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Novel Approach for Disinfecting and Sterilizing using Autonomous Robot Equipped with UV-LEDs

Shankari R[1], Apoorva Sunilkumar Menon[2], Priyadharshini K[3], Priyadharshini S[4], Seetha Lekshmi R[5]

Assistant Professor, Department of Electronics and Communication, Velammal Engineering College, Chennai, India[1]

UG Students, Department of Electronics and Communication, Velammal Engineering College, Chennai, India[2,3,4,5]

Abstract: There are many ways of sterilization. Of these, the one gaining the most popularity is UV sterilization. This is a low-cost UV sterilizing robot. Ultraviolet (UV) sterilization technology is employed to assist in the reduction of microorganisms that will remain on the surfaces after a typical cleaning to the minimum number. For this purpose, a UV robot for sterilization in a room would be befitting. The UV bot has UV LEDs mounted on top of the UV bot platform covering 360° direction. The UV bot employed an embedded system based on Arduino to aid in navigation to avoid obstacles. This robot is driven with an Arduino board controlled by an infrared sensor. The Bluetooth module is used as an interface to communicate with the device using the android app.

Keywords*:* Ultraviolet Sterilization, Robot, Disinfection, Arduino, Bluetooth module, Motor driver, Infrared sensor, Obstacle detection.

I.INTRODUCTION

The Light wavelength for germicidal irradiation is a technology that utilizes UV light in the range between 100- 400 nanometers. UV-C radiation (200 – 280 nm), which is considered the most germicidal wavelength range due to the fact that it can inactivate microorganisms. UV light helps hospitals in the current battle to prevent microbes from persisting in the hospital rooms that could potentially lead to new infections. This is effective in inhibiting bacteria, viruses, and fungi. In addition, it can be used to sterilize in air, in water, on the surface, and very effective when using disinfection. Studies have shown that frequent disinfection is the key to keep microbes at bay. This makes the environment safe at all times for people. The bio-organisms and microbes such as bacteria, spores and viruses are deactivated when it is exposed to UV-C light irradiation.

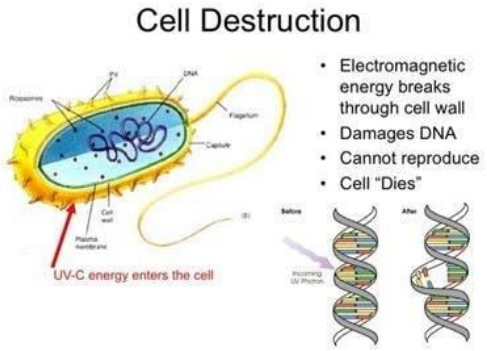

Fig. 1 Cell Destruction by irradiation of UV-C

When irradiated with UV light it is absorbed by the DNA and RNA of microorganisms resulting in the dimerization of adjacent molecules (particularly thymine). This occurrence within the DNA and RNA of viruses and bacteria makes it impossible for the microorganisms to duplicate and infect as shown in Fig. 2.

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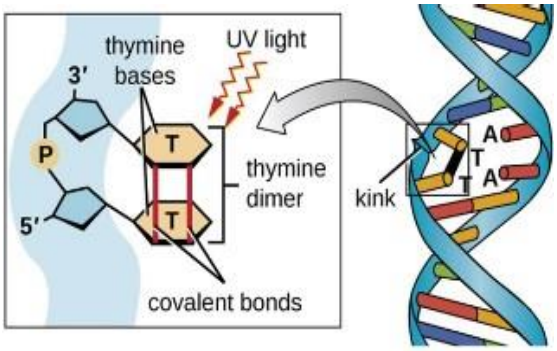

Fig. 2 Dimerization of adjacent molecules

Our goal is to disinfect common grounds using UV light which is proven to kill disease-causing microbes. Ultraviolet (UV) sterilization technology is employed to assist in the reduction of microorganisms that will remain on the surfaces after a typical cleaning. We also have to reduce human presence in the disinfection process using a robot that can detect obstacles and move around.

II. EXISTING SYSTEM

We have current systems and facilities that provide disinfection by deploying health workers and housekeeping staff that are required to use floor cleaning solutions for disinfection. Disinfection provided by floor cleaning solutions is not sufficient as we leave out the ceiling and walls and also is very laborious to have housekeeping staff do regular disinfection. It also puts them at risk to high-risk zones where a room could be contaminated by disease-causing microbes. Furthermore, it cannot be used to disinfect in some areas hidden under the shadow of the object and as there are many blind spots or unreachable areas such as walls and ceiling.

