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A DUAL-TRIGGER SMART HAND WASHING MACHINE

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ABSTRACT

Hand washing is simple and effective in preventing the transmission of infection and sickness in various contexts, including the home, workplace, childcare facilities, and hospitals. It is important to note that contaminated surface like tap heads and manually operated hand sanitizer pose threat to the users of such facility and as such has constituted a global concern due to the emergence of diseases that can be easily transmitted. Hence, this project presents a low-cost automatic hand washing machine with a temperature sensor and counter, triggered by an Ultrasonic sensor and Laser-Light Dependent Resistor (LDR) trip wire that puts ON or OFF the pump and counting at the same time. The system design was done in two levels, the 3D model and circuit diagram design: firstly, the 3D model design was done with Autodesk Inventor 2017 while the circuit diagram design was done using Fritzing software and simulations performed for both levels. The system was fabricated and evaluated; the result obtained revealed reliable water dispense since the water flow can be activated by either an ultrasonic or laser-LDR sensor, a strong frame at a threshold weight of 166.6 N, and reliable temperature measurement. The uniqueness of this work is that it combines automated temperature measurement, hand-washing, and counting systems in a single device. Temperature measurement and hand-washing help to prevent disease spread while the counting system assists in recording the number of people using or entering a facility to aid the practice of social distancing as means of curtailing the spread of the diseases.

Keywords: *Hand washing, automatic control, temperature sensor*

INTRODUCTION

The Personal hygiene is a vital routine daily activity that helps keep the body healthy, clean, and fit. Practicing proper personal hygiene involves the regular removal of dirt from all parts of the body to keep it clean, this activity helps in maintaining both mental and physical health (Temitayo 2016). Poor personal hygiene provides an enabling environment for the growth of germs, making it vulnerable to infection. There are several ways by which personal hygiene can be carried out and this includes, taking a regular bath with soap, washing hands before and after meals and defecation with soap, keeping nails short to avoid housing germs, brushing the teeth, and taking regular exercise (Ali et al, 2013). However, for this research, focus will be placed on hand washing. Hand washing as a type of personal hygiene involves the physical or mechanical removal of dirt, organic material, or microorganisms from the hands thereby preventing the transmission of infection (WHO, 2009). Hygiene specialists consider hand washing to be one of the essential activities in illness prevention. According to research, hand washing with soap after leaving a toilet facility and other critical periods can prevent more than 42% of diarrhea occurrences (Curtis and

Cairncross, 2003). In the history of human civilization, there has never been a greater need for adequate hand washing than now, and this is due to the emergence of the novel coronavirus (COVID-19) in December 2019 which can be transmitted by contact with contaminated surfaces or by air (Wu *et al,* 2020). A health expert has recommended regular hand washing as one of the non-clinical methods of preventing the spread of the COVID-19 virus and other diseases from person to person (Keni, *et al.,* 2020). Apart from hand-washing, other prescribed methods of preventing COVID-19 include temperature measurement of individuals, social distance observance, and inoculations through COVID-19 vaccines (Cdc, 2023) among others. These measures are expected to be observed to prevent the high transmission rate of the disease. Since hand washing is important, it can further foster the spread of the virus if users operate a contact water, soap, or sanitizer dispenser (usually tap) to carry out hand cleaning and sanitizing. Hence the need for a non-contact water and soap dispenser.

