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The effect of UV- Bacteria Exposure Distance in Cleaning Process by Using UV Remote Controlled-Sterilization Robot

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Abstract

This robot is made to be a room sterilizer from bacteria and viruses. Robots can sterilize a room by utilizing radiation generated by ultraviolet lights. Radiation from ultraviolet lamps has been proven to kill bacteria and viruses. The robot can be controlled remotely by using the remote control as its main control by utilizing Arduino Nano as the microcontroller so that it can still ensure user safety when operating the robot. Because this robot is controlled remotely, the robot is equipped with a camera module used as the eye of the robot to monitor the path to be traversed by the robot connected to the Smartphone using a wireless protocol. There are two ultraviolet lamps installed on this robot. The sterilization method is done by placing the robot in one room with a distance of 50cm, 100cm and 150cm against the bacterial sample for 15 minutes of irradiation. The results showed a relationship between the reduction in the number of bacteria in the room with the distance to the robot in the same length of time of exposure

Keywords:
Bacteria Cleaning, Microcontroller, Ultraviolet Lamp, Robot

1 Introduction

Corona virus disease 2019 (COVID-19) is a respiratory disease caused by a virus that is transmitted via droplets through close contact with an infected individual. These droplets (e.g. from coughs, sneezes and body fluids) may land on objects and surfaces around the person. Other people may become infected by touching these contaminated objects or surfaces and then touching their eyes, nose or mouth [1].

Research conducted on 3 COVID-19 patients in airborne infection isolation rooms in Singapore showed that from 26 surface points used as test samples, after testing on day 2, it showed that 87% of the 26 surface points were positively contaminated with SARS-CoV-2 [2]. This indicates that the virus can survive on the surface of an object for a long time. So to avoid direct transmission of the virus and bacteria, room surfaces should be regularly sterilized and disinfected to inhibit indirect transmission from that place and to eliminate or reduce the contamination of microorganisms (including COVID-19) both attached to objects (equipment), floor or air [3].

Ultraviolet light-based sterilization methods have long been used because of their high germicidal effect on a broad spectrum of microorganisms [4]. Traditionally, sterilization using ultra-violet light has been used with either a continuous monochromatic low-pressure mercury lamp at 254 nm or a continuous polychromatic medium pressure mercury lamp, both of which require application over long periods with low average peak power to achieve significant inactivation effects [5]–[7]. Sterilization by ultraviolet is environmentally friendly and becomes an effective sterilizer for disinfection [8], [9]. Ultraviolet light can deactivate bacteria, viruses, and protozoa [10]–[12]. Ultraviolet light also can be an effective measure for decontaminating surfaces that may be contaminated by the virus responsible for COVID-19, SARS-CoV-2 Virus [13]–[15]. Absorption of ultraviolet radiation by proteins, RNA, and DNA can cause cell death and mutation. Therefore, ultraviolet light can be used as a disinfectant [7], [11].

In carrying out sterilization using ultraviolet light, it is not allowed the rays from UVC hit human skin or eyes because of the strong radiation influence [16]–[18]. The risk of interaction between the medical team and the virus is considered immense reducing the risk requires a method or tool that can effectively disinfect and sterilize remotely [3]. Therefore, the role of remote robots in this method of sterilization using ultraviolet lamps is needed [19]. Robots can move freely without worrying about radiation generated by ultraviolet rays, and robots can replace humans to enter areas that are too dangerous [20]–[22]. The purpose of this study was to determine the effect of exposure to ultraviolet light contained in the robot on the reduction of bacteria in the sample in the room with several experiments using the distance between the robot and the bacterial sample and the length of time of exposure.

2 Materials and methods

2.1 Materials

In making a sterilization robot using ultraviolet light, there is a remote control as the robot controller and the robot body as the main robot [19].

2.1.1 Remote Control

Wi-Fi wireless technology can be used to exchange data with other electronic devices. It is possible to create other ecosystems and manufacturers of various constructions; the kit uses Wi-Fi wireless technology as a remote control. The construction kit contains a servo motor, camera, proximity sensor or light control [23]. The remote control block diagram is shown on Fig.1.

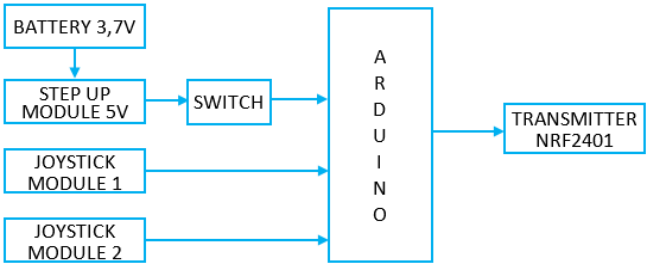

Fig. 1. Block Diagram of Remote Control

Fig.1. explains that Arduino nano will receive commands from the joystick module as input from Arduino, and then Arduino nano will activate the wireless module as a communication medium that functions as a transmitter. The Material design for robot remote control is shown in fig. 2. This remote control utilizes the frame of the Playstation3 joystick. Fig 3. and Table 1. describe a series of each component used on the remote control.

