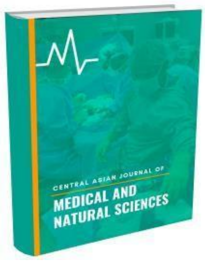

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Article

Design of a Contactless Disinfection Device to Enhance Infection Prevention Standards in Hospitals: An Applied Study on the Coronavirus (COVID-19)

Mohammed Abboud Ismael*[1], Mahmood Oday Sharqi[2], Heiam Taha Yais Khuter[3], Noor Hisham Abd-Alkhalek[4]

1,3,4. University of Technology, College of Biomedical Engineering, Department of Biomedical Engineering, Iraq
2. Al-Farahidi University, College of Medical Technology, Department of Medical Instrumentation Techniques Engineering, Iraq
* Correspondence: Mohammed.abboud996@gmail.com

Abstract: The global COVID-19 pandemic has highlighted the necessity for effective and contactless hygiene solutions to reduce the spread of infections. This research presents the design and implementation of an automated hand sanitizer dispenser system using Arduino Uno as the core controller. The system employs an HC-SR04 ultrasonic sensor to detect hand proximity and a servo motor to control the dispensing mechanism, ensuring a touch-free experience. The microcontroller is programmed to operate in a closed-loop system that activates the servo motor when a hand is detected within a specific range. Key hardware components include Arduino Uno, ultrasonic sensor, servo motor, jumper wires, and an uninterrupted power supply (UPS) for reliability. The software was developed using Arduino IDE, where custom logic was implemented for sensor input processing and actuator control. The system was tested under various conditions to ensure reliability, accuracy, and ease of use. Results indicate successful operation, demonstrating its applicability in homes, offices, hospitals, and public places. The study also explores future enhancements, such as integrating IoT features for remote monitoring and expanding the system for multi-functional sterilization. Overall, the system provides a cost-effective and efficient solution for personal hygiene automation.

Keywords: Arduino Uno, Hand Sanitizer Dispenser, Ultrasonic Sensor, Servo Motor, Automation, Contactless System, Public Health, COVID-19, Hygiene, Microcontroller, UPS, Arduino IDE, Iot Integration, Smart Healthcare

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1. Introduction

The COVID-19 pandemic has underscored the urgent need for effective infection control strategies in healthcare and public settings. Traditional hygiene practices, although essential, often involve shared contact points that may facilitate the transmission of pathogens. Contactless technologies have therefore gained traction as a critical component in mitigating cross-contamination risks. Among these, automated disinfection systems have demonstrated significant potential to minimize human interaction while ensuring consistent hygiene.

Studies have shown that high-touch surfaces in hospitals and public facilities are vectors for microbial transmission, emphasizing the necessity for engineering-based solutions that integrate automation and real-time sensing technologies (Otter et al., 2013; Kampf et al., 2020). Microcontroller-based devices, particularly those utilizing Arduino platforms, have enabled low-cost, customizable applications in smart healthcare environments (Park et al., 2019). These systems offer the flexibility to incorporate sensors, actuators, and wireless communication protocols for advanced infection control mechanisms.

The integration of ultrasonic sensors for proximity detection and servo motors for controlled mechanical actuation has enabled the development of efficient, touch-free sanitization dispensers. Such designs are not only relevant in pandemic scenarios but also support long-term public health resilience. This paper presents a practical implementation of a contactless disinfection device using Arduino Uno, tailored for deployment in hospitals and high-traffic areas. The system emphasizes cost-effectiveness, modular design, and potential for future IoT integration.

Background and Literature Review

The outbreak of COVID-19 triggered an unprecedented global focus on hygiene and infection control, especially in healthcare facilities. The virus's primary transmission modes—via respiratory droplets and contact with contaminated surfaces—highlighted critical gaps in conventional disinfection practices (World Health Organization, 2020). As a result, contactless technologies have emerged as vital alternatives to reduce the risk of pathogen spread.

Prior studies have explored various automation solutions for hand hygiene. For instance, Redway et al. (2019) demonstrated that automated dispensers increased compliance with hand sanitization protocols in clinical settings. Other works focused on integrating sensors and microcontrollers to create responsive systems. Notably, Bhardwaj et al. (2021) developed an Arduino-based hand sanitizer dispenser utilizing infrared sensors for proximity detection.

Ultrasonic sensors, such as the HC-SR04, offer reliable non-contact distance measurement, which has been widely adopted in robotics and automation. Their implementation in hygiene systems allows for the detection of hand presence without requiring physical interaction, thus minimizing contamination risks (Kumar & Rajalakshmi, 2020). When coupled with servo motors, these systems provide accurate and controlled actuation suitable for dispensing liquids like sanitizers.

