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Design and Implementation of an Arduino Uno Based Smart Automatic Water Dispenser Prototype

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Abstract *- This study aims to design and develop an Arduino Uno–based smart automatic dispenser as a hygienic solution for touchless liquid dispensing. Conventional dispensers require physical contact, increasing the risk of contamination; therefore, a contactless system is proposed to improve hygiene and user convenience. The system utilizes an Arduino Uno as the main controller, an HC-SR04 ultrasonic sensor for object detection, a relay module for switching control, and a DC motor to pump liquid. A 16×2 LCD is integrated to display real-time system status. Experimental testing was conducted using repeated trials to evaluate detection accuracy, response time, and error rate. The results show that the ultrasonic sensor achieves 100% accuracy at 5 cm and approximately 95% at 10 cm, with decreased performance at longer distances. The DC motor and relay system demonstrated a 90% success rate with an average response time of 1.5 seconds. Overall system testing achieved 95% accuracy (19 out of 20 successful trials). These results indicate that the system operates effectively and reliably under defined conditions and has potential for application in public facilities to support hygienic and touchless liquid dispensing.*

Keywords: *Arduino Uno*; *Prototype*; Smart *Dispenser*; *Ultrasonic Sensor*.

1. INTRODUCTION

Technological advancements have significantly improved the convenience and efficiency of daily human activities. One example is the development of water dispensers, which are widely used devices for providing drinking water at different temperature levels such as room temperature, hot, and cold [1][2]. Water dispensers are commonly used in homes, offices, and public facilities to facilitate the provision of drinking water and to support human hydration needs [3][4].

In recent years, the development of automatic water dispenser systems has become an important technological innovation, particularly in efforts to improve hygiene and minimize physical contact [5]. Conventional dispensers generally require users to press buttons or pull levers to release water. Although this mechanism is simple, repeated physical contact by multiple users may increase the risk of spreading bacteria, germs, and viruses [6]. This issue became especially significant during the global COVID-19 pandemic, when reducing physical contact and maintaining hygiene became a major concern in public facilities [7]. Therefore, the development of touchless automatic dispenser systems has become increasingly important as a solution to improve sanitation and user convenience.

Despite the growing number of studies on automatic dispenser systems, several limitations remain. Many existing systems focus primarily on basic automation without integrating additional features such as precise distance control, water volume regulation, or real-time monitoring. In addition, some studies lack optimization in sensor accuracy and system responsiveness, which may affect reliability in real-world applications. Furthermore, comparative analysis between different implementations is often limited, making it difficult to evaluate the effectiveness and efficiency of various approaches. These gaps indicate the need for a more integrated, accurate, and efficient automatic dispenser system.

Microcontrollers play an important role in the development of automated systems [8][9]. One of the most widely used microcontrollers in embedded system development is the Arduino Uno [10]. The Arduino Uno platform offers flexibility, ease of programming, and compatibility with various sensors and actuators, making

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it suitable for prototyping automation systems [11][12]. The microcontroller acts as the main controller that processes input signals from sensors and controls output devices such as motors, pumps, or relays automatically based on programmed instructions [13].

One of the key components used to enable touchless interaction in automatic systems is the ultrasonic sensor [14]. The HC-SR04 ultrasonic sensor is commonly used for distance measurement applications because of its high accuracy, low cost, and ease of integration with microcontrollers [15].The sensor emits ultrasonic waves and measures the time required for the waves to reflect back after hitting an object [16][17]. Based on this time interval, the distance between the sensor and the object can be calculated. Based on this time interval, the distance between the sensor and the object can be calculated. Several studies have demonstrated that the HC-SR04 ultrasonic sensor can effectively detect objects within a specific distance range with relatively low error rates [18]. However, variations in environmental conditions and object positioning may still affect measurement accuracy, indicating the need for system calibration and optimization.

Previous research has also shown that Arduino-based automatic dispenser systems can improve efficiency and hygiene by eliminating the need for direct contact with the dispenser mechanism [19]. In such systems, the ultrasonic sensor detects the presence of a glass or container placed within a certain range, and the microcontroller then activates an actuator such as a motor or pump to release water automatically [20][21].In addition to improving convenience, automatic dispenser systems can also support hygienic environments in public facilities. These systems can be implemented in locations such as hospitals, schools, offices, internet cafés, and places of worship, where shared equipment may pose hygiene risks [22]. Furthermore, automatic dispenser technology can be integrated with additional features such as LCD displays, water level monitoring, volume control, and Internet of Things (IoT) connectivity for remote monitoring and system management [23].

Based on these limitations, this study proposes a touchless automatic water dispenser system based on Arduino Uno and the HC-SR04 ultrasonic sensor with enhanced functionality. The novelty of this research lies in the integration of optimized distance detection, improved system responsiveness, and the potential addition of features such as water volume control and monitoring systems to enhance both efficiency and hygiene. Therefore, the problem formulation in this study can be defined as follows: (1) how to design and implement a touchless automatic water dispenser system using Arduino Uno and an ultrasonic sensor; (2) how to improve the accuracy and responsiveness of object detection; and (3) how to enhance system functionality to support better hygiene, efficiency, and user convenience in public facilities.

