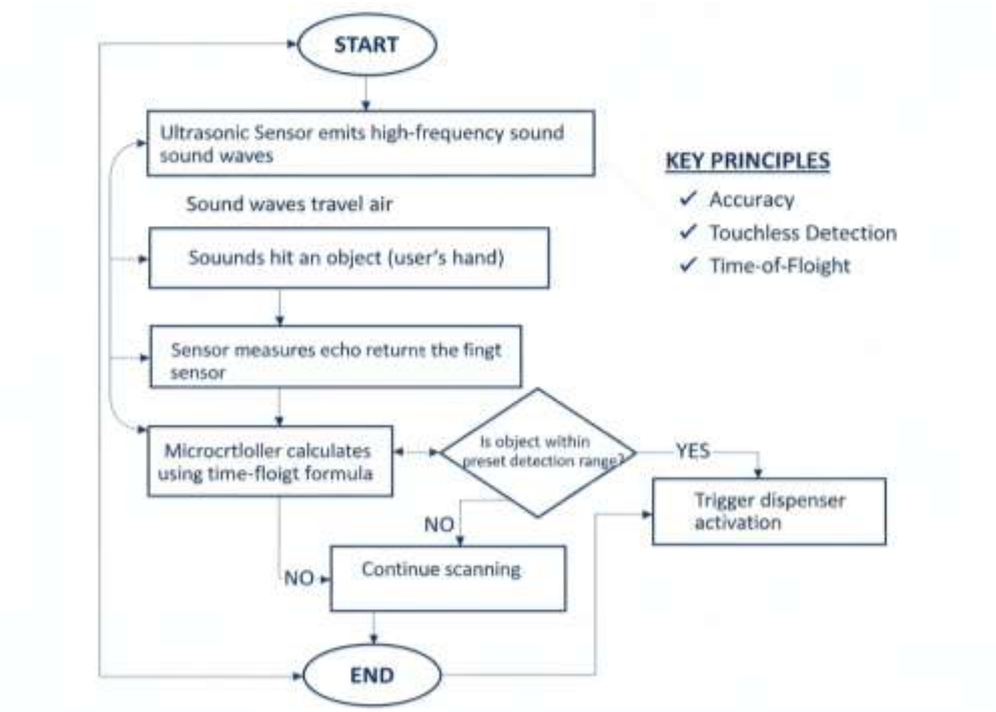
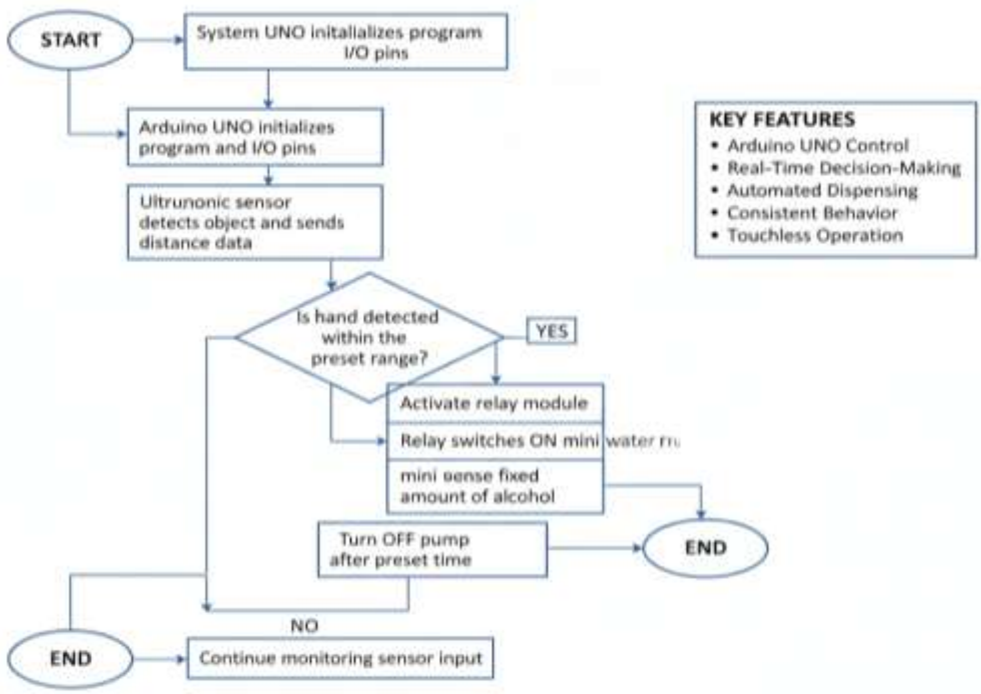
Sensor-based automation refers to the use of sensors and control systems to automatically perform tasks without human intervention. In automated hygiene systems, sensors detect user presence and trigger predefined actions, such as dispensing sanitizer. This theory supports the concept that automating repetitive tasks improves efficiency, consistency, and safety. In the context of this study, ultrasonic sensing combined with microcontroller control enables reliable touchless operation and reduces human contact with shared surfaces.

