# The Potential Use of the Microcontroller-based Automated Disinfection Device (MADD) in Eliminating Bacteria in Fomites

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***Abstract-*** Ultraviolet (UV) radiation has been utilized as a germicidal or disinfectant for many years, particularly in the medical industry. With its potential to eliminate bacteria among fomites or any inanimate object that, when contaminated with or exposed to infectious agents, can transfer disease to a new host like parcels, the study on developing and designing a Microcontroller-based Automated Disinfection Device (MADD) using Arduino that can help eliminate bacteria found on parcels received by online shoppers was conducted during the first semester of the Academic Year 2020-2021 at Quezon City University (QCU). An evolutionary prototyping technique was adopted in developing and testing the MADD. The results show that MADD is durable, efficient, functional, and useful when it comes to disinfecting bacteria found on the surfaces of selected objects. The study concludes that aside from its present use, the microcontroller is useful when developing a technology like MADD, and it can be maximized when it is combined with other devices like the UV C light lamp to disinfect surfaces and objects that are possible carriers of disease-causing agents. Since MADD uses C++ programming language, it is suggested that using other programming languages may improve the device's efficiency. And lastly, improvement on MADD's over-all design and disinfecting ability is highly recommended.

***Index Terms***- Microcontroller-based device, Disinfection device, Ultraviolet radiation disinfection, Fomites, Bacterial disinfection

## I. Introduction

For many years, ultraviolet (UV) radiation has been used as a germicidal or disinfectant, most notably in the medical industry (Reed, 2010). UV lights have been shown in studies to have germicidal properties, which means they kill bacteria and microbes (Levetin, et al. 2001). UV light technology has been used for disinfection purposes for centuries (Menzies, et al. 2003).

Ultraviolet Lights come in a variety of types and are used for a variety of purposes: Ultraviolet A, Ultraviolet B, and Ultraviolet C are the most commonly used in the industry (Hockberger, 2002). Ultraviolet A is a type of ultraviolet light that is less harmful than Ultraviolet B, but approximately 1,000 times less effective than Ultraviolet B and Ultraviolet C, which can cause skin aging and increase the risk of developing unusual skin cancer (Hockberger, 2000). While ultraviolet B is effective at inactivating SARS viruses, it is significantly less effective than ultraviolet C and significantly more dangerous to humans (Reed, 2010; Hockberger, 2002; Hockberger, 2000). UVB radiation is capable of penetrating the skin and eye. This type of Ultraviolet B has the potential to damage deoxyribonucleic acid (DNA), making it one of the risk factors for skin cancer and cataracts. While ultraviolet C is commonly used to disinfect air, water, and nonporous surfaces, it has been used to prevent the spread of bacteria (tuberculosis) for decades and is referred to as germicidal (Beggs, 2006).

SARS-CoV-2, the virus that causes Covid19, is an enveloped virus, which means that its genetic material is enclosed within a protein and lipid outer layer. The envelope contains spike proteins that allow the virus to attach to human cells during infection. SARS-CoV-2, like other enveloped respiratory viruses, has a labile envelope that degrades rapidly when exposed to surfactants found in cleaning agents and under certain environmental conditions. The risk of fomite-mediated transmission is proportional to the community's infection prevalence rate. the amount of virus that infected people expel, the deposition of expelled virus particles onto surfaces (fomites), which is affected by air flow and ventilation, the interaction of virus particles with environmental factors that cause damage to virus particles while airborne and on fomites, the time interval between when a surface becomes contaminated and when a person touches it, the efficiency of virus particle transfer from fomite surfaces to hands and from hands to mucous membranes.

