Design and Modeling of IoT-based Sterilization Box using UV-C Radiation

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Abstract. The design of the sterilization box is based on the ATmega2560 microcontroller which utilizes the concept of 254 nanometer UV-C shortwave radiation and disinfectant spray to increase the effectiveness of the sterilization box. In order to prevent transmission through touch from users through physical contact via sterilization box, researchers designed a system that can make users access sterilization box without the need to make physical contact with the device, namely by using IoT system with the help of applications that can be accessed through the user's smart device. Based on the results of the analysis and experiment that has been carried out, it is concluded that the sterilization box in this study can work optimally at a distance of less than 700 cm. This tool can operate using smartphone media via bluetooth HC-05 module, so it can minimize the process of spreading Covid-19 that occurs through physical contact.

Keywords: IoT-based Sterilization, UV-C Radiation, Covid-19

1 Introduction
In the new normal era, people are still facing the shadow of the Covid-19 virus, plus the number of people exposed is still increasing to this day. The spread of the virus occurs through direct and indirect contact. Transmission from direct contact can be in the form of touching the patient or it can be from objects exposed to the Covid-19 virus. From this, an inactivation medium is needed in order to kill viruses or pathogens on objects after use. The Covid-19 inactivation media will use short-wave UV-C light with a wavelength of 254 nanometers and a disinfectant spraying device to sterilize tools suspected of being exposed to pathogens.

The inactivation media comes from the design of the tool whose prototype has been tested for success. The design of the tool is used to sterilize everyday objects that are indicated to be exposed to viruses or bacteria such as PPE for medical personnel, cloth masks, clothing, shoes, cutlery, food delivery, money, and the like. That way, the possibility of spreading the Covid-19 virus can be minimized and even prevented through sterilizing objects before and after use. In addition, the use of UV-C sterilization is not limited to the Covid-19 virus, but can also be applied to sterilize medical surgical instruments, baby equipment, work equipment and others. This tool is designed using a Smartphone application using the Bluetooth module (HC-05) as a liaison between the smartphone application and Arduino.

2 Study literature

2.1 Ultraviolet germicidal irradiation (UV-GI)
UVGI modules are typically produced from low-pressure mercury lamps that emit light from 100–290 nm, typically at a wavelength of 254 nm. This wavelength is close to the wavelength that can kill bacteria, which is 265 nm [1]. Mercury lamps produce ozone as a by-product which is reactive oxygen that can inactivate bacteria. Studies have found that the disinfection time required to inactivate MS2 bacteriophages is much shorter with light sources emitting UV-C and combined ozone than with UV-C alone. This system is limited due to restrictions related to ozone emissions and the toxic effects of ozone on human health [1].

A study of N95 FFR infected with influenza A H1N1 found a reduction of 3 log after a UVGI dose of 1 J/cm2 was administered for 60–70 seconds. This dose has been supported by additional studies, and higher doses (> 1 J/cm2) provide reduced benefit. UV-GI has also been shown to effectively inactivate coronaviruses including severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV). This could be one potential explanation for the UV-C dose variation reported in the literature [1].
2.2 Arduino Mega 2560

ATmega 2560 is a microcontroller on ATmega 2560 which has 54 digital inputs/outputs of which 16 pins are used as PWM outputs, 16 analog inputs, and in it there is a 16 MHZ crystal oscillator, USB connection, power, ICSP, and reset button. This arduino performance requires microcontroller support by connecting it to a computer with a USB cable to turn it on using AC or DC current and can also use batteries [2].

Fig. 1. Arduino Mega.

2.3 Bluetooth module HC-05

The bluetooth module is a device that functions as a liaison between the android smartphone and the microcontroller (arduino) embedded in the module. HC-06 is an easy-to-use SPP (Serial Port Protocol) bluetooth module for wireless serial communication (wireless) that converts serial ports to bluetooth. This module can be used as either a slave or a master [3].

Fig. 2. Bluetooth HC-05 Module.