Figure 2. Ultrasonic Distance Measurement Theory



Ultrasonic sensors operate based on the principle of sound wave reflection. The sensor emits high-frequency sound waves and measures the time taken for the waves to return after hitting an object. The distance is calculated using the time-of-flight principle. This theory is fundamental to the system's hand detection mechanism, as it allows accurate measurement of the distance between the sensor and the user's hand, ensuring precise activation of the dispenser only when needed.

Figure 3. Microcontroller-Based Control Systems



Microcontrollers act as the central processing units in embedded systems, executing programmed instructions based on input signals from sensors. The Arduino UNO microcontroller follows this theory by processing ultrasonic sensor data and controlling the pump through a relay module. This enables real-time decision-making and consistent system behavior, which is essential for automated dispensing applications.

Related Studies

Dianta, Setiawan, and Seubelan (2023) developed an automated hand sanitizer dispensing system using an Arduino platform for an elementary school environment. Their study demonstrated that touchless dispensers significantly reduce cross-contamination and improve hygiene compliance among users. The findings support the present study's goal of promoting safer hand hygiene through automation.

Martins et al. (2023) designed an automated antiseptic dispenser using Arduino technology. Their results showed that automated systems provide consistent sanitizer output and reduce waste compared to manual dispensers. This study reinforces the importance of controlled dispensing mechanisms, which is also implemented in the Smart Ultrasonic Alcohol Dispenser.

Emmanuel, Sunmonu, and Ogunlana (2024) designed and implemented an automatic water and hand sanitizer dispensing system using ultrasonic sensors. Their research emphasized the reliability of ultrasonic sensors in detecting hand presence under various environmental conditions. This supports the sensor choice in the current study and confirms its suitability for touchless sanitation systems.

Herzer et al. (2024) conducted a multicenter assessment of hand rub dispensers in healthcare facilities and found that touchless dispensers contribute to improved infection control. Their study highlights the importance of accessibility and automation in hygiene systems, further validating the relevance of developing automated sanitizer dispensers for public use.

Related Literature

CWS Hygiene (n.d.) discussed the advantages of automatic disinfection dispensers, emphasizing their role in reducing physical contact, improving hygiene compliance, and ensuring consistent sanitizer delivery. These benefits align with the objectives of the Smart Ultrasonic Alcohol Dispenser.

Germstar UK (n.d.) highlighted that automatic hand sanitizer dispensers improve user convenience and encourage frequent sanitizer use, particularly in high-traffic areas. This literature supports the study's focus on enhancing user convenience and promoting better hygiene behavior.

Robo Dork (2020) demonstrated the use of Arduino and ultrasonic sensors in building an automatic hand sanitizer dispenser. The tutorial provided practical insights into system integration, sensor calibration, and pump control. This resource served as a technical reference for the development of the prototype used in the present study.

Synthesis of the Review

The reviewed theories, studies, and literature collectively emphasize the effectiveness of sensor-based automation, ultrasonic sensing, and microcontroller control in developing touchless hygiene systems. Previous studies confirm that automated dispensers reduce cross-contamination, improve consistency, and encourage proper hand hygiene. These findings strongly support the design and implementation of the Smart Ultrasonic-Based Touchless Alcohol Dispenser and justify its relevance as a practical, low-cost, and hygienic solution for public and private environments.

Importance And Relevance Of The Study

The Smart Ultrasonic Alcohol Dispenser is important because it promotes safer hygiene practices by eliminating the need for physical contact with traditional manual pumps. Touching shared surfaces increases the risk of germ transmission, especially in public spaces. According to Dianta, Setiawan, and Seubelan (2023), automatic sanitizer dispensers significantly reduce cross-contamination since users no longer have to press or touch contaminated surfaces. Similarly, Herzer et al. (2024) emphasize that improving accessibility to touchless dispensers directly contributes to better infection control in community and healthcare environments.

