UVC ROBOTIC FLOOR CLEANER TO FIGHT AGAINST COVID-19

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Abstract : Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), causes coronavirus disease 2019 (COVID-19), it has threatened the whole world. This is highly infectious disease which spreads very fast in the community. Recent literature showed that SARS-CoV-2 can remain suspended in the air as well as on surfaces for days. There are currently numerous solutions to fight against this disease. Ultraviolet (UV) sterilization technology is used to aid in the reduction of microorganism like SARS-CoV-2 that may remain on the surfaces after a standard cleaning. It is mainly used for domestic, hospitals and industrial purpose. In this work, E- Yantra Fire Bird V and UVC (254nm) light is used for floor disinfection. This robot uses AVR ATmega2560 microcontroller. It employs an embedded system based on Arduino UNO for connectivity to Bluetooth applications and it controls operation of UV light. It avoids obstacles while cleaning.

IndexTerms - **Fire Bird V, Covid-19, SARS-CoV-2, UVC Sterilization, IR Proximity Sensor, Arduino UNO, SHARP Sensor, Obstacle Avoidance, Bluetooth.**

I. INTRODUCTION

The room disinfection method carried by UVC robotic floor cleaner kills the virus present on the surface. It affects a broad range of microorganisms and it has several advantages over chemical based-sanitizing methods .It is also cost effective and it is easily customizable according to our requirement. The floor cleaner is designed to be compact in size than other conventional robots and it is also fast and cost effective.

Vijya Laxmi Kalyani, et al. Highlighted the study on coronavirus and how it spread worldwide in the year 2020. In December 2019, the origin of the respiratory infection identified as novel corona virus was primarily found in Wuhan, China. By early March 2020, novel corona virus, also known as SARS-CoV-2 had infected over 90,000 people worldwide and caused deaths of at least 3,000 people, by June 2020 9.4 lakh confirmed cases of COVID-19 including 4.8 lakh deaths were found. Currently there are various solutions to fight against this virus. Researches on SARS virus have found that Ultraviolet radiation C (UVC) light is susceptible to the SARS-CoV-2 virus. The virus can be reduced when exposure to UVC radiance higher than 90 $\mu W/cm^2$. UVC light of accurately 254nm wavelength has been used for sanitization. Some applications of using UVC of 254nm light are: UV light robots and lamps, autonomous robots in hospitals. Hence, the robot disinfection process is more convenient than human sterilizing as it will prevent human exposure to UVC light.[1]

Currently widely used UV disinfection systems use UVC lamps (germicidal lamps) emitting UVC around 254 nm. However, 254-nm UVC is harmful to the skin and eyes. On the other hand 222-nm UVC light, which belongs to far UVC (207-222 nm), is just as effective as 254-nm UVC for its germicidal properties but it is comparatively less harmful than 254-nm UVC because far-UVC light has a very limited penetration depth in the eye or skin. Hiroki Kitagawa, et al. investigated the effectiveness of UV irradiation (222 nm) to observe reduction of SARS-CoV-2 after UV irradiation (0.1 mW/cm2) at 222 nm for 10-300 seconds using the 50% tissue culture infectious dose ($TCID_{50}$). 1 and 3 mJ/cm^2 of 222-nm UVC irradiation (for 10 and 30 seconds) resulted in 88.5 and 99.7% reduction of SARS-CoV-2.This experiment helps to find the necessary dose and prove that UVC 222nm is effective in the reduction of SARS-CoV-2 and can be used for disinfection[2].

Pacharawan Chanprakon, et al. team built a UV bot which travels around a room autonomously and can sterilize a room without human interference including obstacle avoidance. The robot was designed to prevent all the issues regarding injurious nature of UV exposure. The user can control this robot through website by connecting with Wi-Fi network. The sensors mounted on the robot will help to avoid collision with any object. The UV bot employed 3 UV lamps of 19.3 watt power arranged in a circular manner with 120^0 apart. The exposure time required for UV disinfection is directly proportional to the UV dosage, exposure time for bacteria inactivation was calculated. [3].

Mahesh Pawaskar, et al. used Raspberry pi to interface with Firebird-V robot, which helps in our work for interfacing Firebird-V with Aduino UNO. Firebird-V ATMEGA-2560 provides excellent environment for experimentation, algorithm development and testing in robotics. In this project, monitoring and controlling the Firebird-V robot is done via bluetooth using Arduino UNO. The robotic floor cleaner can be easily controlled using a personal computer or a smart phone application [4].