Due to the numerous variables that influence the efficiency of environmental transmission, the relative risk of fomite transmission of SARS-CoV-2 is considered low in comparison to direct contact, droplet transmission, or airborne transmission (Kampf, et al. 2020; Meyerowitz, et al. 2020). However, the proportion of SARS-CoV-2 infections acquired via surface (fomite) transmission is unknown (Kampf, et al. 2020; Meyerowitz, et al. 2020). There have been a few reports of Covid19 cases that may have been transmitted via fomite. Often, infections can be traced back to multiple transmission pathways. Transmission of fomite is difficult to establish conclusively, in part because respiratory transmission via asymptomatic individuals cannot be ruled out (Bae, et al. 2020; Cai, et al. 2020; Xie, et al. 2020). According to case reports, SARS-CoV-2 is spread between people by touching surfaces where an ill person has recently coughed or sneezed and then touching the mouth, nose, or eyes directly (Bae, et al. 2020; Cai, et al. 2020; Xie, et al. 2020). Hand hygiene acts as a barrier to the transmission of fomite and has been linked to a decreased risk of infection (Doung-Ngern, et al. 2020).

Quantitative microbial risk assessment (QMRA) studies have been conducted to characterize and understand the relative risk of SARS-CoV-2 fomite transmission, as well as to determine the need for and effectiveness of risk reduction measures. These studies' findings indicate that the risk of infection with SARS-CoV-2 via the fomite transmission route is low, generally less than 1 in 10,000, which means that each contact with a contaminated surface has a less than 1 in 10,000 chances of causing an infection (Wilson, et al. 2020; Harvey, et al. 2020; Pitol & Julian, 2020). Certain studies estimated exposure risks primarily by analyzing SARS-CoV-2 RNA quantification data from outdoor environments. They noted that their QMRA estimates are subject to uncertainty, which can be reduced by increasing the accuracy and precision of the data used in the models. Outdoor surfaces should have lower infectious SARS-CoV-2 concentrations than indoor surfaces due to air dilution and movement, as well as harsher environmental conditions such as sunlight. Additionally, one QMRA study evaluated the effectiveness of prevention measures for reducing the risk of fomite transmission and discovered that proper hand hygiene can significantly reduce the risk of SARS-CoV-2 transmission from contaminated surfaces, whereas daily surface disinfection had little effect on reducing estimated risks (Pitol & Julian, 2020).

Globally, the Covid19 pandemic has caused crisis and suffering, affecting commerce and trading, as people are fearful of venturing outside their homes to purchase necessities in order to avoid virus infection. With the rise of online shopping and delivery, disinfection becomes a necessity. Currently, a manual disinfection process is used globally, which involves spraying alcohol on the surface and wiping it clean with a clean towel. Online shopping and delivery have become popular and disinfecting the area where packages or parcels are received has become a common practice. The Department of Health (2020) issued Memorandum No. 2020-0157, which contains guidelines for cleaning and disinfecting in a variety of settings as a means of infection prevention and control against Covid19.

According to the guideline, disinfectants such as 70% ethyl alcohol and a strong bleach solution can be used to combat bacteria and viruses that cause Covid19, and it is recommended to mop or wipe surfaces directly or spray disinfectants directly on them. This technique has been implemented and is in use.

With the potential for UV light to kill bacteria on fomites or any inanimate object that, when contaminated or exposed to infectious agents, can transmit disease to a new host, such as parcels, the development of devices for disinfecting surfaces and other objects that can transmit bacterial or viral-causing diseases has become a trend. Microcontrollers are used in a wide variety of applications and systems (Hsiung, 1992). Multiple microcontrollers are frequently used in devices to perform specific tasks, such as an automated disinfection device (Hsiung, 1992).

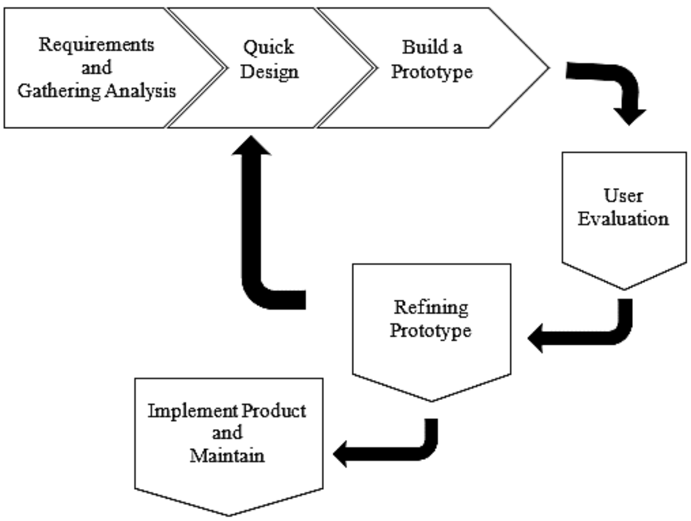
Hence, research into the development and design of an automated disinfection device is necessary. Thus, the primary goal of this study is to develop a Microcontroller-based Automated Disinfection Device (MADD) based on the Arduino platform that is durable, efficient, functional, and useful for disinfecting and eliminating bacteria found on the surfaces of parcels received by online shoppers.