This study is also relevant because it ensures efficient and consistent sanitizer use through sensor-based automation. Manual dispensers often lead to either insufficient or excessive sanitizer output, resulting in poor hygiene or unnecessary waste. Martins, Faggian, Rocha, and Dal Pai (2023) highlight that automated dispensing systems provide a controlled, uniform amount of sanitizer, improving both hygiene effectiveness and resource management. Furthermore, Emmanuel, Sunmonu, and Ogunlana (2024) demonstrate that ultrasonic-based systems increase user convenience and encourage more frequent hand sanitization, making them valuable in schools, offices, and other public spaces.

Problem Statement

Many public areas and households continue to face hand hygiene challenges due to the reliance on manual sanitizer dispensers. These dispensers require users to physically touch the pump, which increases the risk of germ transmission and cross-contamination, particularly in high-traffic or poorly monitored environments. In addition, manual dispensing often leads to inconsistent sanitizer output, resulting in either insufficient amounts that reduce hygiene effectiveness or excessive amounts that cause unnecessary waste. Because of the inconvenience and lack of control associated with manual dispensers, compliance with proper hand hygiene practices in public spaces, offices, and schools is often low. To address these concerns, this project focuses on the development of a motion-activated, ultrasonic-based alcohol dispenser that promotes touchless operation, consistent sanitizer dispensing, and improved convenience for users.

General Objective

To design and develop a Smart Ultrasonic Alcohol Dispenser that automatically dispenses a controlled amount of sanitizer when a user places their hand under the device, thereby promoting proper hand hygiene, reducing cross-contamination, and improving convenience in public and private spaces.

Specific Objectives

This study aims to integrate an ultrasonic sensor with a microcontroller to accurately detect the presence of a user's hand and trigger the dispensing process. It also seeks to design and implement a pumping mechanism capable of releasing a consistent volume of sanitizer upon hand detection. In addition, the study focuses on developing a prototype housing or enclosure that ensures proper sensor placement and promotes user-friendly operation. The system's accuracy and reliability are tested under different conditions to ensure that sanitizer is dispensed only when necessary. Lastly, the study evaluates the effectiveness and user convenience of the proposed dispenser in comparison with traditional manual sanitizer bottles.

Scope And Limitations

This project focuses on the design and implementation of a Smart Ultrasonic Alcohol Dispenser that automatically dispenses sanitizer upon detecting a user's hand. The system is developed in a simple and practical manner to ensure suitability for use in homes, schools, offices, and other public areas. The scope of the study includes assembling the device, calibrating the ultrasonic sensor, and testing the dispensing mechanism to ensure consistent and reliable performance. However, the project has certain limitations. Advanced features such as low-sanitizer level alerts and remote monitoring are not included in the system. The accuracy of the ultrasonic sensor may also be affected by environmental conditions, such as surrounding objects or temperature variations. Additionally, the device requires a continuous power supply and may need recalibration when used in different settings.

METHODOLOGY

This study employed a **descriptive and experimental research design** to develop and evaluate the Smart Ultrasonic-Based Touchless Alcohol Dispenser. The descriptive approach was used to present the system architecture, component functions, and operational logic of the device, while the experimental approach was applied to assess its performance in terms of hand detection accuracy, response time, dispensing consistency, and reliability.