Anusha M R, et al. paper put forward a path traversal idea of robot movement using an algorithm which specify the distance travelled by the robot based on the path drawn along with angle consideration. This is helpful during path traversal in different regions.[5]

Marcel Bentancor, et al. created a robot that is remotely programmed using an Android UNO and mobile app. Some of these features were implemented in our project. Our system is easily scalable to generate higher ultraviolet dosages by adding more UV-C lamps, thus covering larger area and at a faster disinfection speed. This can be used for hospitals and industries.[6]

II. WORKING

The wireless communication is carried out between Firebird- V based UVC robot and user by using Arduino UNO through Bluetooth as shown in Fig. 1. The UVC light of wavelength 254 nm is used for disinfection. In this work, we have designed the Application which is useful for controlling the robot activities and also calculate the exposure time. Using the app, the robot and UVC gets activated and the robot moves in a zig-zag pattern. The robot uses IR and Sharp sensor to navigate around the room, avoiding obstacles. In this project calculation of UV exposure time is important for effective disinfection, so the same is included in the app, along with timer for scheduling the robot to start disinfecting. The software used is Atmel Studio, AVR Dude and Arduino IDE.

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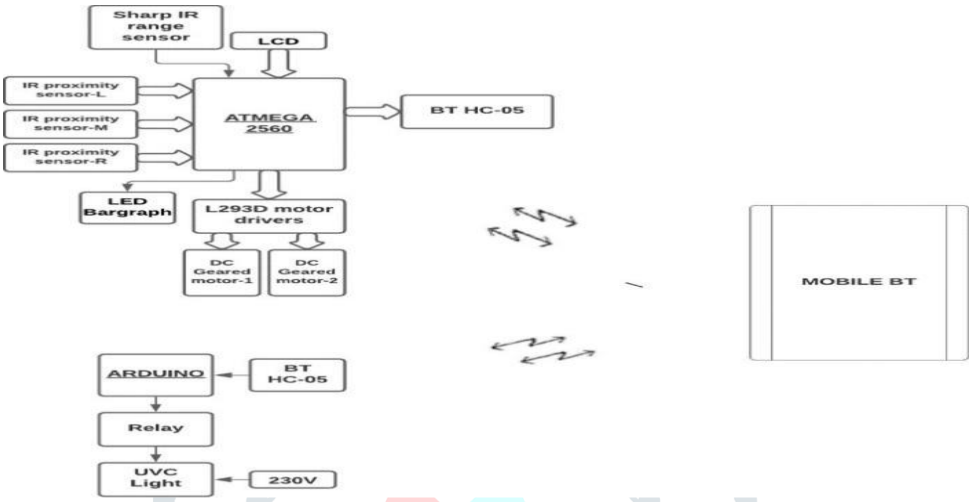

Fig. 1: System Block Diagram

A. Fire Bird V

The Firebird V robot (Fig. 2) is e-Yantra's research and educational robot developed by the Embedded and Real-time Systems (ERTS) laboratory of IIT Bombay. The robot provides the operation and hardware for us to appropriately develop our floor disinfection robot. Its modular architecture allows us to control it using multiple processors such as 8051, AVR, PIC and ARM7 etc.

Fig. 2: Fire Bird V Robot.

1.Power And Battery:

Fire Bird V has a 9.6V, 2.1 Ah Nickel Metal Hydride battery, it powers the robot for approximately 2 hours. It varies between 12V (fully charged) to 8V (discharged) battery voltage. Before beginning the charging process, the battery charger checks the state of battery. It selects optimal charging by looking at battery voltage, current and temperature. Battery charge status is indicated by a green LED, a red LED and buzzer. ATmega2560 microcontroller adapter board consists of power management block which provides power to the microcontroller and other devices.

2. Motion Control:

Fire Bird V robot has caster wheel for the support and two 75 RPM DC geared motors in differential drive configuration. 24cm per second is the robot's top speed. By rotating one wheel in clockwise direction and other in counterclockwise direction the robot can turn with zero turning radius. Position encoders are mounted on both the motor's axles to supply a grip feedback to the microcontroller. It uses L293D motor drivers which could control direction and velocity of the two motors. Direction of robot when changed uses suitable logic levels applied to L293D direction pins. the speed of wheel is controlled by Pulse width modulation [PWM] and it enables the pins of L293D IC. The control logic are applied during this project are forward (0x06), soft right (0x02), soft left (0x04).[7]

B. Sharp IR range sensors

There is one Sharp sensor by default and additionally we can add up to 4 Sharp sensors. They are used for accurate distance measurement. These sensors give the distance from the obstacle in the millimeter accuracy. It uses triangulation method to measure this distance. Hence, the reading does not get affected by ambient light which gives it a significant advantage over IR sensor.This sensor has blind spot in the range of 0mm to some specific distance depending on the type of the sensor. The Sharp sensor we are using is GP2D120X which ranges from 30cm to 20cm and a blind spot range of 4cm to 0cm.