## II. METHODOLOGY

For many years, ultraviolet (UV) radiation has been used as a germicidal or disinfectant, most notably in the medical industry. With the potential to eradicate bacteria from fomites or any inanimate object that, when contaminated or exposed to infectious agents, can transmit disease to a new host, such as parcels, the study on developing and designing a Microcontroller-based Automated Disinfection Device (MADD) using Arduino that can assist in the elimination of bacteria found on parcels received by online shoppers was conducted during the first semester of the Academic Year 2020-2021 at Quezon City University (QCU).

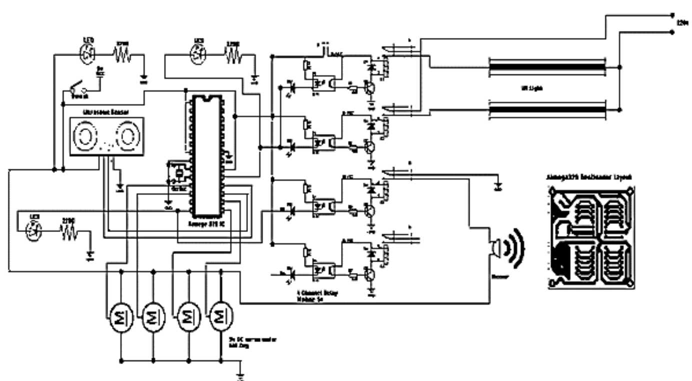
To address the objectives of the study, the evolutionary prototyping technique was adopted in developing and testing the Microcontroller-based Automated Disinfection Device or MADD. Figure 1 shows the prototyping model used in the study.

**Figure 1**. Prototyping Model




The first stage of the process in developing the Microcontroller-based Automated Disinfection Device (MADD) involves the identification of the existing needs, problems and formulating the objectives. After the needs, problems and objectives were clearly identified, the researchers come up with the design of the model which primarily helped them to visualize the final output. This stage is known as the quick design phase of prototyping, at this point, the researchers did the layout of the design of the model and made a sketch where each component of the model would be placed. Also, in this phase the researcher created a circuit diagram design (see figure 2) to describe and show how each component would be interfaced in the circuit board and to other parts of the prototype.

**Figure 2**. Schematic Circuit Diagram



As shown in figure 2, the components of the MADD were interfaced and connected properly. The signal input of servo motors in pairs are connected to ATmega328 microcontroller to open the doors of the device, and the UV lamp and buzzer were connected to the relay module, which is connected to ATmega328 microcontroller to switch it on once the parcel is inside the device.

Software development of the device was also included in building the prototype. The primary function of the program is to initiate the disinfection process by animating the device itself with the help of sensor recognition, ATmega328 microcontroller, and UV light lamp. The program used was C++ using Arduino IDE. Arduino IDE supports programming languages C and C++. The proponents decided to use the C++ among the programing languages supported by Arduino IDE. Studies shows that C++ being one of the programming languages supported by Arduino Programming Language based on performance is way better than C language in terms of speed, compatibility, memory and point of emphasis. The process flowchart that guided the entire process involved within the device is presented in figure 3.