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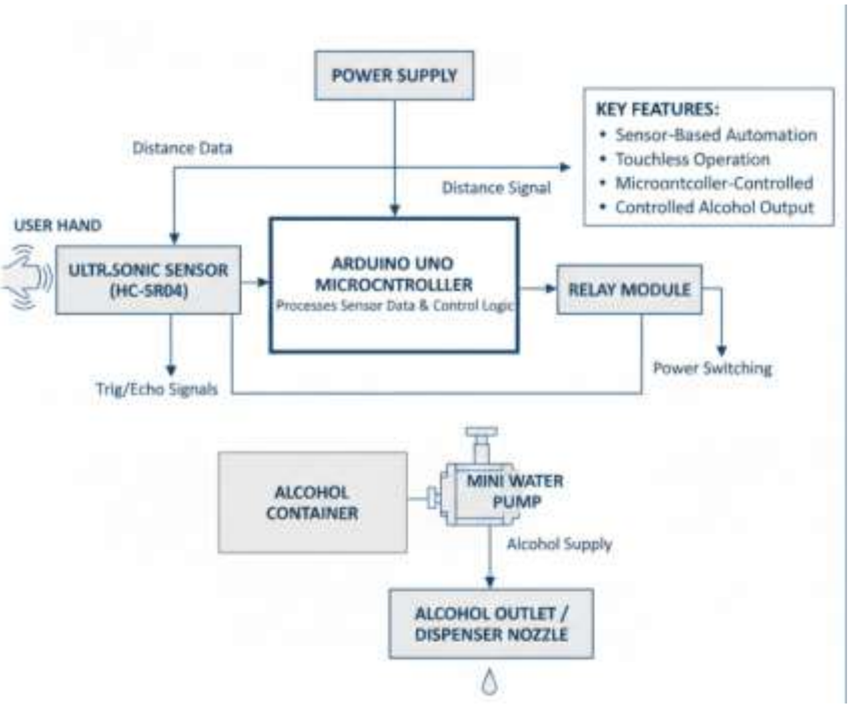
Research Design

The descriptive research design focused on documenting the structure, components, and functionality of the Smart Ultrasonic Alcohol Dispenser. The experimental research design involved controlled testing of the prototype to evaluate how effectively the ultrasonic sensor detects hand presence and how consistently the system dispenses alcohol. This combined approach ensured that both the design quality and operational performance of the system were thoroughly examined.

Figure 4. Block Diagram



Materials and Components

The system was built using an Arduino UNO microcontroller as the main processing unit. An ultrasonic sensor was used to detect the presence of a user's hand through distance measurement. A single-channel relay module acted as an electronic switch to control the mini water pump, which dispensed the alcohol. Additional components included connecting wires, a breadboard for initial testing, a container and tubing for alcohol storage and flow, and an Arduino cable for programming and power supply. All components were selected based on availability, affordability, and suitability for automated dispensing systems.

Components List and Functions

Table 1. The Smart Ultrasonic Alcohol Dispenser utilized the following components:

ARDUINO UNO	- Serves as the main microcontroller that processes sensor data and controls the operation of the dispenser.
SINGLECHANNEL RELAY	- Acts as an electronic switch that allows the Arduino to safely control the mini water pump.
ULTRASONIC SENSOR	- Detects the presence of a user's hand by measuring the distance using ultrasonic sound waves.
MINI WATER PUMP	- Dispenses alcohol when activated by the system.
BREADBOARD	- Used to temporarily connect and test electronic components without soldering.

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CONNECTING WIRES	- Provide electrical connections between the Arduino, sensor, relay, and pump.
CONTAINER AND TUBING	- Holds the alcohol and directs it from the pump to the dispensing outlet.
ARDUINO CABLE	- Used to upload the program from the computer to the Arduino UNO and provide power during testing.

Component selection was based on availability, cost-effectiveness, and suitability for automated dispensing systems. Prototyping tools such as breadboards were excluded from the list, as only permanent components were considered.