Fig. 2. Remote control of sterilization robot Design

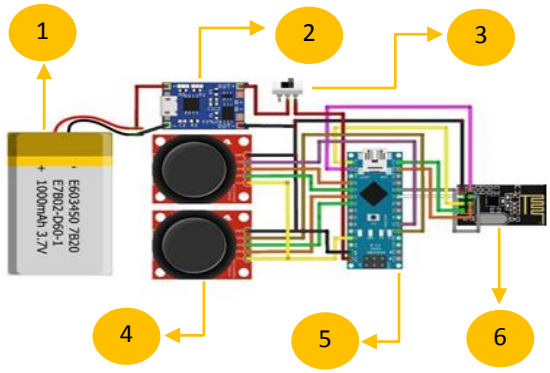

Fig. 3. Remote Control Circuit

Table 1. Remote Control Component Specification based

No	Component Specification
1	Battery lithium polymer 3.7V
2	Module Kit Power Bank LI-ION Charger TP4056
3	Switch
4	Joystick module
5	Microcontroller (Arduino Nano)
6	Communication module (NRF24L01)

2.1.2 Sterilization Robot

Fig. 4, explain that the wireless module will receive (Receiver) commands from the transmitter and then send commands to the Arduino Nano. From this command, Arduino will activate the motor driver. The motor driver will drive the 12 V DC motor following the commands that have been received. DC1 motor functions to move the right wheel, DC2 motor functions to move the left wheel. Arduino will also activate a relay connected to an ultraviolet lamp as a sterilization lamp.

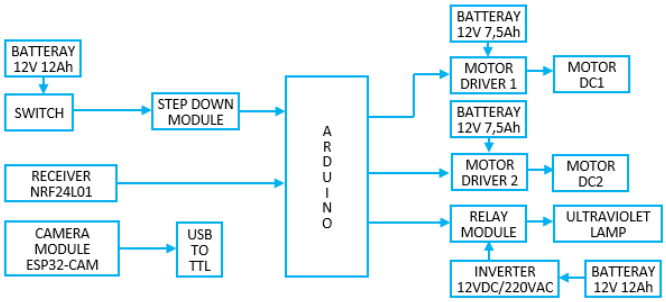

Fig. 4. Block Diagram of Sterilization Robot

The camera module is used as the eye of this robot to monitor the path that will be traversed by the robot connected to a Smartphone using a wireless protocol. The material design for the robot is shown in fig. 5.

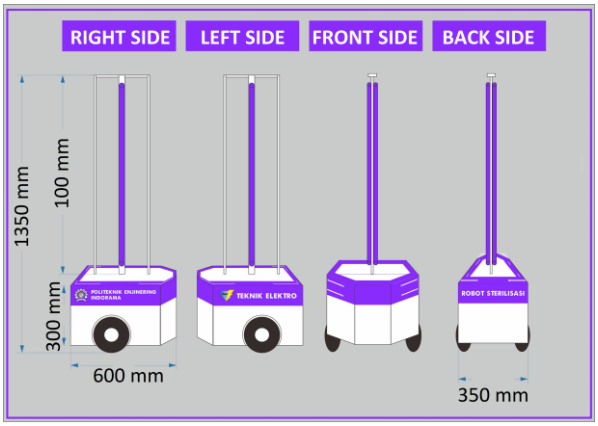

Fig. 5. Material Design of Remote Controlled-Sterilization Robot

2.1.3 Robot Specification

Specifications for a room sterilizing robot using ultraviolet lights is shown in Table. 2.

Table 2. Sterilization Robot Specification

Mechanical Component	Specification
Robot Weight	28 Kg
Remote & Robot Controller	Arduino Nano
Robot Size	60cm x 35cm x 135cm
Frame material	Galvanized Iron Plate 0.6 mm
Back Wheel	8 inch plastic wheel
Front Wheel	3 inch plastic wheel

2.1.4 Robot Circuit Schematic

Fig. 6 describes and Table 3. a series of each component used in the robot body.