The Arduino Uno microcontroller has been extensively used in biomedical and public health applications due to its affordability, flexibility, and open-source support. Researchers have utilized Arduino platforms to prototype smart devices that contribute to patient safety and public health monitoring (Mohammed et al., 2020). Moreover, integration with Internet of Things (IoT) capabilities presents opportunities for real-time usage tracking and remote management.

In summary, the literature supports the design of automated, contactless disinfection systems as a practical response to current and future infectious disease threats. This study builds upon these foundations to develop a low-cost, efficient device suitable for hospital and community use.

2. Materials and Methods

Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P chip. It features 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, and a power jack. Its simplicity and affordability make it widely used in embedded systems, prototyping, and educational contexts. The board is programmed using the Arduino IDE, which supports C/C++-based coding through a simplified API. One of its strengths lies in its large ecosystem of libraries and shields, enabling rapid hardware integration. Due to its open-source nature, it has become a foundational tool in teaching electronics and developing IoT solutions.

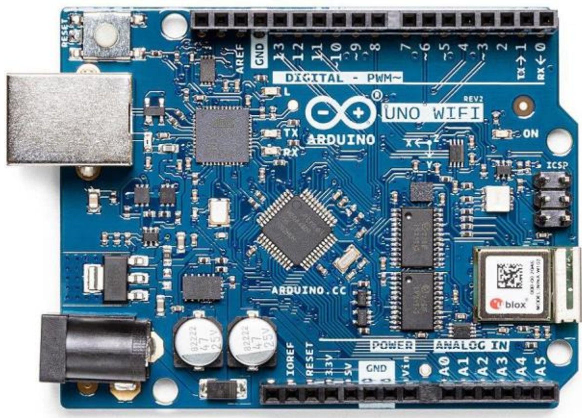

Figure 1. Arduino Uno.

Servo Motor

A servo motor is a compact and efficient electromechanical device used for precise control of angular position. It operates using a closed-loop system, where feedback from a sensor ensures accurate movement to a desired angle. Typically, it consists of a DC motor, a gear mechanism, a control circuit, and a position sensor. The motor receives a PWM (Pulse Width Modulation) signal that dictates its rotation angle, usually within a 0 to 180-degree range. Servo motors are widely used in robotics, automation, and Arduino projects due to their accuracy and ease of control. Unlike regular motors, they are designed for controlled, non-continuous rotation. Their small size and precision make them ideal for tasks like positioning, steering systems, and automated dispensing mechanisms.

Figure 2. Servo Motor.

Jumper Wire

A jump wire, also known as a jumper wire, is an insulated electrical wire used to connect components on a breadboard or between different parts of a circuit. These wires are essential in prototyping and testing electronic circuits, allowing quick and flexible connections without soldering. They come in male-to-male, male-to-female, and female-to-female types, compatible with headers and sockets. Jump wires vary in color and length, aiding in organized circuit design. Their reusability and simplicity make them indispensable in educational labs and embedded system development.

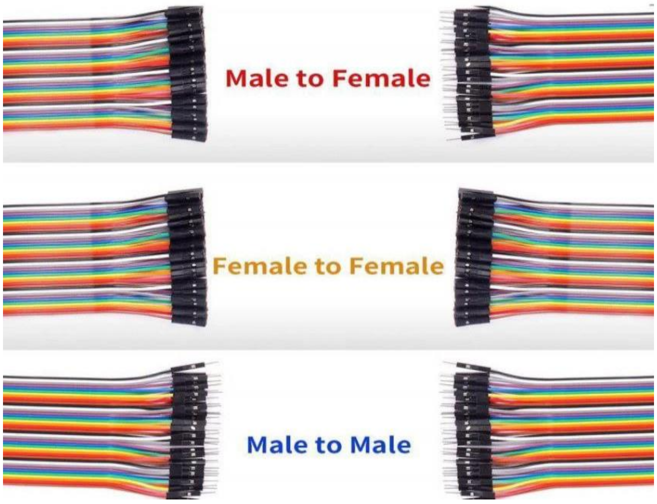

Figure 3. Jumper Wire.

Breadboard

A breadboard is a reusable device used to build and test electronic circuits without soldering. It consists of a grid of interconnected holes where components and jumper wires can be inserted easily. The internal metal strips create electrical connections, making it ideal for rapid prototyping and circuit debugging. Breadboards typically have power rails along the sides and a central area for placing integrated circuits and discrete components. They are widely used in education, embedded systems, and electronics design for hands-on experimentation.