Figure 5. Flow Chart

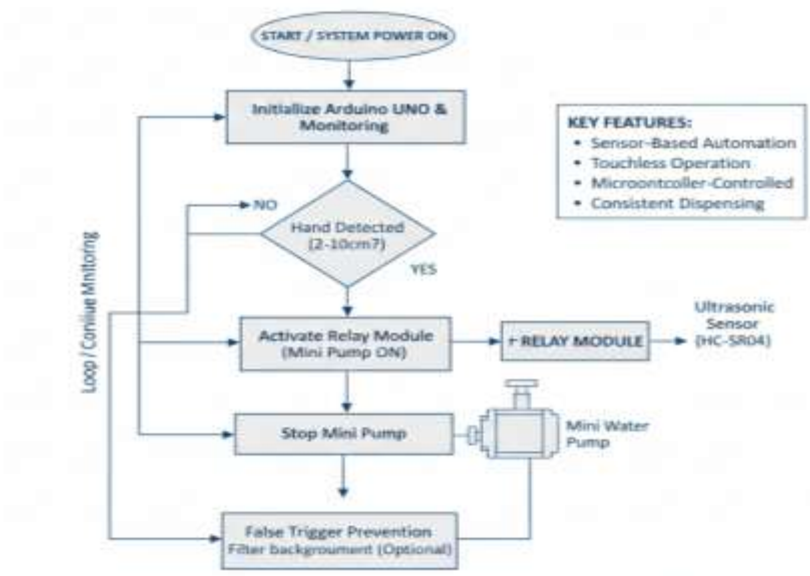

Figure 3. Smart Ultrasonic Alcohol Dispenser Code


```
C > Users > 007 > ultrasonic sensor.cpp > loop()
const int trigPin = 2;
const int echoPin = 3;
const int relayPin = 4;

const int distanceThreshold = 10;
bool hasPumped = false;

void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(relayPin, OUTPUT);

  digitalWrite(relayPin, HIGH);
  Serial.begin(9600);
}

void loop() {
  long duration;
  int distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);-
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  duration = pulseIn(echoPin, HIGH);
  distance = duration * 0.034 / 2;

  if (distance > 0 && distance <= distanceThreshold) {
```

```
C: > Users > 007 > ultrasonic sensor.cpp > loop()
  int distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);-
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  duration = pulseIn(echoPin, HIGH);
  distance = duration * 0.034 / 2;

  if (distance > 0 && distance <= distanceThreshold) {

    if (hasPumped == false) {
      Serial.println("Dispensing Alcohol...");
      digitalWrite(relayPin, LOW);
      delay(1000);
      digitalWrite(relayPin, HIGH);

      hasPumped = true;
    }
  } else {
    hasPumped = false;
  }

  delay(100);
}
```

The system operates using a touchless detection mechanism. The ultrasonic sensor, positioned above the dispensing outlet, continuously measured the distance between the sensor and any object below. The Arduino UNO processed the distance data.

When a hand was detected within a predefined range, the Arduino sent a signal to the motor driver to activate the centrifugal pump. The pump dispensed a controlled amount of alcohol and automatically stopped after a short interval to prevent over-dispensing and minimize waste.