In recent times, hand washing has become almost a household name owing to different health issues around the world. These health challenges are most times transmitted from one person to another by coming in contact with infected surfaces or persons, necessitating the need for regular hand washing. As a way of proffering a solution to this challenge, a foot-operated hand-washing machine was developed by Bernard *et al.* (2016). The foot-operated hand washing machine is mechanized, it constitutes of various functional parts like the pedals, taps used to dispense water, and the spring mechanism, which enables the pedals to function accurately. In the same vein, Moharir and Porwa, (2020), developed a similar version of the hand washing machine. The developed machine is a foot-activated lever mechanism hand sanitizing machine. However, this design is limited to dispensing liquid hand sanitizer alone. Samuel *et al.* (2020), fabricated a manual hand washing machine to reduce the spread of coronavirus which was operated using the foot. considering the height of an average human and when operated using pedals and a spring mechanism to dispense soap and water from the machine to wash hands. The idea of fabricating the foot-operated hand washing machine is to avoid contact with the tap while washing hands. As the need for non-contact hand washing and sanitizing machine continue to grow, several researchers have tapped into the numerous benefits associated with the Internet of Things (IoTs) and process automation to develop smart hand washing and sanitizing machine that could be operated by body gestures. Lee *et al.,* 2020 developed an automatic hand sanitizing machine to fight the deadly coronavirus disease. The design prevents direct contact with hand sanitizer by the use of a novel mechanism driven by a DC motor. Thin *et al.,* (2019) developed an automatic hand washer. This system was designed to prevent the unhealthy pattern of washing hands in restaurants and intended to help improve the hand-washing culture. The hand washer comprises a DC motor for water flow, LM 358 as controller, and a hand proximity sensing circuit which triggers the DC motor for water flow. Also, Ombiro et al. (2021) developed a solar-powered automatic hand washing and sanitizing system that uses LM358N as a microcontroller. This research shows an improved version of Thin et al. (2019). As researchers continue to take advantage of the benefit of IoTs, Hamza *et al.* (2021) work on a user-friendly smart hand washing machine that utilizes an Ultrasonic Sensor to detect the presence of hands. The smart hand washer dispenses liquid soap and water automatically when the sensor senses any presence. Arduino Uno microcontroller was used as the brain of the system. Another innovation was developed by

Jolan *et al.* (2020) titled the automatic hand washing system with the hand dryer. This system performs a dual function, washing and drying the hand. Components such as Arduino Uno, DC motor, Ultrasonic sensor, blower fan, and relay were used to develop the system.

Usually, fever (rise in body temperature) is an indication of infection in the blood. Some researchers have worked in the development of temperature-measuring devices (Ajewole et al., 2021, Ogidan et al., 2022), and others contributed to the development of hand-washing devices both mechanical and automated types (Satria et al., 2022, Sharma et al., 2020). Some others have gone ahead to research the possibilities of vaccines to prevent the pandemic (Tregoning et al., 2020). This work presents a unique approach that combines automated temperature measurement, hand-washing, and counter to assist in recording the number of people using the facility or entering the premises where the device is the place to aid the practice of social distancing as means of curtailing the spread of the pandemic. Table 1 shows a comparison between this work and other research carried out by researchers.

Table 1: Comparison of current work with some existing research

S/N	Research conducted	Hand washing	Type of controller	Temperature sensor	Counter	Power source	
						DC	AC
1	Bernard *et al*. (2016).	Yes	None	No	No	No	No
2	Thin et al. (2019)	Yes	LM358	No	No	Yes	No
3	Jolan *et al.* (2020)	Yes	Arduino Uno	No	No	Yes	No
4	Hamza et al (2021)	Yes	Arduino Uno	No	No	Yes	No
5	Ombiro et al. (2021)	Yes	LM358N	No	No	Yes	No
6	Current research	Yes	Arduino Uno	Yes	Yes	Yes	Yes

METHODOLOGY

This section contains the materials and method used to develop the proposed smart hand-washing machine

Materials

The following materials as shown in Figures 1 to 9 were used in the fabrication of the smart hand-washing machine.

Arduino UNO microcontroller: Arduino is the brain of the system, this component processes analog signals from sensors, then activates the actuators based on the signal received to perform the necessary action

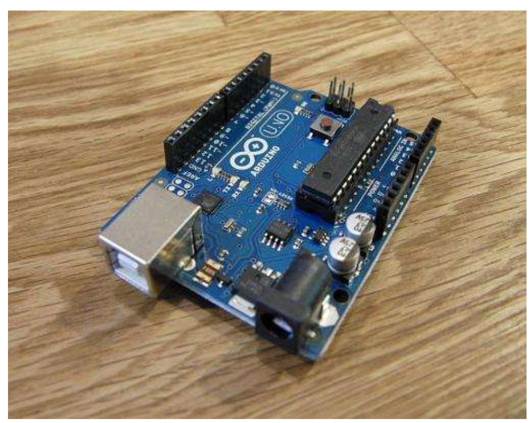

Figure 1: Arduino UNO microcontroller

LCD Screen: A liquid-crystal display (LCD) is a flat-panel display used to display the results of the machine while the machine is in use. A 16X2 character LCD screen was used for this research.