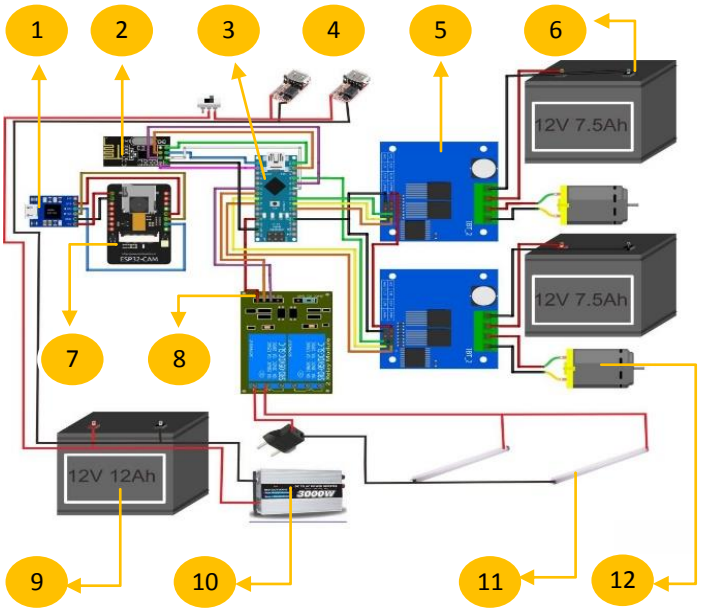

Fig. 6. Circuit of Stylization Robot

Table 3. Component of Robot Specification

No	Component Specification
1	USB to TTL Module
2	NRF24L01 Module
3	Microcontroller Arduino Nano (Atmega328P)
4	Step Down Module 12 V to 5 V
5	Motor Driver BTS7960 IBT-2
6	Dry Battery 12 V 7,5Ah
7	Camera module ESP32-CAM
8	Relay Module 5V/220V-10A
9	Dry Battery 12 V 12Ah
10	Inverter Power 3000W 12 VDC to 220 VAC
11	UV Lamp OSRAM HNS 30W 96V G13 7800cd
12	DC Motor 40 RPM 12 VDC

2.1.5 Robot Algorithm Flowchart

The input and output programming structure of this robot can be seen in Fig. 7, when the communication module (NRF24L01) receives a signal from the remote control (NRF24L01) then Arduino will process it and then issue a signal on the pin that has been declared in the program.

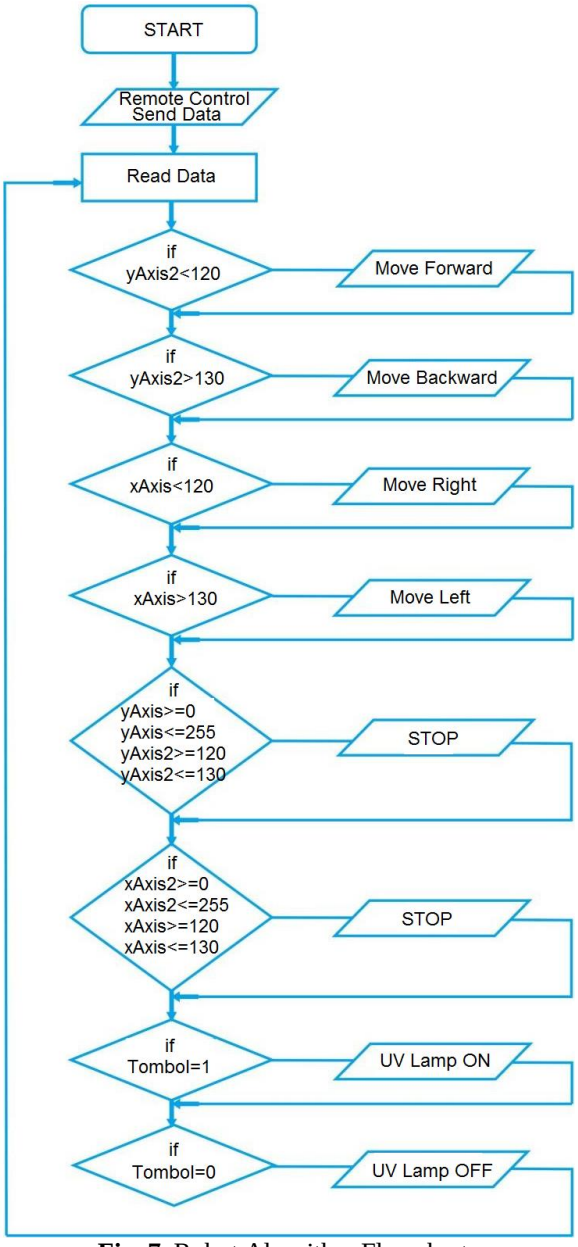

Fig. 7. Robot Algorithm Flowchart

2.2 Methods

2.2.1 Research Procedure

Fig. 8 decribes steps in conducting the study on the proposed robot.