2. RESEARCH METHODOLOGY

This study was conducted through several structured stages, starting from system requirement analysis, hardware preparation, system design, implementation, and performance testing. In the initial stage, all required tools and components were identified and prepared according to system specifications. The design phase involved both hardware and software development, including the creation of a system architecture. Once the design was validated, the implementation stage was carried out, followed by functional and performance testing to evaluate system reliability and accuracy. The overall programming workflow of the system is illustrated in the flowchart shown in Figure 1.

2.1. Tools and Materials

The hardware components used in this study include an Arduino Uno microcontroller as the main controller, an HC-SR04 ultrasonic sensor for distance measurement, a relay module for switching control, a 16×2 LCD for user interface display, a DC water pump, a regulated power supply (12V), a rechargeable battery, and jumper cables for circuit connections. The overall hardware configuration and circuit connections are illustrated in Figure 2. Each Component was selected based on compatibility, operating voltage, and system requirements to ensure stable and efficient operation [24].

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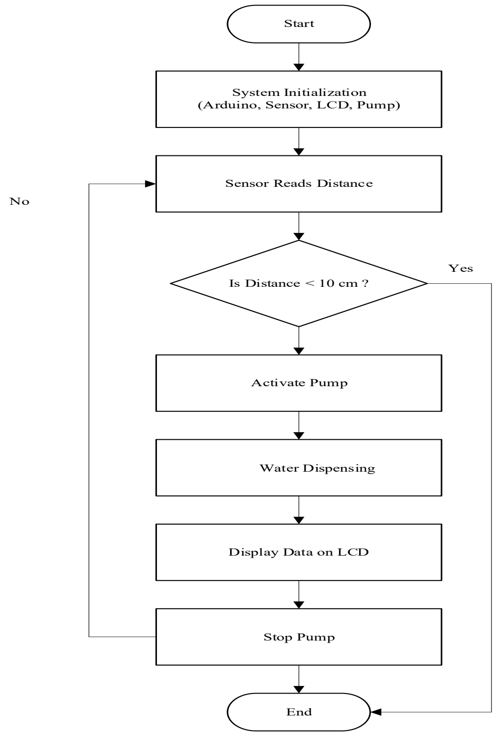

Figure 1. Flowchart of the automatic smart dispenser.

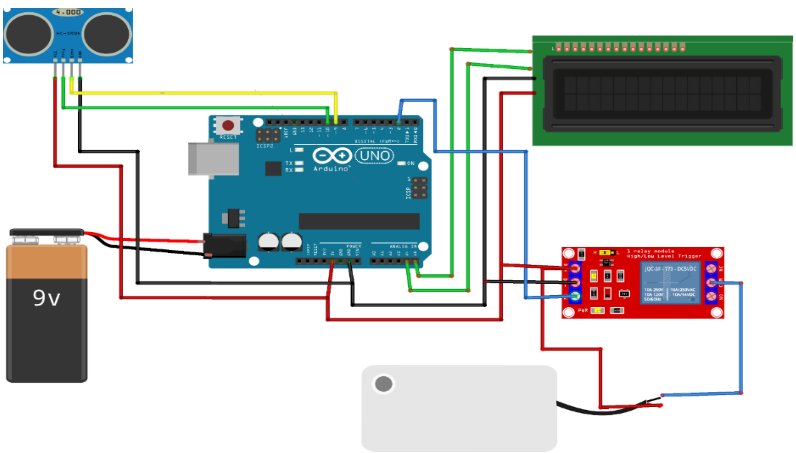

Figure 2. Circuit schematic.

2.2. System Working

The system operation begins with the initialization of all main components, including the Arduino Uno, ultrasonic sensor, LCD, and water pump module. The Arduino Uno functions as the central processing unit that controls data acquisition and actuator response [25].After initialization, the ultrasonic sensor continuously measures the distance between the dispenser and an object placed below it, such as a glass [26][27]. The distance is computed using the time-of-flight principle. In this system, a threshold distance of 10 cm is defined as the trigger condition for object detection.When an object (e.g., a glass) is detected within a distance of less than or equal to 10 cm, the Arduino processes this input and activates the relay module, which in turn switches on the DC water pump. The pump dispenses water into the glass for a predefined duration (e.g., 3–5 seconds, adjustable in the program), ensuring a consistent volume of water output. During operation, the LCD displays real-time system status messages such as "Object Detected" and "Dispensing Water" to provide user feedback. After the dispensing duration has elapsed, the Arduino deactivates the relay, stopping the pump automatically.

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[28]. The system then returns to its initial monitoring state, where the ultrasonic sensor continues detecting objects placed near the dispenser.