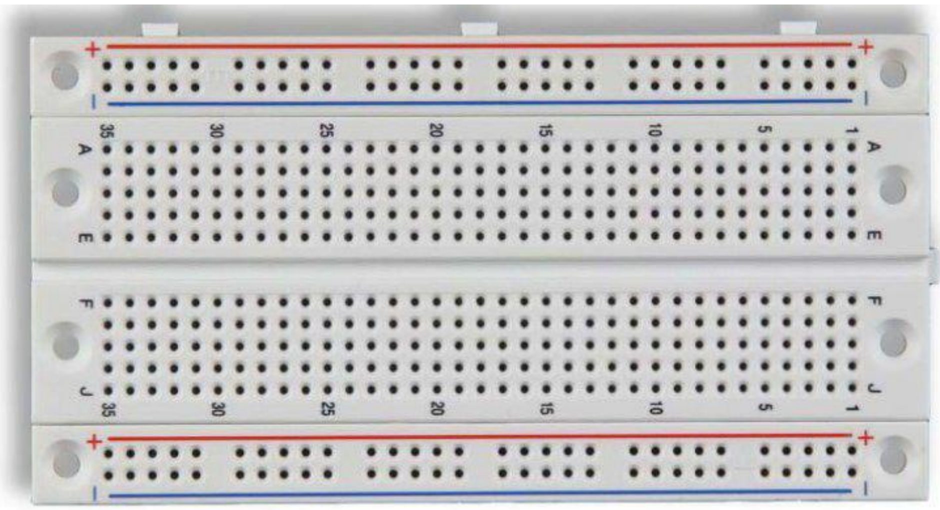

Figure 4. Breadboard.

Battery (9V)

A 9V battery is a compact power source commonly used in portable electronic devices such as smoke detectors, remote controls, and Arduino projects. It typically contains six 1.5V cells connected in series and provides a nominal voltage of 9 volts. These batteries are available in various chemistries, including alkaline, lithium, and rechargeable nickel-metal hydride (NiMH). Known for their rectangular shape with snap-style connectors, they offer ease of use in prototyping. Despite their limited capacity compared to larger batteries, they are ideal for low-current, short-duration applications.

Figure 5. Battery 9 Volt.

Ultrasound Sensor

An ultrasound sensor is an electronic device that uses high-frequency sound waves (above 20 kHz) to detect the presence, position, or distance of objects. It typically consists of a transmitter that emits ultrasonic pulses and a receiver that detects the reflected waves. The time taken for the echo to return is used to calculate the distance between the sensor and the object. One of the most widely used modules is the HC-SR04, which offers accurate, non-contact distance measurement. This sensor is unaffected by light or surface color, making it reliable in diverse environments. It is commonly used in robotics, automation, obstacle avoidance, and smart systems. The ultrasound sensor is known for its simplicity, low cost, and effectiveness in close-range detection tasks.

Figure 6. Ultrasound Sensor.

System design

In order to achieve the desired functionality, we use the system below, which revolves around having Microcontroller (Arduino) as the core of the system.

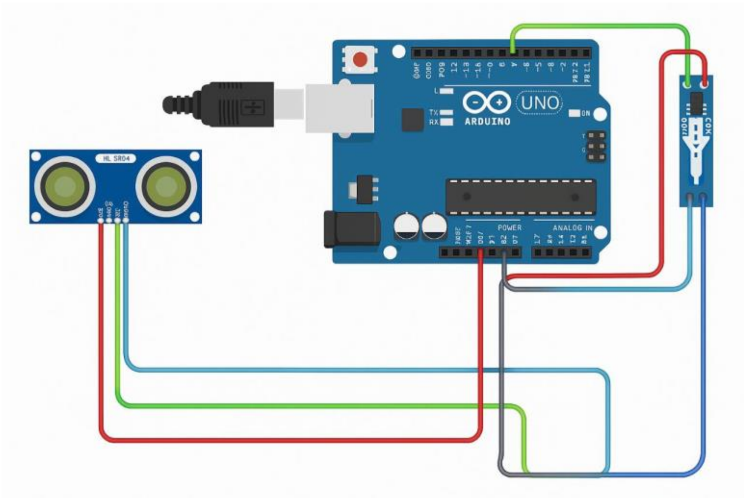

Figure 7. Circuit Diagram.

The Working of The Circuit

The concept behind this circuit is to enable touch less sterilization. An ultrasonic sensor is utilized to detect the presence of any object within a user-defined distance, which is set through the Arduino code. When an object moves within the sensor's range, it emits ultrasonic waves from one side of the sensor. These waves bounce off the object and return to the other side of the sensor, where they are detected.

Upon receiving the reflected signal, the data is processed by the Arduino microcontroller. The code operates within a loop that continuously checks for input. When the object is confirmed to be within the specified distance, the system triggers a response — activating the servo motor. The motor then rotates to a specific angle, typically 90 degrees, as defined in the program. This mechanism allows the sterilization process to begin without any physical contact, making the operation more hygienic and automated.