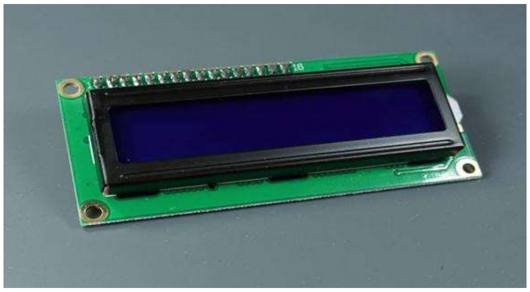

Figure 2: LCD

Relay: A 5-volt, one-channel relay module interfaced with the Arduino Uno to control high voltage, this device serves as a switch for the pump.

Figure 3: Relay

DC pump: This device produces a suction effect that pulls water from the water tank to the tap head. A 12-volt pump was used for this research.

Figure 4: DC pump

Buzzer: The Buzzer is an audio signaling device that is usually mechanical or piezoelectric. In this project, this device serves as an alarm that comes on if the user's current body temperature status is very high.

Figure 5: Buzzer

MLX 90614 Temperature sensor: The MLX90614 is a temperature Sensor that measures the temperature of the user and displays the temperature on the LCD screen.

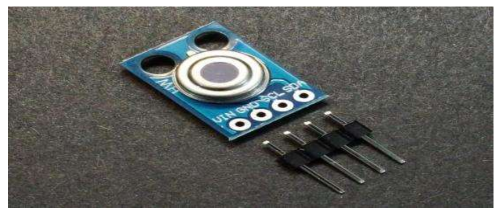

Figure 6: MLX 90614 Temperature sensor

Ultrasonic sensor: the ultrasonic sensor is an electronic device that measures the distance of a body by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal that is sent to the microcontroller. This device is capable of detecting objects between 2cm and 400cm

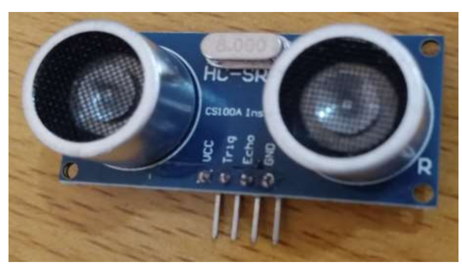

Figure 7: Ultrasonic sensor

Laser diode: Laser is a semiconductor device similar to a light-emitting diode in which a diode pumped directly with electrical current can create lasting conditions at the diode's junction. A 5volt laser diode was used for this work

Figure 8: Laser diode

Light Dependent Resistor (LDR): These are electronic components used to detect light intensity and change the operation of a circuit depending upon the light levels. A 5mm, 100 ohms LDR was used for this research.

Figure 9: LDR

Mode of operation

The smart hand washing machine is made up of five major components; namely: Arduino Uno, ultrasonic sensor, laser-LDR trip wire, DC pump, and MLX 90614 temperature sensor. The ultrasonic sensor and Laser-LDR tripwire form the dual trigger for the system that is capable of triggering the system simultaneously or independently. This Ultrasonic sensor detects an object at a distance between 2 cm and 20 cm while in the case of laser-LDR, it is activated when any obstruction blocks the laser beam which breaks the laser-LDR tripwire connection. A signal is sent to the relay to switch the pump ON or OFF based on detection and also does the counting of users. The laser-LDR tripwire serves as a backup switching system should the ultrasonic sensor fails. Once there is a break in the laser-LDR tripwire connection, the Arduino Uno sends a signal to the relay to trigger the pump to enable water flow from the tank. The dual trigger system for this smart hand washing machine is to reduce the risk of the system failing. The MLX 90614 temperature sensor measures the body temperature of users, and sends it to the Arduino Uno, at the controller level the temperature measured is compared with a threshold temperature (body temp >=36.0 degrees celsius but < = 37.5). If the measured temperature is lower than or equal to the threshold temperature, the user is notified by the LCD screen displaying the measured temperature else the user receives the LCD screen notification 'body temperature is high' and a buzzer is activated to call the users attention to temperature indicating the person needs medical attention. Figure 10 and 11 respectively, shows the block diagram and the circuit diagram for this research.