Fig. 3 Immobile sterilization machine

There also exists fixed UV sterilization systems that have found commercial use. It is a machine that is immobile and with an in-built UV-C lamp it can sterilize the contents put in it. This model allows us to only disinfect items that can be put inside and those that can be confined within the dimensions of this machine. We tend to leave out the common grounds and surfaces where people walk and talk. The UV rays are not human-friendly and exposure to such UV light is not preferable.

Also being in risk zones and having constant high UV exposure is harmful to users if they are exposed for a long time or in a very large quantity. It can cause redness of the skin and eye infections (conjunctivitis) or ceiling lamp types. The low-pressure mercury lamp cannot get at high brightness because of the low load. Hence, mercury lamp emits light with very little optical control. The current model is also not a very economical solution given the scenario the world is facing today.

III. PROPOSED SYSTEM

To eliminate all the aforementioned issues, we propose a UV robot or UV bot that can either manually or autonomously navigate around a room including avoiding obstacles enabling it to thoroughly sterilize with or without human intervention. Having a mobile robot can help to also avoid human presence near the UV light-emitting areas. Regular disinfection of common grounds can help to hugely contain the spread of viruses. The proposed system can help to ensure mobile and also remote operation. There is also an inclusion of a condition that ensures there is no exposure of humans to UV light. The lights turn out on the detection of human beings. This ensures there is no human exposure. Since it

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detects the presence of humans it avoids them and the UV lights turn out to avoid human exposure to UV light. The robot is also completely autonomous and can detect obstacles and can find its course i.e., it can operate autonomously without the help of humans. During remote operation, the robot can be operated by an operator. This is preferable with difficult areas to reach or just an area where humans can't reach. It is also a low-power consumptive and environment-friendly sterilizer. UV-LED operates at a wavelength that is presently used for curing UV curable resin presently, and the use of UV LED for sterilization is a very novel approach. UV-LED has a wavelength that is not very hazardous for human eyes and skin than mercury lamps. Furthermore, mercury is not included in UV-LED and it does not have harmful effects on either the human body or the environment. UV-LED will be used not only as alternatives to the low-pressure mercury lamps but also as a piece of small and space-saving sterilization equipment. UV-LED is smaller and has an operating life longer than that of low-pressure mercury lamps. Due to the compact size, UV-LED can sterilize small or narrow space and will be used to carry out different kinds of sterilizer for many purposes. It gives a 360° sterilization with low noise. It is very small and compact looking and is 100% safe to operate. It can be operated autonomously within rooms and other spaces. It will detect items in the environment for the safety of operators (obstacle avoidance). It is durable and relatively maintenance-free and can also maneuver in standard bathrooms.

IV. METHODOLOGY

A. UV Bot Design

The Key design for our UV bot is in aiding navigation in various environments. Essential components of our UV bot are:

1) Arduino UNO 2) L293D Motor driver 3) Bluetooth module 4) three Infrared sensor 5) UV LEDs 6) Arduino IDE.

The heart of the robotic system is a microcontroller. It is a central command center of the UV bot. It is programmed to accept inputs to sense obstacles around it and navigate the robot around the room to avoid any collisions. There are 3 infrared sensors mounted on the UV bot. Those locations are the front, left, right of the robot platform. If there is an obstacle in the pathway, two controlled wheels will help steer around that obstacle according to processed signals received from infrared sensors. If there is an obstacle, or a risk of collision, the microcontroller controls the robot's wheels by a motor driver to prevent the collision. The L293D motor driver is used so that it can control the wheels of the bot. The wheels of the bot are controlled by two DC motors Left DC motor and the right DC motor. They rotate as follows.

TABLE I L293D MOTOR DRIVER LOGIC TABLE

Pin 2	Pin 7	Direction
1	0	Clockwise
0	1	Anticlockwise
0	0	Idle
1	1	Idle

Likewise, the motor can also operate through the 15,10 input pins for the right DC motor. The PIR sensors are present to detect the motion of any living entities present and it signals the Arduino to turn off the UV LEDs if the output of PIR is HIGH. The presence of UV LEDs is the core of the sterilization system. The Bluetooth module connects with the app and makes possible the remote operation of the UV bot. The Bluetooth module then translates the instructions to the Arduino which moves accordingly.

