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IoT Based Ultra-Violet Sterilization Robot for Disinfection, Food and Goods Delivery

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Abstract: Utilizing ultraviolet sterilization can help in reducing the count of bacteria on surfaces that may still be present after routine cleaning. For sterilizing in an operating room or a patient room, our team has created a UV Robot or UV bot. Three 19.3Watt UV lamps positioned on the top of the UV robot platform provide 360-degree coverage for the UV bot. The Node-MCU ESP8266 based embedded system that the UV robot used to navigate and avoid obstacles. Additionally, we examined how well UV light exposure eliminated Staphylococcus Aureus germs from sample plates that were 35 cm from our UV robot within 8 seconds of exposure.

Keywords: Internet of Things, UV exposure, Staphylococcus aureus, 360-degree disinfection, Automatic safety shut-off, Sterilization.

I. INTRODUCTION:

In order to maintain a safe environment for the patient and healthcare worker, environmental management in the operating room (OR) or patient room setting aims to limit microorganisms, especially drug-resistant bacteria, to an irreducible minimum. Currently, there are 14–17% infections in operating rooms, and 38% of hospital infections affect patients who have had surgery [1]. As a result, one of the best infection control strategies utilized to achieve the objective of reducing the count of microorganisms, dust, and organic material present in the environment is daily pre-operative and terminal cleaning of the OR environment.

However, there are numerous blind spots or inaccessible regions, such as the walls and ceiling, where a typical cleaning method using cleaning solutions by humans alone cannot reduce the amount of these microorganisms. An ultra-violet (UV) technology has recently been developed that might help hospitals in their continuous fight to prevent microorganisms from staying in patient rooms and spreading new diseases [2]. The C band of UV radiation, or the spectrum between 200 and 280 nm, is the specific range of wavelengths that may destroy microorganisms (UV-C). Bacteria, viruses, and fungi may all be effectively inhibited by this wavelength range. Additionally, it works well when utilizing decontamination in the operating room and may be used to sterilize in air, water, surfaces, and more.

Fixed UV sterilization systems currently have a lot of usage restrictions. UV exposure, for example, might be detrimental to users if it occurs frequently or over an extended period of time. Conjunctivitis, skin diseases, and some types of ceiling lamps can all result in redness. Additionally, it cannot be used to disinfect some places that are concealed by an object's shadow. We have created a UV robot or UV robot that can either manually or autonomously (using machine learning or ML) travel around a room, avoiding obstructions, and overcoming all the identified issues. This allows it to completely sterilize the whole OR with or without human interaction.

II. BACKGROUND

A. Ultra-Violet Disinfection

The germicidal irradiation process uses UV light with a wavelength between 100 and 400 nanometers (Fig. 1). Due to its ability to render bacteria inactive, UV-C radiation (with a wavelength range of 200–280 nm) is regarded as having the highest germicidal efficacy.

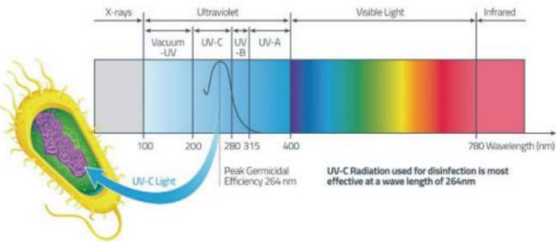

Fig 1: Light Spectrum **(**www.uvguard.com/knowledge-centre/**)**

As a result of the microorganisms' DNA and RNA absorbing the light, nearby molecules become dimerized (especially thymine). It is impossible for viruses and bacteria to multiply and infect due to this condition in their DNA and RNA, as demonstrated in Fig. 2 [4].

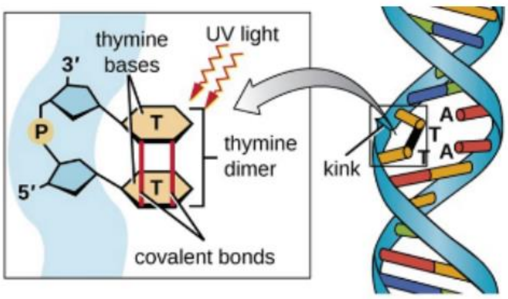

Fig 2: Thymine dimer phenomenon
(courses.lumenlearning.com/microbiology/chapter/mutation/**)**

B. Surgical site infections

One of the most frequent causes of significant surgical complications is still surgical site infections (SSIs). They are responsible for 14–17% of all hospital-acquired infections and 38% of nosocomial infections in patients who have had surgery. According to Figure 3 [1], Staphylococcus aureus (S. aureus) is responsible for 20–30% of surgical site infections.