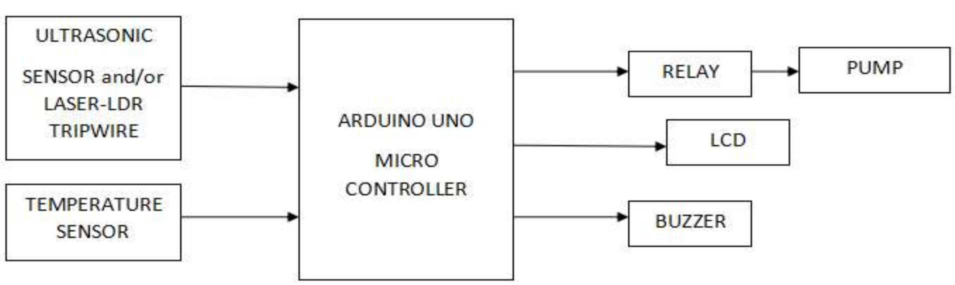

Figure 10: Block diagram

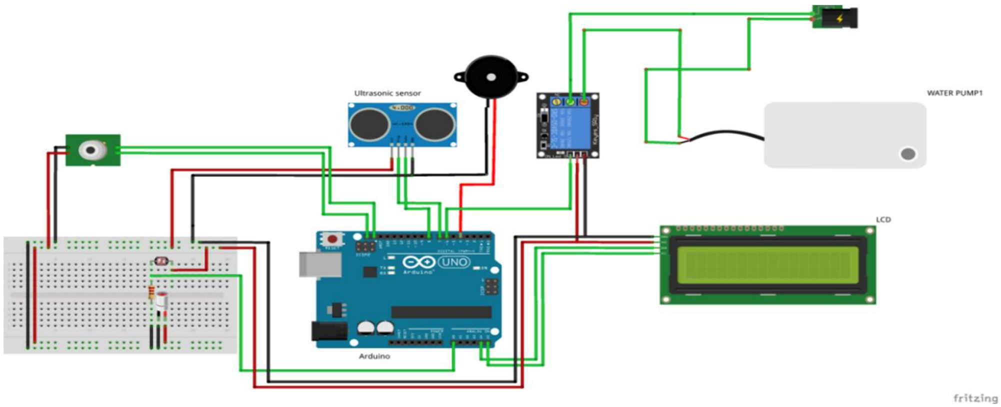

Figure 11: Circuit diagram

RESULTS AND DISCUSSION

Different tests were carried out in the developed device shown in Figure 12 which include a structural integrity test, temperature measurement test, counter test, and dual trigger test.

Structural Integrity Test

To test the structural integrity of the smart hand washing frame, a stress analysis was carried out on this part using Autodesk Inventor 2017, and a load of 166.6 N was applied on the frame- this is the weight of the water and the container (tank) that act on the frame. Table 2 shows the mesh properties and Figure 13 shows the meshed frame based on the mesh properties in Table 2. This test predicts the behaviour of the materials under loading. From the results obtained, the minimum and maximum Von Mises Stress is 0.0 MPa, and 4.78MPa respectively. This is illustrated in Figure 14. Comparing these results with the yield strength of wood (70 - 120MPa), the yield strength is greater than the maximum Von Mises Stress which means the material will not fail under the applied load. It was also noted that the frame has a minimum deformation (displacement) of 0.0 mm, and a maximum of 0.02076 mm resulting from the applied load as shown in Figure 15. The maximum displacement value of 0.02076 mm resulting from the load (water and container) placed on the lower part of the frame has very little or no effect on the frame hence considered negligible

Table 2: Mesh Properties

Average element size	0.1
Minimum element size	0.2
Total number of element	8422
Total number of nodes	16334

