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Design and Implementation of an Automated Hand Sanitizer Dispenser using Ultrasonic Sensor

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Research Article

Abstract

For generations, hand washing and sanitizing with water and disinfectants has been considered a measure of personal hygiene. With the level of increase in the use of hand sanitizer, the need arises to automate the dispenser processes in order to monitor the level of the sanitizing fluid and minimize wastage. Therefore, this work focuses on design and implementation of an automatic hand sanitizer dispenser. The system was built using a microcontroller (Arduino nano) interfaced with two different sensors (HC-SR04) ultrasonic sensor and an infrared (IR) sensor. The ultrasonic sensor detects the presence of a hand within the distance of 10cm from the ultrasonic sensor. When the presence of a hand is sensed, a signal is sent to the Arduino nano which serves as the major memory of the system to activate the DC pump for the discharge of the gel. The IR-sensor monitors the level of sanitizer in the container and sends an active signal to the Arduino nano to activate the SIM800l module to send a message to the owner when the sanitizer level is at the minimum predefined level of 3cm. The ultrasonic sensor senses the presence of a hand within a 10cm range in 1 second. Having successfully established a communication link between an automatic hand sanitizer dispenser and its indoor owner through a SIM module, this work has brought an innovation to hand sanitizing process with ease of management and seamless operation.

Keywords
Automation; Dispenser; Hygiene; Infrared Sensor; Microcontroller; Ultrasonic Sensor.

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1. Introduction

For centuries, personal hygiene habit has been driven through the use of soap and water for hand washing for adults and children (Staniford and Schmidtke, 2020). The cause of hospital-visit contracted infections, the rate at which hands are contaminated with different hospital-visit pathogens, and the part hands of health care workers play during outbreaks is an indication that a hygienic hand preparation will give room for the least bacteria activity, yeasts, and coated viruses (Kampf and Kramer, 2004). During the COVID-19 pandemic in 2020, hand washing with soap was a major recommendation by World Health Organizations and other health bodies as an important precautionary measure to mitigate its spread. This recommendation was premised on the mode of transmission of the virus which were through surface and human contacts (Handwashing Research Summary, 2020; Ngotho, 2020). The report given by Ignaz Semmelweis in 1846 was that the mortality rate of babies delivered by students and physicians were higher when compared to ones delivered by midwives at a general hospital in Vienna. The first clinic was manned by students and physicians while the second clinic was manned by midwives. Further investigations showed that physicians who visited the obstetrics from the autopsy suite, had some odour even though they washed their hands with soap and water at the arrival at the obstetrics clinic. He submitted that the disease that affected many women in labour that delivered at the clinic, the "puerperal fever", was transmitted from the autopsy suite to the obstetrics clinic through the touch of students and physicians. Cadaverous particles were indicated to be the cause of the puerperal fever. The use of chlorine compounds for disinfecting the hand was recommended and the students and physicians were to apply this to the hands after attending to a patient and before attending to the next patient in the clinic. A significant drop in maternal mortality rate was observed and it remained so for years in the ward where the students and physicians attended to patients after the recommendation was implemented. This account is the first documented evidence that shows that the use of antiseptic soap with water while washing a heavily contaminated hand with transmittable diseases may be more effective when compared to using a non-antiseptic soap with water (Codell, 1983). Few years after, Guey-Chaun Shiau filed to patent the first automated dispenser in 1991 under the name "Automatic Cleaning-liquid Dispensing Device. The description of this patented gadget was described as: "An automatic cleaning-fluid dispensing device". The device has provision for fluid storage and a device integrated to its lower mark of the container for fluid datum level check. The detection of the presence of a near object to the machine is achieved with an outlet where light source of the sensing circuit passes through and the sensing circuit has an electric motor connected to it. This assembly is designed to deliver automatically a prescribed amount of cleaning fluid for cleaning purposes. In

summary, the device dispenses its antiseptic fluid without human intervention (Guey-Chuan, 1991). Nowadays, sanitizing hands to prevent the spread of pathogens and bacteria has become a norm because transmitting infectious diseases are primarily done through touches by the hand particularly for close proximity dwellers as is obtainable in residence halls of colleges, shops/malls, banking halls and the market vicinity (Global Patient Safety Challenge, 2005). Before now, contamination of various diseases was frequent. Meanwhile, the advent of simple hand sanitizer has drastically reduced the spread of bacteria. Advancement in science and engineering resulted in the development of more efficient and simple automation means to sanitize our hands without having contact with the sanitizer dispenser (Edozie et al., 2020; Lesmana et al., 2020). Therefore, this work aim to design and implement a low cost smart hand sanitizer dispenser that alerts the user by SMS through a SIM module when the sanitizer gel level goes below a pre-set minimum. The design incorporates a microcontroller, a GSM module, some ultrasonic sensors, DC submersible pump, a buzzer, LED and a charging system. The sensors enable the system to interact with its environment to decide to activate an actuator (DC pump) that dispenses the hand sanitizer. The GSM module connects with the service provider to send messages. The Printed Circuit Board (PCB) for the design circuitry template was done with kicad software and necessary components were placed in position to perform the specified functions. This paper is organized as follows; section 2 contains related works review, section 3 covers the design and implementation, section 4 showcases the result and discussion while section 5 summarizes the conclusion.