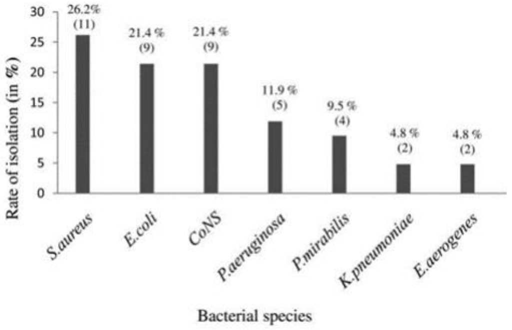

Fig 3: Bacteria that causes infection in the operating room [5]

C. Exposure time required for inactivation of bacteria

Calculating the exposure period for bacteria inactivation is necessary to determine the UV robot's travel speed. Since every commercially available UV lamp emits a different quantity of UV radiation. It must be measured with a power meter. The quantity of UV dose per brightness is detailed below in (1) and (2) [3], and is commonly represented in microwatts per centimeter squared (W/cm2) and the exposure period used for UV dosage.

$$Brightness = \frac{Luminosity(w)}{4\pi \times Distance^2\,(cm^2)}$$

$$Time = \frac{UV\ Dose(\mu W\,\frac{sec}{cm^2})}{Brightness(\frac{w}{cm^2})}$$

III. METHODS

A. The UV robot's compact physical factor and lack of electrical control lines (battery driven) for easier mobility throughout the OR are key designs. The following are crucial UV robot (Fig. 4) parts:

1) A Robot platform or frame
2) Three UV lamps
3) A Controller Box
4) A power source equipped with 12 volts battery
5) A driving terrain
6)Two ultrasonic sensors
7) Control Software

The UV bot height is 143.5cm with its base size of 60x60x30 cm.

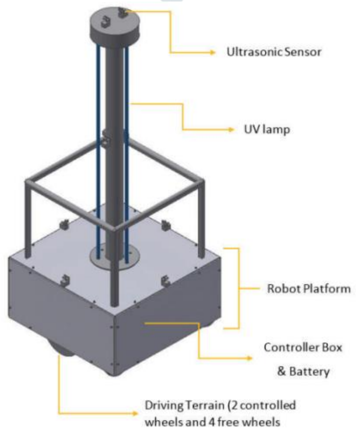

Fig 4: Design of UV Sterilization Robot

The micro-controller is the heart of the system. That is the UV robot's main command post. As seen in Fig. 5, it is configured to take inputs to detect obstructions nearby and guide the robot around the room to prevent any collisions. The UV robot has six mounted ultrasonic sensors. The robot's front, left, right, and back are those places. Two controlled wheels will assist in steering around any obstructions in the road based on the data from the ultrasonic sensors that have been analyzed. The robot's wheels are controlled by a driver using the microcontroller to steer clear of obstacles or possible collisions. Our control software's flowchart and controller block diagram are depicted in Figs. 6 and 7, respectively.

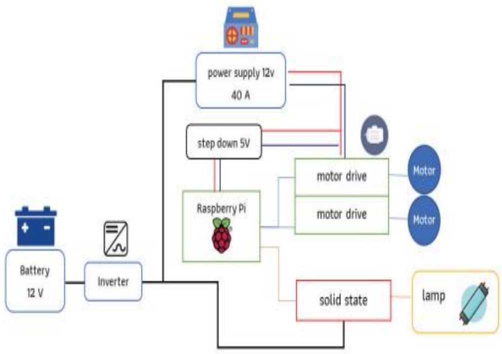

Fig 5: Block Diagram of controller box.

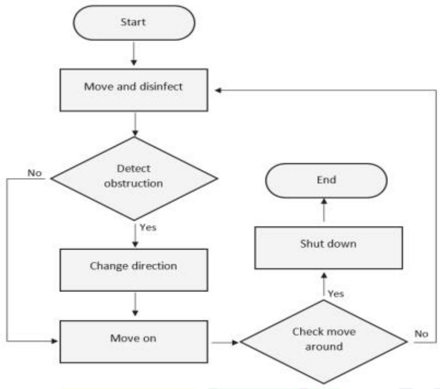

Fig 6: Flowchart of UV Robot control software

B. Calculated time for disinfection

In designing the UV robot we used three UV lights that were spaced 120 degrees apart and positioned in a circle. Each light produces 19.3 watts (as listed on a UV lamp datasheet). The formulas for calculating the brightness at a specific distance (35 cm) are as follows:

We chose the UV dosage necessary for S.aureus inactivation to be 6,600 microwatt second per centimeter square in order to determine the duration of exposure time received at sample plates [7]. As a result, the minimal amount of time needed to eliminate germs is stated below.