2.3. Software Design

The software developed in this study functions as the main control system that enables the hardware components to operate automatically according to the designed mechanism. The program is developed for the Arduino microcontroller to control and coordinate the operation of all connected devices. The coding process is performed using the Arduino Integrated Development Environment (IDE), where the program is written, compiled, and uploaded to the microcontroller [29].The implemented software includes several functional modules such as object detection, distance measurement, color recognition, and short-range communication [30]. In addition, the program controls the movement of the servo motor and regulates the operation of the DC motor to support the system's functionality. The integration of software and hardware ensures that the system operates efficiently and performs the intended tasks automatically.

3. RESULTS AND DISCUSSION

Implementing the device requires assembling the hardware as needed. Software is then used to give commands to the hardware so the device functions as intended. Building this system also requires supporting tools and materials. The hardware assembly stage consists of an ultrasonic sensor to measure the distance between the cups and a DC motor to draw and flow liquid from the tank to the dispenser mouth.

3.1. Component and Tool testing

This testing stage is conducted to evaluate the performance, accuracy, and reliability of each component using repeat trials (n = 20) for each scenario. The evaluation includes quantitative metrics such as detection accuracy, response time, and error rate.

3.1.1 HC-SR04 Ultrasonic Sensor Test

The ultrasonic sensor was tested at various distances (5 cm, 10 cm, and 20 cm) to evaluate its detection accuracy. Each test was repeated 20 times as shown in Table 1.

Table 1. Ultrasonic sensor performance.

Distance (cm)	Trials	Detected	Not Detected	Accuraccy (%)
5	20	20	0	100
10	20	19	1	95
15	20	18	2	90
20	20	20	0	100

3.1.2 DC Motor and Relay Testing

The testing of the DC motor and relay was conducted to evaluate the proper operation of the motor control mechanism within the system. The relay and DC motor were tested to measure respon accuracy and timing consistency. The system was tested 20 times under object detection. Succesfull activation 18/20 (90%), Average respon time 1,5 seconds. Error rate 10 %.

3.1.3 Overall System Testing

The overall system testing was conducted to evaluate the performance and integration of all hardware and software components in the developed system. This testing stage aims to ensure that each component operates properly and that the entire system functions according to the designed mechanism.

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a. Filling Water into A Glass

The system was tested by placing a glass within the detection range. The system automatically dispenses water for a predefined duration 3-5 seconds. From 20 trials, succesfull operation 19, failures 1 and accuracy 95%. This can be seen in Figure 3.

Figure 3. Filling water into a glass.

b. Process of Retrieving Glasses from the Dispenser

The process of filling water and removing a glass from an automatic dispenser can be done by placing an empty glass under the dispenser tap. The device will automatically fill the glass. Once the filling process is complete, the user then lifts the filled glass. This can be seen in Figure 4.

Figure 4. Process of retrieving glasses from the dispenser.

c. Smart Dispenser Prototype Testing

The prototype testing was conducted to evaluate the performance and functionality of each component used in the smart automatic water dispenser system. This testing aims to ensure that every component operates according to the designed specifications and responds properly to the given input conditions. Several components were tested, including the ultrasonic sensor, relay, and DC motor. The ultrasonic sensor was

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evaluated to determine its ability to detect the presence of a glass within a certain distance, while the relay and DC motor were tested to verify their response when the sensor detects an object. The results of the component testing are presented in Table 2.

Table 2. Smart dispenser prototype testing.

No	Componenet Name	Testing Scenario	Expected Result	Actual Result	Accuracy
1	Sensor Ultrasonic	The glass is placed < 10 from the sensor	Object detected	Detected 19/20	95%
2	Relay and DC Motor	When the sensor is active, the motor runs required time	The motor turns on and stop when glass is removed	Motor turns on and off correctly 19/20	95%

4. CONCLUSIONS

The developed smart dispenser system is capable of dispending liquid auyomatically in an effective and efficient manner when the sensor detecs the presence of an object. The liquid dispensing process occurs accurately and is controlled within the programmed time duration, while the system status is displayed in real-time through the LCD screen. The HC-SR04 ultrasonic sensor operates based on the reflection principle of ultrasonic waves to measure the distance between the sensor and the detected object, such as a glass.

Based on experimental results, the HC-SR04 ultrasonic sensor demonstrates reliable performance within the effective detection range of 5–10 cm, achieving an accuracy of up to 100% at 5 cm and approximately 95% at 10 cm. However, the accuracy decreases at greater distances, indicating that system performance is influenced by object range and positioning. The DC motor and relay testing showed a successful activation rate of 90% with an average response time of 1.5 seconds and an error rate of 10%. The overall system testing indicates that the automatic water dispensing process achieved an accuracy of 95% (19 out of 20 successful trials). These results suggest that the system performs reliably under defined conditions, although it does not achieve a perfect success rate. Therefore, the previous assumption of “100% success rate” is revised to reflect actual measured performance.

In conclusion, the proposed smart dispenser system has good potential for practical implementation in public facilities such as schools, hospitals, and offices, particularly in supporting hygienic and touchless operations. However, further improvements are recommended, such as enhancing sensor accuracy at longer distances and optimizing system stability to reduce error rate.

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