Figure 12: Smart hand washing machine

Figure 13: Meshed frame

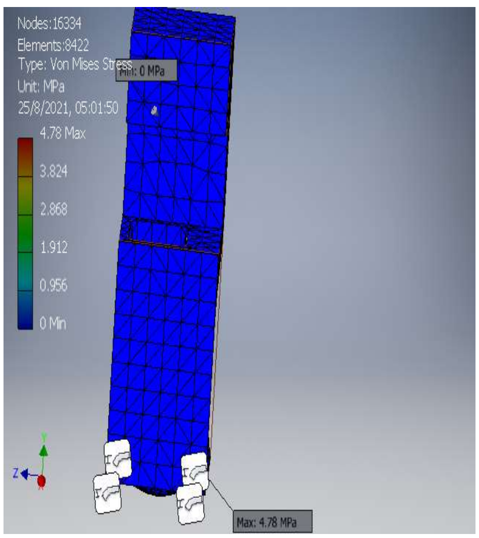

Figure 14: Vom Mises stress analysis

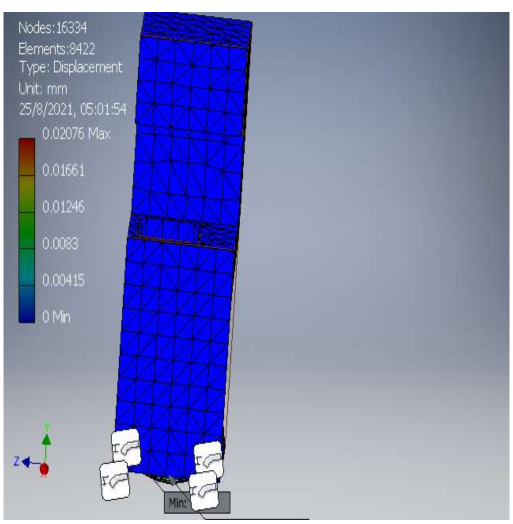

Figure 15: Displacement due to applied load.

Performance evaluation test of the temperature sensor

Table 3 shows the results obtained before calibration. The calibration of the MLX 90614 temperature sensor of the smart hand washing machine was done against a standard contact thermometer (Mercury in glass thermometer). A total of 15 experiments were carried out where each user used the machine three times and the body temperature, the same procedure was repeated for the contact thermometer. The average body temperature was calculated for each user and recorded. The average body temperature value for the contact thermometer and MLX 90614 temperature sensor was compared, and the results show a difference of approximately three degrees Celsius (3℃). The result shows that the accuracy of the contact thermometer is higher than MLX 90614 temperature sensor. However, to compensate for the differences between the contact thermometer and MLX 90614 temperature sensor, 3 degrees Celsius was added to the Arduino code. Figures 16 and 17 respectively show a bar chart comparing the contact thermometer and developed temperature device before and after calibration with their errors. From this result, it is clear that the error reduced greatly after calibration.

Trigger System and Counter-Evaluation Result

The performance of the trigger system and counter was evaluated with 10 users that operated the smart hand washing machine. The system worked as designed, the number of users reflected on the LCD screen, and the water kept on running until the hand was moved away from the trigger systems. Table 5 shows the test results for the trigger system and counter