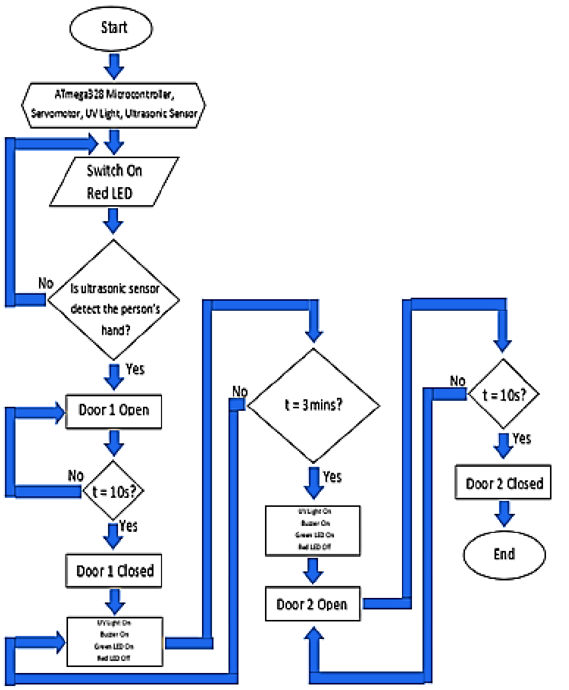
Figure 3 shows that the components involved in the processes were the ultrasonic sensor, servo motors, relay modules and the UV light lamps. The input signal comes from the ultrasonic sensor and it sends to ATmega328. If signal received does not satisfy the condition, it will repeat the loop until the condition satisfies and proceed to the next condition and execute the disinfection.

After the prototype development, the users evaluated the device in terms of its functionality and usefulness when it comes to disinfecting bacteria.

The device is supposed to achieve a 90 to 95% functionality rate. The researchers tested the device’s the functionality of the switch to determine whether the sensor responded and recognized the items upfront. During the process of the evaluation, the researcher inspected the device whether the servo motors responded to inanimate the device's doors and observed if the relay module reacts to turn on the UV light and the buzzer. In addition, the researchers observed the LED light indicator to determine if the ATmega328 microcontroller processed the programming language embedded to it and if the UV light is working properly.

The switch was tested if it allowed a sufficient power supply to flow through the device. And then the sensors were tested if they were recognizing the item accordingly. The servo motors were tested if they responded as quickly as one second to open the doors of the device from zero to one hundred degrees within ten seconds and close after the same time frame. Furthermore, the relay module was tested if it reacted accordingly by switching on and off the UV light and the buzzer. Also, the microcontroller was tested if it controlled the required operations in the system. And lastly, the UV light was tested if it responded properly when the microcontroller sends the signal to the relay module by switching it on.

**Figure 3**. The Process Flowchart




To check the functionality of the system, they conducted multiple tests to validate that the module, sensors, and components of the system were functional.

To determine usefulness of the device in terms of eliminating bacteria in fomites, the third author conducted a bacterial analysis using bacteria gram staning technique before and after the parcel and other objects placed in the device. There were four samples placed inside the device labeled as SP1 for the surface of online shopping bag, SP2 for the surface of a Twenty Peso bill, SP3 for the surface of a ballpoint pen (SP3), and SP4 for the surface of a face shield commonly used as personal protective device to Covid19 virus. The number of bacteria present in fomites of these samples were tested and compared before and after to establish how MADD is useful in eliminating bacteria in fomites.

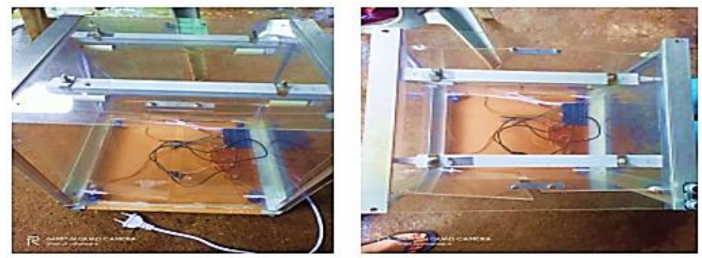
After the user's evaluation phase, the prototype was refined. At this stage, suitable adjustments were made based on the results of the evaluation phase. And lastly, in the final stage of the prototype development, the final output was deployed, operated, and maintained for use.