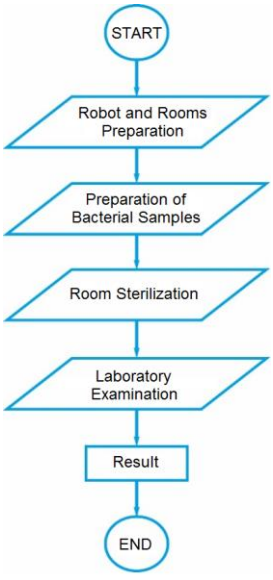

Fig. 8 Research Procedure Flowchart

2.2.2 Preparation of sterilization robots and rooms

Preparing the sterilization robot is by trying the movement and function of each robot component, namely: 1. Remote control. 2. Robot camera. 3. Robot movement (DC motor). 4. UV lamp. 5. Relay. 6. Robot speed. After the robot succeeds in carrying out some of these experiments, the robot is ready to sterilize the room. The room used for this research is the workroom. The workspace is prepared by turning off all available lighting sources to maximize the performance of this sterilizer robot. After the robot sterilization assembly has been successfully assembled and then tested, the following performance is obtained:

2.2.2.1 Communication Distance

Simulation that is planned of controlled remote control distance can be seen in Table 4.

Table 4. Comparison of communication ranges without and with barriers

Reach (m)	without a barrier	with a barrier
10	Connected	Connected
20	Connected	Connected
30	Connected	Connected
40	Connected	Connected
50	Connected	Connected
60	Connected	Connected
70	Not Connected	Not Connected
80	Not Connected	Not Connected

2.2.2.2 Camera

This camera test is in the form of testing the live streaming range of the camera. The camera can be accessed using a Smartphone provided that one server/network with the ESP32-Cam is used. In this test, the internet network uses a hotspot from a Smartphone. Using this hotspot, the maximum distance video from a camera that can be reached is 30 meters (Table 5).

Table 5. Testing the live streaming range of the camera.

Reach (m)	Hotspot	Wi-Fi	Visualization
10	Connected	Connected	Clear
20	Connected	Connected	Clear
30	Connected	Connected	Clear
40	Not Connected	Not Connected	Not Connected
50	Not Connected	Not Connected	Not Connected

2.2.2.3 DC Motor Measurements

In DC motor measurements, when the wheel is supported (not touching the ground) and when the wheel touches the ground (with a load) will be different. Measurement results (Current, Voltage and Power) on DC motor wheels based on the test results are presented in the table 6.

Table 6. Measurement current, voltage and power of DC Motor

	No Load (Wheels propped up)			With a load (The wheel hits the ground)		
	(V)	(A)	(W)	(V)	(A)	(W)
Wheels	12	1.65	19,8	12	2.52	30.24

2.2.2.4 Robot Speed

Robot speed testing measures the robot's travel time against a given distance. Based on the value obtained from the test results, the robot's speed can be seen whether the robot's speed remains stable over the distance travelled. Table 7 shows the results of the robot speed test.

Table 7 .The speed test on a straight line on the floor

No.	Reach (m)	Time (s)	Speed (m/s)
1	1	2.8	0.36
2	2	5.6	0.36
3	3	8.4	0.36
4	4	11.2	0.36

2.2.3 Preparation of bacterial samples

Preparation of this bacterial sample by preparing a plate to catch room bacteria. There are four plates used. One plate was used for data on the number of bacteria before being exposed to ultraviolet. At the same time, three plates were used for data on the number of bacteria after being exposed to ultraviolet. After the plates to be used are available and the room is ready for sterilization, the following procedures are 1. Each plate is left to rest at room temperature for two hours to find out how many bacteria are at room temperature. 2. Bacterial samples are stored in a storage box with ice to maintain the plate temperature.

2.2.4 Implementation of room sterilization

The implementation of room sterilization is done by:

1. The robot is placed in the room that has been prepared. (the robot is in a fixed position for 15 minutes).
2. 3 pieces of bacterial samples were placed in a room with a distance of 50cm, 100cm, and 150cm to the robot to find out how effective the ultraviolet exposure distance is on bacterial reduction.
3. Duration of ultraviolet exposure is 15 minutes [24].
4. During the process of ultraviolet exposure to bacterial samples, the room is closed and it is not allowed to enter the room [21].
5. After the sterilization process or ultraviolet exposure to the bacterial sample is complete, the bacterial sample is again stored in the storage box.