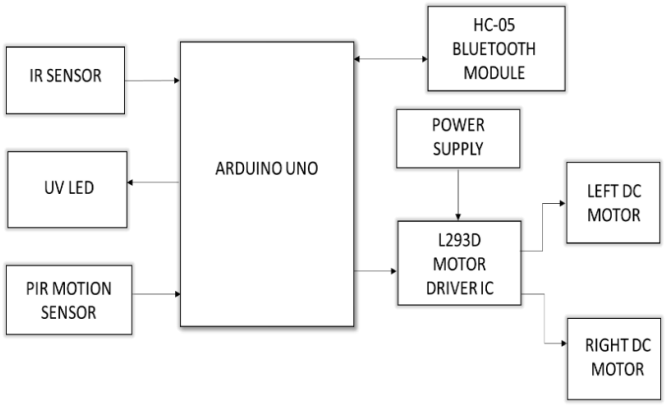

Fig. 4 Block diagram of the UV Robotic system

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The Arduino can operate in two modes namely:

Autonomous mode
Remote Control mode

B. Autonomous mode

The IR sensors radiate infrared light and sense the presence of any obstacles and if any, the appropriate detour is taken.
The IR sensors produce an output LOW in case of any obstacle and if absent then the output is HIGH.
The Arduino reads from the IR sensors and moves accordingly. The UV LEDs are always turned on during the autonomous mode.
The PIR motion sensor is used to sense human motion and if any the UV LEDs are turned out to prevent human exposure.

C. Remote Control mode

In the remote mode of operation, the wheels stop running and when any of the buttons of the Android App is pressed the value is sent to the Bluetooth module which in turn signals the Arduino to take appropriate steps. This could be left, right, forward and right. The UV LEDs turn off in this mode when exposed to humans.
The Android App shown in Fig. 5, is used in remote control operation mode. It is used to control the robot remotely. It firstly is connected to the car using the Settings icon and from the tray, we select the Connect to Car. Then we select the Bluetooth module in use which is HC-05 from the list of Bluetooth devices. Once Connected to Car we use a button that turns green and we get a Connected message. Then we can use one of the four buttons to move left, right forward-backward. When such a button is pressed the value is sent to the Bluetooth module which in turn signals the Arduino to take appropriate steps. The corresponding flow diagram of operation is shown below in Fig.5.

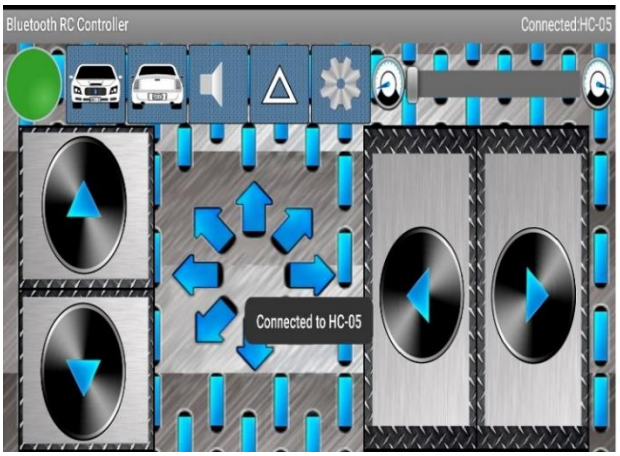

Fig. 5 Android App after Bluetooth connection

D. Irradiation of UV

The UV LEDs are the source of UV irradiation here. UV LEDs are very compact and small in size. UV LEDs are also inexpensive and offer plenty of benefits over low-pressure mercury lamps. The UV LEDs are turned on at the start of the autonomous mode and remain on as long as the PIR detects low.

As soon as, the PIR detects HIGH indicating the presence of a human or any living being the UV LEDs turn off and preserve the battery also ensuring that there is no human exposure. This way it eliminates any possibility of exposure to UV light.

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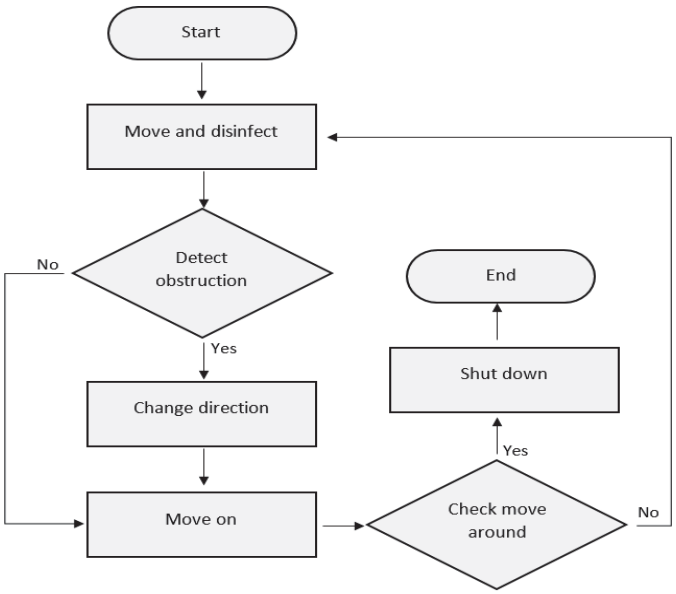

Fig. 5 Flow Diagram of operation

V. RESULTS AND DISCUSSION

A. UV Sterilization Bot

Our UV robot has demonstrated a great potential to aid sterilization by keeping microorganisms including drug-resistant bacteria to a minimum to provide a safe environment to the common man and most importantly to the health workers, nurses including the housekeeping staff and children who are at most risk. In addition, our UV bot will be able to move around a room and avoiding obstacles either autonomously or by using a wireless control system via the app by connecting through the Bluetooth module and enabling it to thoroughly sterilize the entire room. Our robot was able to last for about 30-45 mins with a 7V battery. This is dependent on the number of obstacles in its path as the UV LEDs turn off when there is any possibility of human exposure. The operation of such a device was found to be optimum in both dark and light environments. Such a device finds its use in

Disinfection at homes: Cost-effective technology to instantly disinfect your home keeping your family safe from viruses and infections.