2. Related Work

In today's world, system automation is evolving at an unprecedented pace. This would spike to new heights with the proliferation of remotely controlled gadgets and physical distance ceasing to be an issue. Convenience, with this unprecedented evolution, is being redefined. Just effortlessly, energy and time-consuming tasks can now be carried out with skill and agility by simple automated machines. One of those "automated machines" that help users maintain proper hand hygiene is the subject of this work. Mukund and Srinath, (2012) designed an automatic pill dispenser to specifically aid users without professional supervision to take medication. The system relieves users of making mistakes of administering the incorrect medicine at the incorrect time. Some of the main components of this medication dispenser are an alphanumeric keypad interfaced with a microcontroller, a LED display unit, a motor controller, a multiple pill container, a dispenser and an alarm system. The whole essence of this operation is to ensure that the user is able to set the accurate times the multiple pills are to be dispensed. The alarm system are in place for two indications; one is to light a LED and the other is to indicate alongside the buzzer while beeping sounds. For the user to take delivery of the pill, a button is pressed and the alarm reset afterwards; the other alarm shows the level of availability of drug in the container, to warn the user to refill the dispenser with the needed quantity of pills. The Programmed Medication Container can serve for any size of pills and capsules. The container can be modified for a 31 day's period for 21 different types of drugs. It has the capability to send alerts up to four times in a day. It is programmed for easy alteration of the frequency and the amount of pills to be picked as per prerequisite. The system is highly effective but is not fully automated because of the requirement by the user to press a button to take delivery of the pill and also to manually reset the alarm. To improve the design, ultrasonic sensors can be incorporated to sense the presence of the user and include program to reset the alarm automatically. Authors in Kanigowska *et al*., (2015) developed a dispenser whose Acoustic Droplet Ejection (ADE) technology focuses on acoustic energy to transfer nanoliter-scale liquid droplets. This low-volume dispensing, non-contact and tipless, technology reduces the possibility of cross-contamination and potentially reduces the costs of reagents and consumables for DNA synthesis and assembly at the nano-liter scale using a Labcyte Echo 550 acoustic dispenser. Candelier *et al*., (2019) and Vargas, (2020) showcased a semi-automatic and automatic food dispenser composed of three modules. Main module; a solid food module for dry powder grains and a liquid food module for live microorganisms in water. The main module has an ergonomic handle, a trigger, a fixation rail, and a microcontroller to interface an LCD screen, rotary encoder, Near Field Communication (NFC) read/write card, and a high-power LED, which is coordinated by the microcontroller. Vineeth et al., (2020) designed an automatic Pet food dispenser using image processing. The implementation of the system was achieved through the use of Digital Image Processing. It begins with a pet call which is carried out using a recorded voice outputted through a speaker which indicates to the pet, its feeding time. Then an ultrasonic sensor integrated to the system notices the pet in front of the system. As soon as the pet detected, the camera switches on to capture the pet's image and to simulate further its processes. Once the pet image is corresponding to the image data saved, a dc motor is triggered to dispense food. Two pets of different species were considered in this project. As a result, two dc motors were employed to hand out two different kinds of food to the different pets. In this design, two sets each of food containers and food bowls were provided. As soon as the pet is successfully fed, the owner's mobile number receives the message via an application-programming interface (API). Dubey *et al*., (2020) designed an IoT-based Automatic Hand Sanitizer Dispenser, which uses an ultrasonic sensor to sense the hand placed near the system. Arduino-uno was used as the microcontroller that sends activation pulse signals to the other device. The transmission and receiving of information over the duration is achieved by the use of the ultrasonic sensor which used sound waves for this operation. The duration was converted to a distance measurement based on the speed of sound (340m/s). Human hand detection and motor pump control were achieved with the aid of the sensor. This motor was attached to an RC timer delay setup and the pipe linked to a (flat pointed opening) reducer which was used to regulate the liquid flow rate of the sanitizer dispenser. The system also had LEDs which shows that the