2.2.5 Laboratory examination

The final product of remote controlled-sterilization robot is show in fig.9. After the entire sterilization process has been completed, the next process is the examination of bacterial samples, which is carried out in the laboratory. The number of bacteria that have been sterilized using a robot in one room is shown in table 8.

Fig. 9. Final Product remote controlled sterilization robot

3 Results and Discussion

The results of placing the bacterial samples at a distance of 50 cm, 100 cm, and 150 cm against the sterilization robot or ultraviolet light showed the effect of distance variations on bacterial reduction. The results obtained when the sterilization robot was placed at a distance of 50 cm against the bacterial sample with an exposure time of 15 minutes showed that the reduction in the number of bacteria was 90% (Fig. 10).

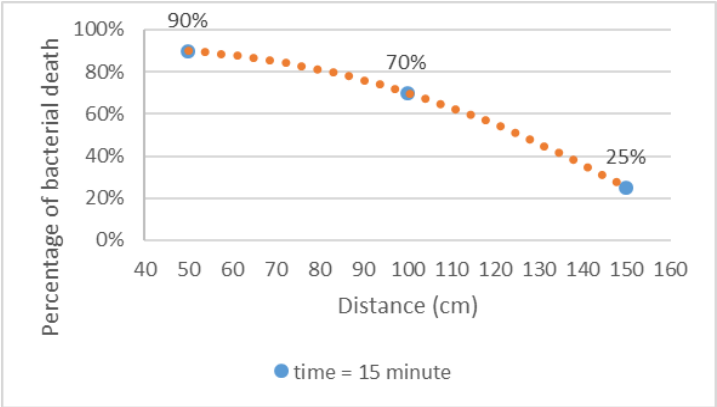

Fig. 10. Percentage of bacterial death with different distance

The initial number of bacterial samples before exposure to ultraviolet was 20 colonies. After being exposed to ultraviolet at a distance of 50 cm within 15 minutes, the number of bacterial samples was reduced to 2 colonies.

The results obtained when the sterilization robot was placed at a distance of 100cm against the bacterial sample with an exposure time of 15 minutes showed that the reduction in the number of bacteria was 70%. The initial number of bacterial samples before exposure to ultraviolet was 20 colonies. After being exposed to ultraviolet at a distance of 100 cm within 15 minutes, the number of bacterial samples reduced to 6 colonies.

The results obtained when the sterilization robot was placed at a distance of 150cm against the bacterial sample with an exposure time of 15 minutes showed that the reduction in the number of bacteria was 25%. The initial number of bacterial samples before exposure to ultraviolet was 20 colonies. After being exposed to ultraviolet at a distance of 150 cm within 15 minutes, the number of bacterial samples decreased to 15 colonies.

4 Conclusion

The comparison between bacterial colonies that were not irradiated (control) and bacterial colonies that had been irradiated with ultraviolet light at a distance of 50 cm and irradiation time of 15 minutes could be seen from the number of bacterial populations (colonies). The control sample was 20 Cfu/m3, while the treated sample was at a distance of 50 cm and had an irradiation time of 15 minutes, and the number of colonies that grew was 2 Cfu/m3. At a distance of 150 cm and an irradiation time of 15 minutes, the number of bacterial colonies was still quite large, namely 15 Cfu/m3.

Distance affects the intensity produced by the ultraviolet lamp. The closer the ultraviolet lamp is to the bacterial sample, the greater the intensity produced by the ultraviolet lamp so that the percentage of bacterial death will be higher. The average percentage of the highest cattery mortality was 90%, at a distance of 50 cm and an irradiation time of 15 minutes. With the same duration of time, at a distance of 150 cm, the lowest average percentage of bacterial death was 25%.

For further research, it is expected to be able to provide the right dose for the inactivation of viruses and bacteria at a longer distance. This means it will take a longer exposure time to UV rays.

Table 8. Laboratory Examination Results

Lab Code Number	Location	UV exposure time (minute)	Distance (cm)	Parameter	Unit	Result	Method
837/A	Office	-	-	Total Plate Number (ALT)	Cfu/m3	20	IK/7.4-1/50 Rev.00
837/B	Office	15	50	Total Plate Number (ALT)	Cfu/m3	2	
837/C	Office	15	100	Total Plate Number (ALT)	Cfu/m3	6	
837/D	Office	15	150	Total Plate Number (ALT)	Cfu/m3	15	

For the system, the thing that needs to be improved is the stability of transmission and receive from the remote to the robot so that the robot's movement can be more stable and smoother. It is also necessary to increase the dispersion distance achieved by the remote to control the robot.

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