Figure 4. Connection Diagram

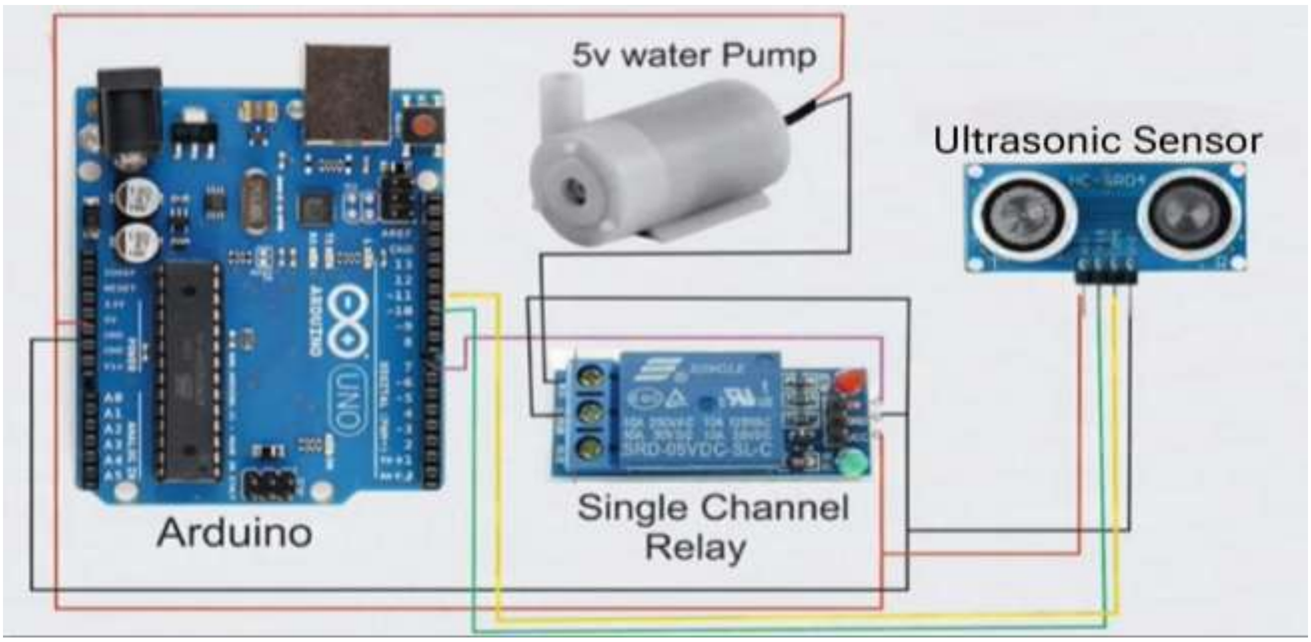

Figure 5. Smart Ultrasonic Alcohol Dispenser Actual Photo

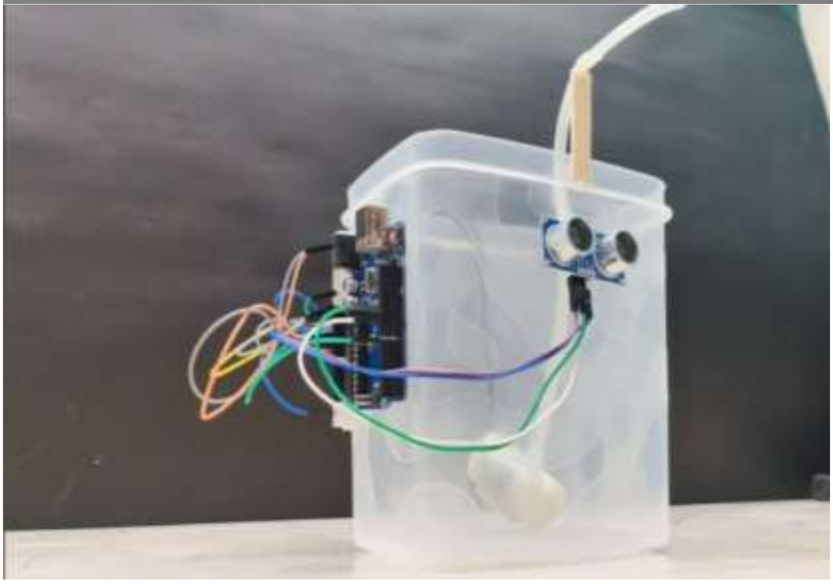

Figure 6. Solidwork Assembly

System Development Procedure

The development of the system followed a step-by-step process. First, all required components were identified and prepared based on the system requirements. Next, the circuit connections between the Arduino UNO, ultrasonic sensor, relay module, and pump were assembled. The Arduino was then programmed to process sensor readings and control pump activation. Initial testing was conducted without alcohol to verify proper hand detection and pump response. After successful dry testing, the pump was connected to the alcohol container and tubing. Final testing involved adjusting the sensor range and pump activation time to achieve consistent dispensing.

Data Gathering Procedure

Data were collected through repeated experimental trials of the prototype. The system was tested multiple times by placing a hand within the detection range of the ultrasonic sensor. The following parameters were observed and recorded: hand detection accuracy, response time between detection and pump activation, consistency of alcohol dispensed per activation, and the occurrence of false triggers. Ten trials were conducted for each test condition to ensure reliability and consistency of results.

Data Analysis Method

The collected data were analyzed using descriptive analysis. Observations from each test were summarized to evaluate whether the system met the research objectives. The effectiveness of the system was assessed based on detection accuracy, reliability, and proper dispensing behavior.

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The results were interpreted to determine the overall performance and practicality of the Smart Ultrasonic Alcohol Dispenser.

RESULTS AND DISCUSSION

The development and testing of the Smart Ultrasonic Alcohol Dispenser yielded a functional prototype that successfully automated the hand sanitization process. Based on the system architecture, the HC-SR04 ultrasonic sensor was positioned to create a detection zone between 2 cm and 10 cm. When a hand entered this range, the Arduino UNO processed the signal and activated the centrifugal pump. Unlike the continuous flow seen in typical automated water taps, which remain active as long as an object is detected, this system was specifically programmed to deliver approximately two distinct pumps of alcohol. This controlled dispensing method ensures that the user receives an adequate amount of sanitizer—roughly 2 to 3 ml—while strictly preventing the fluid waste that occurs with continuous-flow systems or manual pumps.