$$Brightness = \frac{19.3x3(w)}{4\pi \text{ x } (35)^2(cm)^2}$$

$$Time = \frac{6600\left(\mu W.\frac{sec}{cm^2}\right)}{37.6\left(\frac{\mu W}{cm^2}\right)} = 1.75sec.$$

C. Counting of bacterial colony

Using a spread plate approach on five growth plates, S.aureus TISTR 746 was subjected to an ultra-violet sterilization test in nutritional broth (0.35 percent yeast extract, 0.50 percent peptone, and 0.50 percent sodium chloride). The first plate served as a control sample with no UV exposure, while the remaining 4 plates each received a 2, 4, 6, and 8-second UV exposure, respectively. The UV robot was 35 cm away from each plate. Each plate was then incubated for 24 hours at 37°C. Following that, each plate's total number of colonies that form units was counted.

IV. RESULTS

The UV robot that was created is seen in figure 7. The robot's capability is that it may be controlled online by a human by connecting to the same Wi-Fi network. The user has control over movement, motor speed, and lamp on/off. By using the camera to view the surroundings, we may also observe them. The robot can navigate the area and avoid obstacles with the help of a camera and ultrasonic sensors. The UV robot can work for 30 to 45 minutes on a battery and has a top speed of 0-1.4 meters per second. It can also be connected to an electrical outlet.

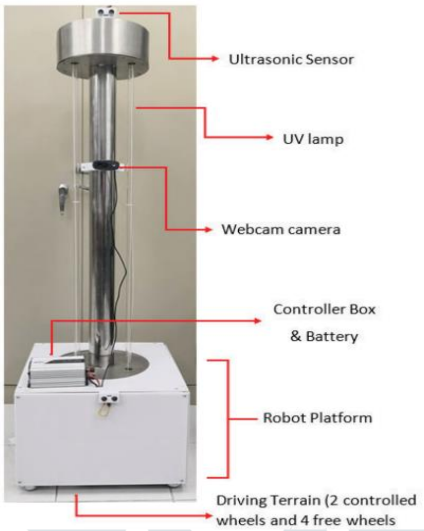

Fig 7: UV Sterilization Robot

B. Ultraviolet sterilization test

In Table 1 and Fig. 8, the number of bacterial colonies on the reference plate (without the UV bot disinfection) and the sample plate under various disinfection times are displayed.

Table1. Result comparison from UV disinfection and Reference

Time(s)	Number of Staphylococcus aureus colonies	
	Reference	UV disinfect
2	23	7

4	23	8
6	23	1
8	23	0

According to the findings, the sample plate exposed to our UV robot's UV rays for just 2 seconds would dramatically reduce the number of S.aureus colonies from the initial colonies of 23 in the reference plate to just 7. S. aureus will be completely eliminated in 8 seconds with a further increase in UV exposure period, as indicated in Table 1.

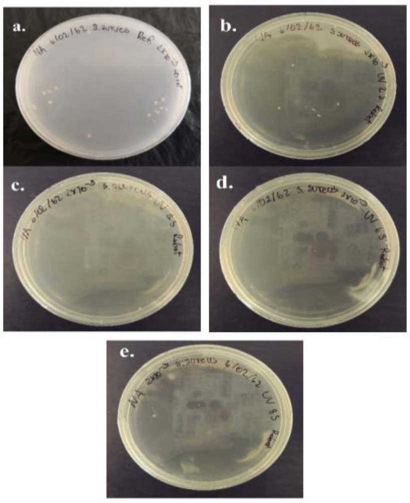

Fig 8: Photos of cultured plates with variant exposure time: a) Reference plate, b)2 Seconds, c) 4 seconds, d) 6 Seconds, and e) 8 Seconds

V. DISCUSSION AND CONCLUSIONS

According to the experimental findings of the disinfection test, the UV robot needs at least 8 seconds to thoroughly destroy the S.aureus colonies. This figure exceeds the value that was theoretically estimated by more than 4 times. These are a few of the primary causes that can be described. First off, there is a significant difference between the UV lamp manufacturer's advertised output power (19.3 W) and the actual output power (5.3 W). Second, the degree of UV light exposure to S.aureus colonies may vary depending on how transparent culture plates are. UV robot can currently move around manually using a wireless remote control. The UV robot is currently navigating itself.

By reducing the count of microorganisms, including drug-resistant bacteria, to an unreachable minimum, the UV robot has shown a huge potential to assist sterilization and provide a safe atmosphere for patients and healthcare professionals. Additionally, the UV robot will be equipped with a wireless control system that can be used to navigate from one place to another place while avoiding obstructions. By connecting to the same Wi-Fi network, this technology will allow the UV robot to properly sterilize the whole operation room.

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