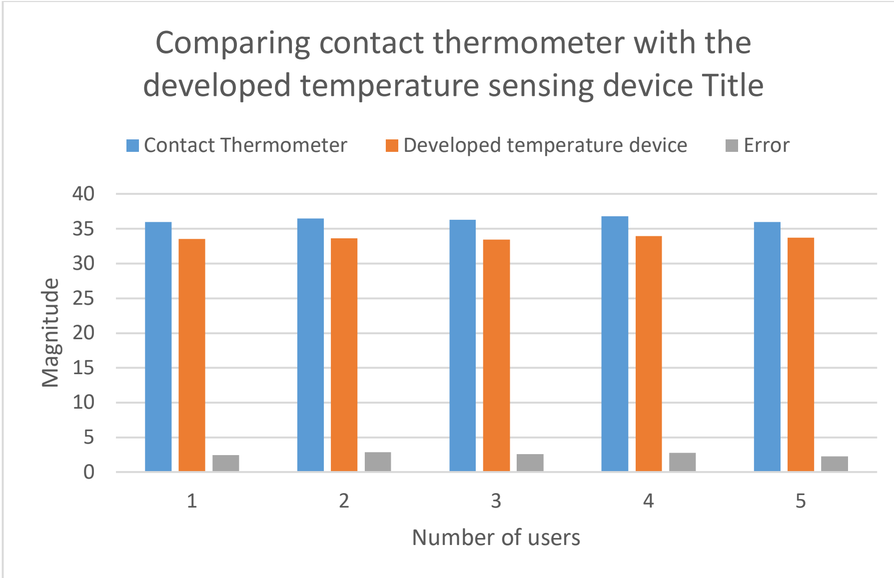

Figure 16: Bar chart before calibration

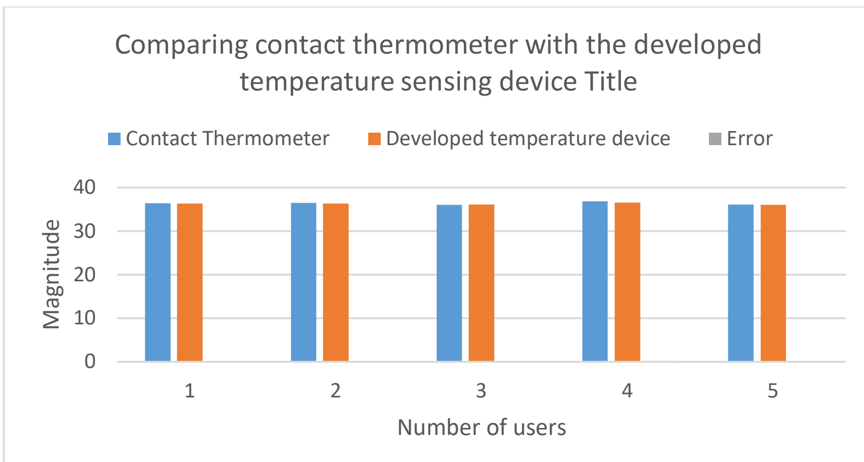

Figure 17: Bar chart after calibration

Table 5: Counter Evaluation

Number of users	Trigger System	Counter
1	Triggered	Counted
2	Triggered	Counted
3	Triggered	Counted
4	Triggered	Counted
5	Triggered	Counted
6	Triggered	Counted
7	Triggered	Counted
8	Triggered	Counted
9	Triggered	Counted
10	Triggered	Counted

Discussion of Results

The fact that a single device can perform hand-washing and temperature measurements would assist in saving cost, space, and time. Cost in the sense that there is no need to spend extra for a temperature measuring device and no need to employ someone who has to manually hold an infrared thermometer to measure temperature because the measurement is automated. It will save space because a hand-washing machine and temperature measurement device are likely going to compete for space and time. After all, it is easy to simultaneously wash hands and also measure temperature at the same location and from the same device.

If the device is placed at the entrance of the premises, the counter helps to count the number of persons using the facility or entering the premises to easily ascertain the total number of users. With this, it is easy to evaluate the entry rate and avoid over-crowding to ensure social distancing.

The system having temperature and hand-washing capability helps to solve the two problems that are used in the prevention of the COVID-19 pandemic which is temperature measurement to detect a possibly infected person. Hand washing helps to ensure there is no transmission of possible infection from one individual to another other while the counter helps to ascertain the number of persons entering into premises to dissuade over-crowding of the facility to ensure social distancing and prevent further spread of COVID-19 and other communicable diseases. The choice of the wood and the stress test performed on it helps to know in advance the possible period of deterioration of the framework for possible maintenance to ensure the device is always in use to safeguard spreading of diseases.

CONCLUSION

A dual-trigger smart hand washing machine was developed as designed, and performance evaluations were carried out. The system can be powered via AC and DC power source from a 12v battery, giving end-users the liberty to power the system with any of the two available sources. From the results obtained, the following were deduced: the developed system dispensed water when any of the two triggers (ultrasonic sensor or laser-LDR) is activated by the presence of the hand. The system can be powered using an AC or DC from a 12v battery. From simulation results, the frame of the dual smart hand washing machine will not fail when loaded with water up to the weight of 166.6 N. Body temperature measured using the MLX 90614 temperature sensor works almost like the mercury in glass thermometer after calibration with a little temperature difference ranging from 0.04 - 0.21 which is negligible. However, for better results, users should stand 0.5 m away from the temperature sensor.

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