2.4 Relay

The relay functions as a controller for opening and closing electric currents that can be controlled by Arduino, the basic function of the relay is as a switch that is turned on by a Direct Current (DC) voltage. So, to turn on and off an Alternating Current (AC) flow object, a relay is needed that is connected to the Arduino [4]. The first part is connected to Normally Open or Normally Closed depending on the system you want to use [1]. Arduino is used to control relays to function via Bluetooth signal input.

Fig. 3. Relay.

2.5 Humidifier spray module

Humidifier spray module is a module for atomizers in UV-C media applications. This module has a working voltage of 5.0V (DC), a maximum power of 2 watts, a peak output voltage of 65 ± 5 V, an operating frequency of 105 ± 5 kHz.

Fig. 4. Humidifier Spray Module.

2.6 Piezo buzzer

Piezo is commonly used as a speaker that has a high-pitched sound output. Piezo is needed if Arduino is used in projects that require sound as an indicator [4]. Piezo works by utilizing a surging electric current which is then converted into vibrations and the vibrations propagate through the air (turning into sound). In its use, piezo is usually applied to home security alarms, fire alarms, weaker clocks, sensors for car parking and others.

Fig. 5. Piezoelectric Buzzer Module.

2.7 MIT App inventor

App Inventor is a very popular mobile device due to the availability of various applications easy-to-use mobile. Mobile applications have increased the interest of educators because they can facilitate teaching and learning [5]. To create applications mobile is a challenge for anyone with no previous programming experience. Several visual programming languages have been developed to address this challenge. MIT App Inventor is a visual block-based programming language. This is originally a product Google, but later released as open source software maintained by Massachusetts Institute of Technology. MIT App Inventor allows nonprogrammers to create mobile applications for devices running the Android operating system and capable of develop all kinds of applications, not just animation.

3 Research methods

This research uses literature study and quantitative data analysis. The quantitative data is obtained in the form of the range of the HC-05 bluetooth module which is tested along with the testing of application on the user's smartphone. Data collection was carried out on connection testing in the unobstructed state and in the unobstructed state.
3.1 Block diagram

- Android smartphone is used to display the control interface.
- HC-05 is used as a connection bluetooth module between the smartphone and the microcontroller.
- Arduino Mega is used as a microcontroller or the working brain of the tool system.
- UV-C Lamp and Humidifier Module are used as sterilization devices.
- LED and Buzzer are used as indicators of the sterilization box.

3.2 Flowchart

- Insert item you want to Sterilize
- Turn on the sterilization box through the app that has been installed on Smartphone
- Is the Red LED turn on?
- Wait for the Sterilization start to working for 3 minutes

3.3 Hardware designing

The hardware design uses the ATmega2560 microcontroller as the main control device, the relay is used to allow electricity to flow to the UV-C lamp and the humidifier spray module which both work as the main components in the sterilization process, the buzzer and LED are used as an indicator of the status of the sterilization box and for connection with. The user uses the HC-05 bluetooth module which connects the Arduino Mega control unit with the user.
3.4 Software designing

This android application is designed using the App Inventor tool as an application builder. App Inventor is an application builder to create applications that run on the android operating system provided by googlelabs. The design of this application involves the connection between the HC-05 bluetooth module which is connected to the microcontroller and bluetooth from the user's android smartphone.

4 Result and testing

4.1 Software testing

The Application testing is begins by activating the HC-05 bluetooth which is connected to the microcontroller and power source, after the HC-05 bluetooth module is active, open the application that was created earlier.

Press the yellow button with "PKM-KC" name, at the top then select the HC-05 option to connect the HC-05 bluetooth module with the program in the application.

Press the green button to activate the sterilization box and press the red button to force the sterilization box to turn off.
4.2 Hardware testing

The test was carried out using the ATmega2560 microcontroller according to the schematic design. The process starts after the Bluetooth of the user's smartphone is connected to the HC-05 Bluetooth module through the application. After the application is connected, the cabinet is ready to use.