system is in operational mode. In the work done by Sarkar, (2020), an automatic hand sanitizer with temperature sensing that works simultaneously with each other was presented. The system comprises an ultrasonic sensor, PIR sensor, a submersible pump, RGB LED, a buzzer, LCD, and an Arduino. The ultrasonic sensor and PIR sensor are connected to Arduino uno for detecting human/object motion, respectively. Once an object is detected, the sensor sends an activation signal through the Arduino to the spraying pump. The person's body temperature is detected by the temperature sensor as soon as it is touched, then the LCD screen displays the temperature in ^{0}F. Then the system converts it to ^{0}C as programmed. An alarm buzzer is triggered if the sensed temperature is above the normal body temperature (97^{0}F) and the RGB LED turns red, but if the temperature sensed is below or equal to normal body temperature, the led turns green, depicting a symbol of safety. Rusimamto et al., (2020) designed an automatic hand sanitizer dispenser where soap and water are dispensed simultaneously. Heat presence and motion of an object within a distance of 50mm is sensed by the infrared (IR) sensor. The data received is then sent to the Arduino Nano which then activates the pump. Once the ultrasonic sensor identifies water within a distance of about 35cm from it, it will send data to node of the microcontroller unit (MCU) connected to blink server. The implemented prototype work to satisfaction.

This work is an improvement on design and implementation of an automated hand sanitizer dispenser because the IR sensor monitors the level of sanitizer in the gel container and sends an active signal to the Arduino nano to activate the SIM800l module to send a message to the owner when the sanitizer level is at the minimum predefined level of 3cm.

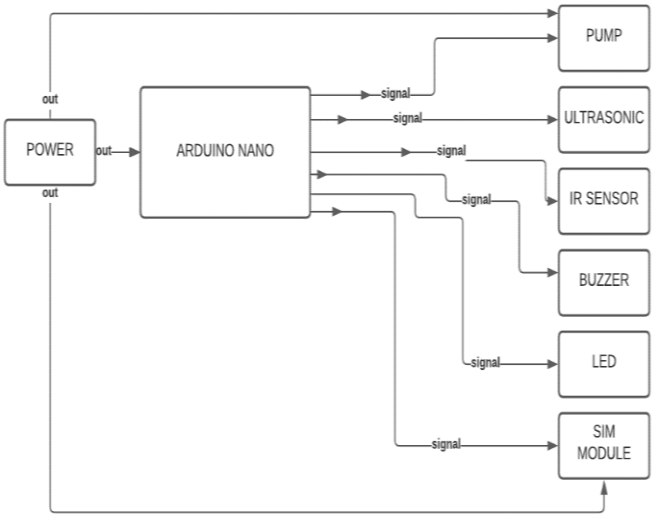

Figure 1: Block diagram of an automated hand sanitizer dispenser

3. Design and Implementation

The overall system design of this work is divided into five major parts: the processing unit, the sensing unit, data management unit, power supply unit, and communication unit. The processing unit coordinates the action of every other unit by comparing the incoming data with the stored data to perform a specific function while the sensing unit receives the incoming data from real-world activities. The data-managing unit collates data for storage purposes. The power unit supplies energy to activate the function. Although the communication unit is independent, yet its actions are coordinated by the processing unit. The system block diagram is shown in Figure 1.