## III. RESULTS AND DISCUSSION

### Microcontroller-based Automated Disinfection Device (MADD)

The developed Microcontroller-based Automated Disinfection Device (MADD) is shown in the figure 4. The prototype is mainly composed of ultrasonic sensor, servo motor, relay, switch, and ultraviolet light. The ultrasonic sensor is interface with the microcontroller, once triggered, it will position the servo motor to ninety degrees, opening the front door. The front door remains open within 10 seconds and close afterwards. After the door closes, the ultraviolet light lamp will be turned on and emit light for disinfection process. Once the disinfection process is done, the back door of the device will open, and the user can pull out the parcel inside the device.

**Figure 4**. Microcontroller-based Automated Disinfection Device (MADD)



### Assessment of the Microcontroller-based Automated Disinfection Device (MADD)

The functionality test used to check the ultrasonic sensor, servo motor, relay module, LED indicators, Atmega328 microcontroller and UV light revealed that these components are functional. Table 1 shows the result of the functionality test performed to the different components of the device.

The results showed that all the components of the MADD gained a positive remark, thus the push button switch, ultrasonic sensor, servo motor, relay module, ATMEGA 328 microcontroller, UV light and the buzzer found in the device were all functional.

Specifically, by pressing the switch on, the device automatically turned on, and when the evaluator pressed the off button, the device automatically turned off. In the actual test, the device successfully detected the hand of the user 5cm away from it. The distance primarily sensible to achieve contact less process when inserting the parcel or products inside the device. In addition, the device did not open when the hand of the user is beyond the 5cm distance from the detector.

**Table 1**. Summary of the Functionality Test to the Components of MADD

| Components and Modules | No. of Functional Requirements | Test Case | Remarks |
|---|---|---|---|
| Push-button | 1 | 10 | Passed |
| HC-SR04 | 1 | 10 | Passed |
| SG90 Micro | 4 | 10 | Passed |
| 4 Channel | 1 | 10 | Passed |
| LED | 3 | 10 | Passed |
| ATmega328 | 1 | 10 | Passed |
| UV Lamp | 1 | 10 | Passed |
| Buzzer | 1 | 10 | Passed |

Furthermore, the actual test shows that the door of the device successfully opened and closed using servo motor from 0 degree to 100 degrees and vice versa. And in terms of the relay module of the device, the actual test shows that the relay module successfully operates and controls the buzzer and UV light by turning it on and off.

The LED light indicator test revealed that the green and red LEDs are turned on and off successfully by the microcontroller. And being the brain of the device, the ATmega328 microcontroller via C++ program, successfully sends signals to the relay module, servo motor, and LED-based on the program. And lastly, during the actual test, the UV light automatically turned on as well as the buzzer when the object is placed inside the device and turned off immediately after three minutes, to completely disinfect the object. Based on the studies, the duration of the exposure of the object under UV light allows to disinfect the object completely.

Since the device is a microcontroller based, it allows MADD to execute sequence of instructions and process that will enable to disinfect fomites of selected samples used in the study. The ATmega328 microcontroller used in the device was able to perform the expected task. The results supported the claim of Hsiung in 1992 that microcontrollers like the ATmega328p microcontroller completely perform specific tasks, such as disinfecting the surfaces of the samples specifically and accurately. Furthermore, the results show how the ultrasonic sensor allows the device to open its door from zero to ninety degrees with servo motor, which able to detect objects at a certain distance, that allows contactless feature of the device.