Public places: They require frequent disinfection since they are commonplaces of interest and this includes movie theatres, malls, restaurants.

Healthcare and HVAC: A proven technology, UV air sanitizer thoroughly frees a hospital environment of viruses, infections and harmful microbes.

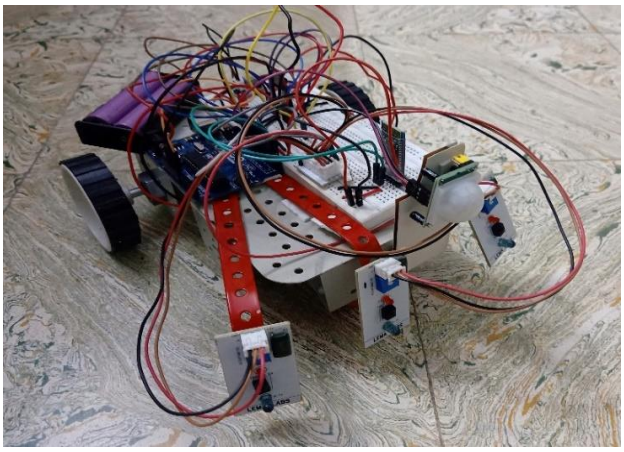

Fig. 6 The UV disinfecting robot (Bottom layer)

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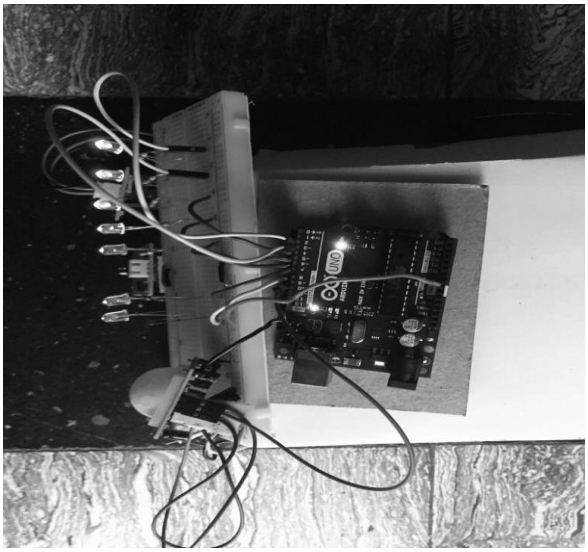

Fig. 7 Top Layer

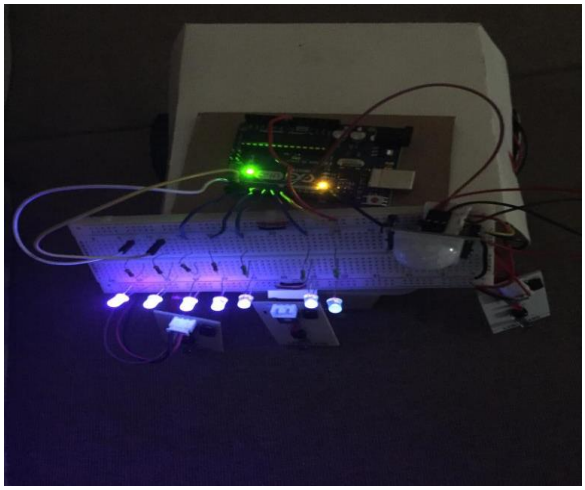

Fig. 8 UV LEDs ON

VI. CONCLUSION

The purpose of this UV bot was to demonstrate its capability to sterilize by UV-LEDs and to make possible the autonomous operation as well as the remote operation conditioned to the suitability of the operating environment while avoiding any obstacles as such and to apply UV-LED to the sterilization device. From the results, it was proved that it could sterilize virus and bacteria almost completely by irradiating UV-LED. Such sterilization could be done for a specific amount of time and if required the UV-LED sterilizer can sterilize for a certain amount of time depending on the type of microbes since all microbes take different amounts of time to be killed. Compared with the low-pressure mercury lamp, UV-LED is very small and the largest brightness so it has a much broader range of applications.

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