During the experimental phase, the prototype demonstrated high reliability and precision. Testing showed that the response time between hand detection and pump activation was near-instantaneous, ensuring a seamless user experience. The use of ultrasonic technology proved superior to basic infrared sensors because it maintained consistent detection regardless of lighting conditions or skin tone, which are common points of failure in optical sensors. While the reference water tap system provides a steady stream for washing, the modification to a "2-pump" cycle for this alcohol dispenser proved more effective for sanitization purposes. This logic ensures that even if a user leaves their hand under the sensor, the device will not deplete the alcohol reservoir, addressing the problem of resource management highlighted in the study's objectives.

The results further indicated that the housing and sensor alignment played a critical role in the system’s effectiveness. By securing the sensor at a specific downward angle, the occurrence of false triggers from background movement was minimized. The pump mechanism delivered a consistent volume of alcohol across multiple trials, proving that automation eliminates the inconsistency of manual pressing. Overall, the findings confirm that the Smart Ultrasonic Alcohol Dispenser is a viable, hygienic, and resource-efficient alternative to traditional dispensers. It effectively reduces the risk of cross-contamination by providing a completely touchless interface while encouraging better hygiene through its ease of use and controlled dispensing logic.

CONCLUSION AND RECOMMENDATIONS

The Smart Ultrasonic Alcohol Dispenser was successfully designed, developed, and tested as a touchless and automated hand sanitation system. The device utilized an ultrasonic sensor integrated with an Arduino UNO and a pump mechanism to detect the presence of a user’s hand and dispense a fixed amount of alcohol without physical contact. Based on the testing results, the system demonstrated reliable performance and fast response once a hand was detected within the specified distance range, ensuring efficient and hygienic operation.

The ultrasonic sensor proved to be effective for hand detection since it operated consistently under different lighting conditions and did not depend on skin color or brightness. The programmed dispensing logic, which limited alcohol release to a specific number of pump activations, helped prevent excessive use and reduced sanitizer waste. Compared to manual dispensers, the automated system provided a more consistent alcohol output and minimized the risk of cross contamination. These results confirm that the system met the objectives of the study by offering a practical, affordable, and hygienic solution suitable for homes, schools, offices, and other public areas. The findings also highlight that sensor based automation can significantly improve hand hygiene practices and support safer environments.

To further enhance the system’s functionality and readiness for real world application, several improvements are recommended. Adding a low alcohol level indicator would allow users or maintenance personnel to easily monitor sanitizer levels and ensure continuous operation. Future development may also include testing other types of sensors or combining multiple sensors to improve detection accuracy and reduce false activations. Enhancing the enclosure design is recommended to increase durability and ensure long term use in public settings.

Additionally, extended testing in real world environments such as schools, offices, and healthcare facilities is suggested to evaluate long term performance, reliability, and user acceptance. Improving power efficiency through the use of rechargeable batteries or low power components may also increase portability and reduce dependence on a constant power supply. Implementing these improvements can further strengthen the reliability, usability, and practicality of the Smart Ultrasonic Alcohol Dispenser and support its wider application in promoting proper hand hygiene.

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Janelle Olien A. Dela Cruz is a Bachelor of Science in Computer Engineering student at the Eulogio Amang Rodriguez Institute of Science and Technology (EARIST). Her interests focus on electronics, sensor integration, and system design. She contributed to the planning, development, and testing of the Smart Ultrasonic Alcohol Dispenser, applying her academic training to support the system's functionality and reliability.

Raana Factor is a Bachelor of Science in Computer Engineering student at the Eulogio Amang Rodriguez Institute of Science and Technology (EARIST). Her academic interests include automation systems, hardware interfacing, and basic embedded programming. She actively participated in the design, implementation, and evaluation of the project, contributing to the development of a hygienic and efficient touchless dispensing system.

Chriscian Reeve R. Falle is a Bachelor of Science in Computer Engineering student at the Eulogio Amang Rodriguez Institute of Science and Technology (EARIST).His areas of interest include microcontroller-based systems, electronics troubleshooting, and practical engineering applications. He was involved in system assembly, testing, and performance evaluation of the Smart Ultrasonic Alcohol Dispenser.

Engr. Meshelle N. Fabro is a Professional Computer Engineer with extensive academic and industry experience. She has worked with leading technology companies such as Hewlett-Packard (HP) and IBM, where she specialized in systems and enterprise solutions. She currently serves as a Part-time Instructor in the Computer Engineering Department of the Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST), where she is actively involved in training and mentoring future engineers. Her professional interests include computer systems, VLSI design, artificial intelligence, and emerging technologies in computing.