![Fig. 15. Hardware Testing.](image)

The sterilization process starts with the user pressing the green button on the application to start the sterilization process which begins with the buzzer indicator giving a sound signal and the red LED lights up as a sign that the sterilization box has worked with the UV-C lamp turn on and the humidifier module start spraying disinfectant. The process runs for 3 minutes and ends with a buzzer that gives a return signal and the Green LED lights up indicating the cabinet can be opened and the sterilization process is complete. The red button on the application can be used as an emergency termination of the sterilization process if something unexpected happens.

4.3 Data collecting

This experiment was conducted to determine the range of the HC-05 Bluetooth module to the Bluetooth Smartphone connection. This experiment is carried out with different treatments, Table 1 shows the test given the treatment without any barrier in between and the table 2 shows the test given the treatment with a 16 cm barrier of a wall in between.

**Table 1. Transmission test without any obstruction in between.**

| No | Distance (cm) | Experiment |
|----|---------------|------------|
|    | E1 | E2 | E3 | E4 |
| 1  | 100 | YES | YES | YES | YES |
| 2  | 200 | YES | YES | YES | YES |
| 3  | 300 | YES | YES | YES | YES |
| 4  | 400 | YES | YES | YES | YES |
| 5  | 500 | YES | YES | YES | YES |
| 6  | 600 | YES | YES | YES | YES |
| 7  | 700 | YES | YES | YES | YES |
| 8  | 800 | YES | YES | YES | YES |
| 9  | 900 | NO  | YES | YES | YES |
| 10 | 1000 | NO | NO | NO | NO |

From the experiment in table 1 it can be seen that the Bluetooth HC-05 module can receive information from a bluetooth smartphone well up to a distance of 800 cm, then at a distance of 900 cm a connection failure begins, as shown in experiment 1 which failed even though the next experiment was successful, then at a distance of 1000 cm to 4 experiments failed which showed that the HC-05 bluetooth module failed to receive information from the bluetooth Smartphone.

**Table 2. Transmission test with 16 cm wall barrier of wall in between.**

| No | Distance (cm) | Experiment |
|----|---------------|------------|
|    | E1 | E2 | E3 | E4 |
| 1  | 100 | YES | YES | YES | YES |
| 2  | 200 | YES | YES | YES | YES |
| 3  | 300 | YES | YES | YES | YES |
| 4  | 400 | YES | YES | YES | YES |
| 5  | 500 | YES | YES | YES | YES |
| 6  | 600 | YES | YES | YES | YES |
| 7  | 700 | YES | YES | YES | YES |
| 8  | 800 | YES | NO | NO | NO |
| 9  | 900 | NO  | NO | NO | NO |
| 10 | 1000 | NO | NO | NO | NO |

From table 2 testing with a 16 cm barrier of wall in between, it can be seen that the Bluetooth HC-05 can receive information from a Bluetooth Smartphone well up to a distance of 700 cm, then at a distance of 800 cm a connection failure begins, as indicated by experiment 1 which was successful and the next experiment occurred failure, then at a distance of 900 cm to 4 experiments a failure occurred which showed the HC-05 failed to receive information from the Bluetooth Smartphone.

5 Conclusion

Based on the process of design, manufacture, observation and test results, several conclusions can be drawn for the progress, improvement and development of the application of this system. the following conclusions can be drawn:

- The Arduino Mega 2560 Microcontroller module can function properly as the main control device that has uses to control UV-C lights, Humidifiers, Buzzers, indicator lights, and Bluetooth HC-05.
- Bluetooth HC-05 works well shown in the connection test against distance, found that Bluetooth HC-05 is effective at a distance of 800 cm from a Bluetooth Smartphone, while if given a barrier the Bluetooth connection HC-05 is effective at a distance of 700 cm from a Bluetooth Smartphone.
- Software and programs to control UV-C lamps, Humidifiers, Buzzers, indicator lights, and Bluetooth HC-05 can function properly according to
the time and response required without malfunctions or program failures.

- Applications on smartphones, namely App Inventor, can function as shown by connecting the HC-05 Bluetooth and display interfaces that can work according to their functions.

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