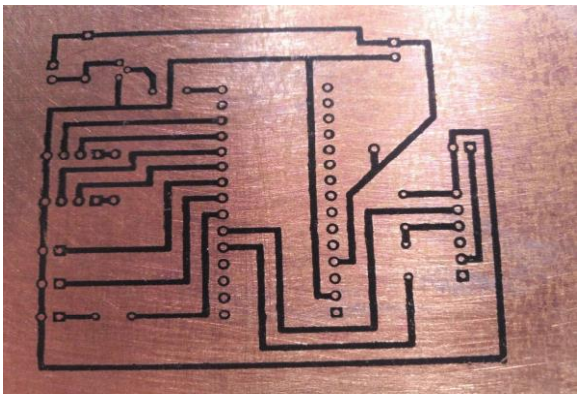

Figure 2: Printed circuit

As shown in Figure 1, the hardware components include a microcontroller (Arduino Nano), a GSM module, ultrasonic sensors, DC submersible pump, a buzzer, LED and a charging system. The Printed Circuit Board (PCB) design template was done using kicad software and components were placed in positions to meet the required specification. Then the circuitry was labeled, printed and various components soldered as shown Figures 2 and 3. The body frame is made up of a plastic of dimension 2.25 x 1.68 x 1.44m. The Arduino Nano, a small, 5V, 19mA, 16 MHz, 8-analogue pins complete and breadboard-friendly board based on the ATmega328 with flash memory of 32 KB serve as the microcontroller. An ultrasonic sensor (HC-SR04) used for the determination of the distance between its transmitter and an obstacle in its front achieved this with the aid of ultrasonic sound waves. The receiver module picks up the reflected ultrasonic wave from the target emitted by the transmitter element. The calculation of the distance between the sensor and the target is done using the principle of time-of-flight and the speed of sound (340 m/s). The sending and receiving of SMS and also the making and receiving voice calls were done using a miniature cellular module, SIM800L, which permits GPRS transmission. Its low cost, quad band frequency and long-range connectivity informed the choice of the module. There is a boot of the power module, a search for cellular network and an automatic login after connection has been established. The module TXD and RXD are connected to pin 2 and 3 of the Arduino pinout respectively. The VCC supplies voltage, the RESET resets, the RXD is used for receiving serial communication, the TXD serial communication is used for transmitting data while the GND grounds the supplied voltage. A 3V-5V, 220mA DC pump is used for the movement of the fluid by mechanical action. The power supply unit of the device is an 11.1v, 6000mah, lithium-ion battery pack. The battery pack is made up of three 18620, 3.7V, 2000mAh connected in parallel. The SIM module is powered from the battery through

a parallel connection. The 18620-power bank module (5v, 2A) is connected to the battery to supply the Arduino board and the sensors. The programming was done in arduino integrated environment. The implemented prototype is shown in Figure 4.

Figure 3: Component's layout

Figure 4: Implemented prototype

4. Result and Discussion

The dispenser completes the entire process of dispensing the sanitizer in a number of steps shown in the flow chart of Figure 5.

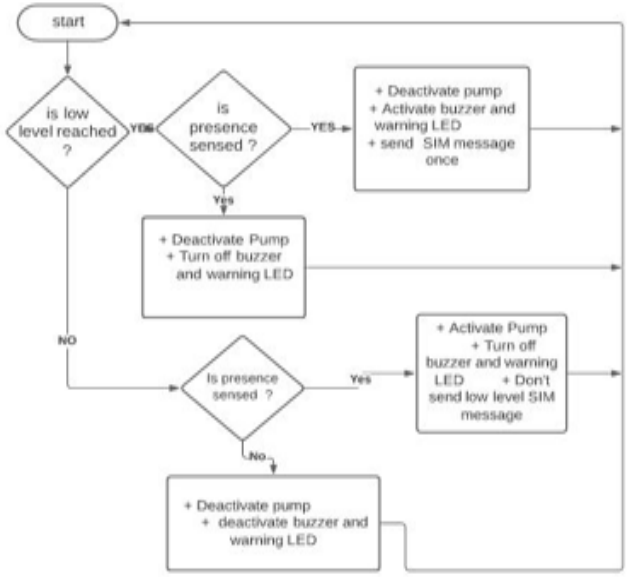

Figure 5: System flow chart

The smart hand sanitizer dispenser works whenever the ultrasonic sensor detects a low distance reading which occurs as a result of obstruction in its line-of-sight. It checks the existence of hands under the outlet of the dispenser, continuously calculates the distance between the sanitizer outlet and the sensed hand within the range of 10cm and sends a signal to the arduino. When, the arduino board receives a low distance reading, the sanitizer is dispensed by the instruction given to the servo motor to actuate and dispense the preset quantity. The result of the performance evaluation carried out shows that the time taken for the ultrasonic sensor to sense the presence of a hand is one second and the IR-sensor monitors the level of sanitizer in the container and sends an active signal to the arduino nano to activate the SIM800l module to send a message to the owner when the sanitizer level is at the minimum predefined level of 3cm. The complete circuit connection and test images of the implemented prototype are shown in Figures 6 and 7 respectively.

Figure 6: System circuitry image

Figure 7: System testing image

5. Conclusion

The smart hand sanitizer dispenser which was built using a microcontroller (Arduino nano) interfaced with two different sensors, ultrasonic sensor (HC-SR04) and an IR sensor. The ultrasonic sensor detects the presence of a hand within the distance of 10cm from the ultrasonic sensor. When the presence of a hand is sensed, a signal is sent to the Arduino Nano which serve as the major memory of the system to activate the dc pump for the discharge of the gel. The IR-sensor monitors the level of sanitizer in the container and sends an active signal to the Arduino nano to activate the SIM800l module to send a message to the owner when the sanitizer level is at the minimum predefined level of 3cm. The ultrasonic sensor senses the presence of a hand within a 10cm range in 1 second. After its development, it was tested and observed to meet the design requirements. Having successfully established a communication link between an automatic hand sanitizer dispenser and its indoor owner through a SIM module, this work has brought an innovation to hand sanitizing process with ease of management and seamless operation.

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