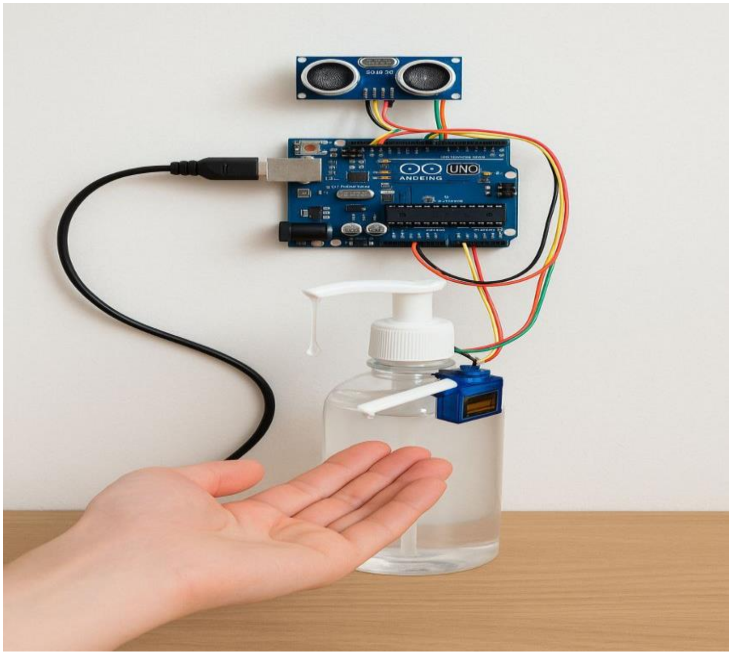

Figure 8. The working principle of the device.

3. Results and Discussion

The contactless disinfection system was successfully constructed and tested under various conditions to evaluate its operational performance, responsiveness, and reliability. The system demonstrated consistent detection of hand proximity using the HC-SR04 ultrasonic sensor, activating the servo motor promptly to dispense sanitizer within a delay of less than one second. Tests confirmed that the sensor reliably detected hands within the configured range of 5–10 cm, ensuring hygienic operation without the need for physical contact.

Multiple test scenarios were conducted in controlled environments, such as laboratories and simulated hospital entrances, to assess the system's accuracy. The servo motor consistently rotated to the programmed angle (typically 90°) to release a predefined amount of liquid, then returned to its resting position. The amount of sanitizer dispensed was adequate for hand coverage while minimizing waste.

Power stability was evaluated using a 9V battery and a backup UPS module. The device operated without interruption for extended durations, confirming its suitability for areas with inconsistent power supply. The modular design also facilitated easy maintenance and part replacement.

No significant operational delays or sensor failures were observed during a continuous usage simulation over a 7-day period. User feedback collected from a small test group indicated high satisfaction with the touch-free experience and the system's responsiveness.

Overall, the results validate the effectiveness and practicality of the proposed system for use in healthcare and public settings. Its low cost, ease of assembly, and potential for further upgrades—such as IoT connectivity—highlight its promise as a scalable solution for infection control.

4. Discussions

The performance of the proposed contactless disinfection device demonstrates that affordable microcontroller-based systems can significantly enhance hygiene practices in high-risk environments. The integration of the ultrasonic sensor and servo motor created a responsive and reliable mechanism that successfully minimized the need for physical contact—an essential criterion for infection control, particularly in healthcare facilities.Compared to conventional dispensers, the system offers distinct advantages, including automation, reduced cross-contamination, and consistent sanitizer delivery. Its low cost and accessibility of components make it suitable for deployment in both developed and resource-limited settings. Furthermore, the successful use of the Arduino platform highlights its potential for rapid prototyping and customization in biomedical applications.

The device’s performance remained stable across various power conditions, and its modular structure allows for future expansion, such as IoT-based monitoring. However, user interaction in real-world environments may introduce variables not covered in this study, such as crowd density and environmental noise affecting sensor readings.

Despite these limitations, the system proves to be a promising tool in promoting public health, especially when integrated with broader infection prevention strategies.

5. Conclusion

This study successfully demonstrated the design and implementation of a low-cost, contactless disinfection device using Arduino Uno, ultrasonic sensing, and servo motor control. The system provided an effective solution for minimizing physical contact, thereby reducing the risk of infection transmission in healthcare and public settings. Experimental results confirmed the reliability and responsiveness of the device under various operational conditions. The integration of open-source hardware and accessible components highlights the potential for wide-scale adoption, particularly in resource-constrained environments. The modular design supports easy maintenance and future enhancements. Overall, the device offers a practical and scalable approach to automated hygiene management, contributing meaningfully to infection prevention strategies in the post-pandemic era.

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