**Usefulness of the Microcontroller-based Automated Disinfection Device (MADD) on Eliminating Bacteria in Fomites**

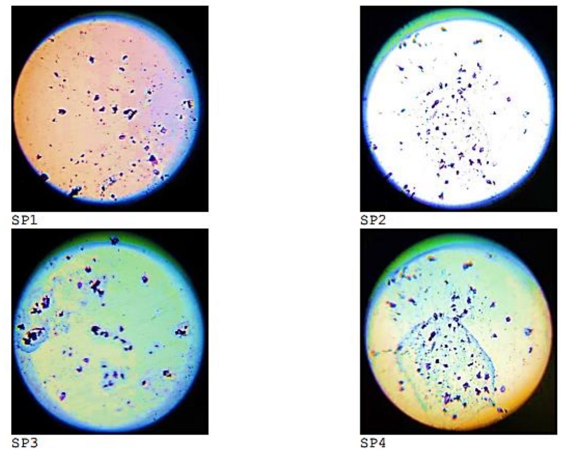
Results show that the developed Microcontroller-based Automated Disinfection Device (MADD) is useful on eliminating bacteria in fomites.

**Table 2**. Results of the Bacterial Staining Technique to the Samples Before Using MADD

| Sample | Presence/Absence | Quantity | Morphology | Type |
|---|---|---|---|---|
| SP1 | Present | Many | rod (bacilli) | Gram + |
| SP2 | Present | Many | spherical (cocci), rod (bacilli) | Gram + Gram - |
| SP3 | Present | Many | rod (bacilli) | Gram + |
| SP4 | Present | Many | spherical (cocci), rod (bacilli) | Gram + Gram - |

As shown in Table 2, the surface of the sample materials being tested shows the presence of gram-positive and gram-negative bacterial cells in a cluster/group as elaborated in figure 4.

**Figure 4**. Bacterial Presence in Fomites of the Samples Before the Use of Microcontroller-based Automated Disinfection Device (MADD)



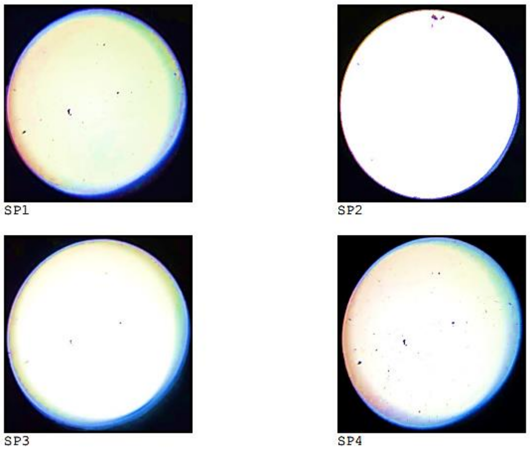

On the other hand, Table 3 shows the results of the bacteria gram staining technique on the surfaces of the samples after they were exposed to UV light using MADD.

**Table 3**. Results of the Bacterial Staining Technique to the Samples After Using MADD

| Sample | Presence/Absence | Quantity | Morphology | Type |
|---|---|---|---|---|
| SP1 | Present | Few | rod (bacilli) | Gram + |
| SP2 | Present | Few | spherical (cocci) | Gram + |
| SP3 | Absent | None | rod (bacilli) | Gram + |
| SP4 | Present | Few | spherical (cocci), rod (bacilli) | Gram + Gram - |

Table 3 revealed that the surface of the sample materials being tested shows a presence to none of mostly gram-positive and some gram-negative bacterial cells in a cluster or group as elaborated in figure 5.

**Figure 5**. Bacterial Presence in Fomites of the Samples After the Use of Microcontroller-based Automated Disinfection Device (MADD)




The above results confirm and support previous studies about the use of UV light as germicidal or disinfectant (Reed, 2010). The comparison between the results of the gram staining technique on fomites of selected samples shows that UV lights have germicidal properties, which can eliminate bacteria and microbes (Levetin, et al. 2001). Furthermore, the results confirm that UV light technology can be used for disinfection purposes (Menzies, et al. 2003).

## IV. CONCLUSION

The study concludes that aside from its present use, the microcontroller is useful when developing a technology like the Microcontroller-based Automated Disinfection Device (MADD), and it can be maximized when it is combined with other devices like the UV light lamp to disinfect fomites of objects that are potential carriers of disease-causing agents. Since MADD uses C++ programming language, it is suggested that using other programming languages may improve the device's efficiency. And lastly, improvement on MADD's over-all design and disinfecting ability is highly recommended.

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