C. IR proximity sensors

Infrared proximity sensors detects proximity of any obstacle briefly range. IR proximity sensors have about 10cm sensing range. These sensors sense the presence of the obstacles within the blind spot region of the Sharp IR range sensors. In the absence of the obstacle there is no reflected light hence no leakage current will flow through the photo diode and output voltage of the photo diode are going to be around 3.3V. As obstacle comes closer, more light gets reflected and falls on the photo diode and leakage current flowing through the photo diode starts to extend which causes voltage across the diode to fall. Thus, it senses the obstacle.

D. Obstacle Detection

The floor cleaner robot uses three IR sensor and one Sharp sensor. The three IR sensors are on the left, right and middle respectively (IR-L, IR-R and IR-M), they detect objects that appear on the left and right and thus prevent the robot from collision. The middle IR sensor senses the presence of the obstacles in the blind spot region of the Sharp sensor. The sensor in the center was selected as Sharp sensor as it is more reliable and less sensitive to light as compared to the IR sensor.

We have utilized a LED Bargraph that shows to the user, which sensor is sensing an obstacle and displays it in hexadecimal format, which is displayed through LED. A LCD screen is also being used that displays the readings of distance of the obstacle from the robot, with carefully measured minimum distance so that the robot has enough space to take a turn. The readings of IR sensor in millimeters is displayed on the first line and the readings of Sharp sensor in millimeters is displayed on the bottom line.

The robot follows obstacle detection and it recognizes obstacles that are in the path and gives signal to the ATmega2560 microcontroller. According to the signal received, the Firebird V robot stops or turns either right or left as described in the flowchart (Fig. 5). The robot is programmed to move in a zig zag pattern to ensure that no area is repeated as well as no area is left out, in this way it completes full coverage of the given area as shown in Fig. 3.

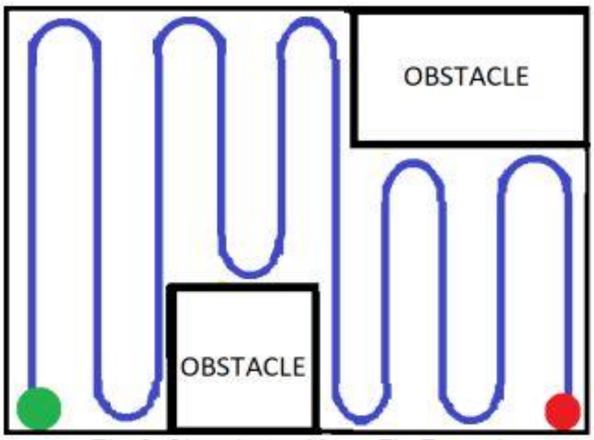

Fig. 3: Obstacle Avoidance Zig Zag path.

E. Arduino and Bluetooth Interface

HC-05 Bluetooth module is used to connect the Arduino UNO with mobile application. Information of robot status is feed to Arduino UNO via Bluetooth module. The app sends the information to the Fire Bird V robot to start and stop the robot

F. Ultraviolet C Light

UV Light spectrum is divided into four different UV bands they are as follows: UVA band ranging from 315 to 400 nm, UVB band ranging from 280 to 315 nm, UVC band ranging from 200 to 280 nm and the Vacuum UV band ranging from 100 to 200 nm. From these bands, only UVC ranging from 200-280 nm is used for disinfection. It breaks DNA of the virus which disables the virus to reproduce. In this project UVC light of 254nm wavelength is used. The light is enclosed in a aluminium sheet reflector with exposure to the floor surface.

- Exposure time required for inactivation of virus: The dosages values can be used to estimate the required exposure time according to the following method [6] :

  $D = (P.t)/(2\pi.L.d)$ (1)

  So, Exposure time becomes:

  $t = (2\pi.L.d.D)/P$

  Where, L is the length of UVC Lamp (25 cm for our project),
  t is the Exposure time in seconds,
  D is the dosage (expressed in J/cm^2), P is the Output Power (11W),
  d is the distance of floor from the robot (fixed at 15 cm).

- With the help of this formula, we evaluate the minimum exposure time to get the desired dosage. This is available in the UVC exposure time calculator screen of the app controlling the robot.

G. Mobile Application

The mobile application gets the data from the Bluetooth module connected to the Fire Bird V robot and Arduino UNO respectively. It controls the Fire Bird V robot and UVC light by turning them on and off. It performs other function including exposure time calculation and scheduling time.

In our app we have created 3 screens as shown in fig. 4:

1. Splash screen: A splash page is an introduction page on the app. Our splash screen is a graphical control element containing the project title (Mini C Robot), and the robot specifications. It appear when the app is launching.
2. Main screen: The main screen has the Bluetooth connection button, to establish Bluetooth connection to the robot. It has on and off buttons. Additionally, it has a timer function available that can be used to schedule to start the robot for disinfection for any time during the day.
3. UVC exposure time calculator screen: It uses (1) to calculate the exposure time. It takes the distance, power and dosage as input from the user in text box.

Fig. 4: Three screens of mobile application.

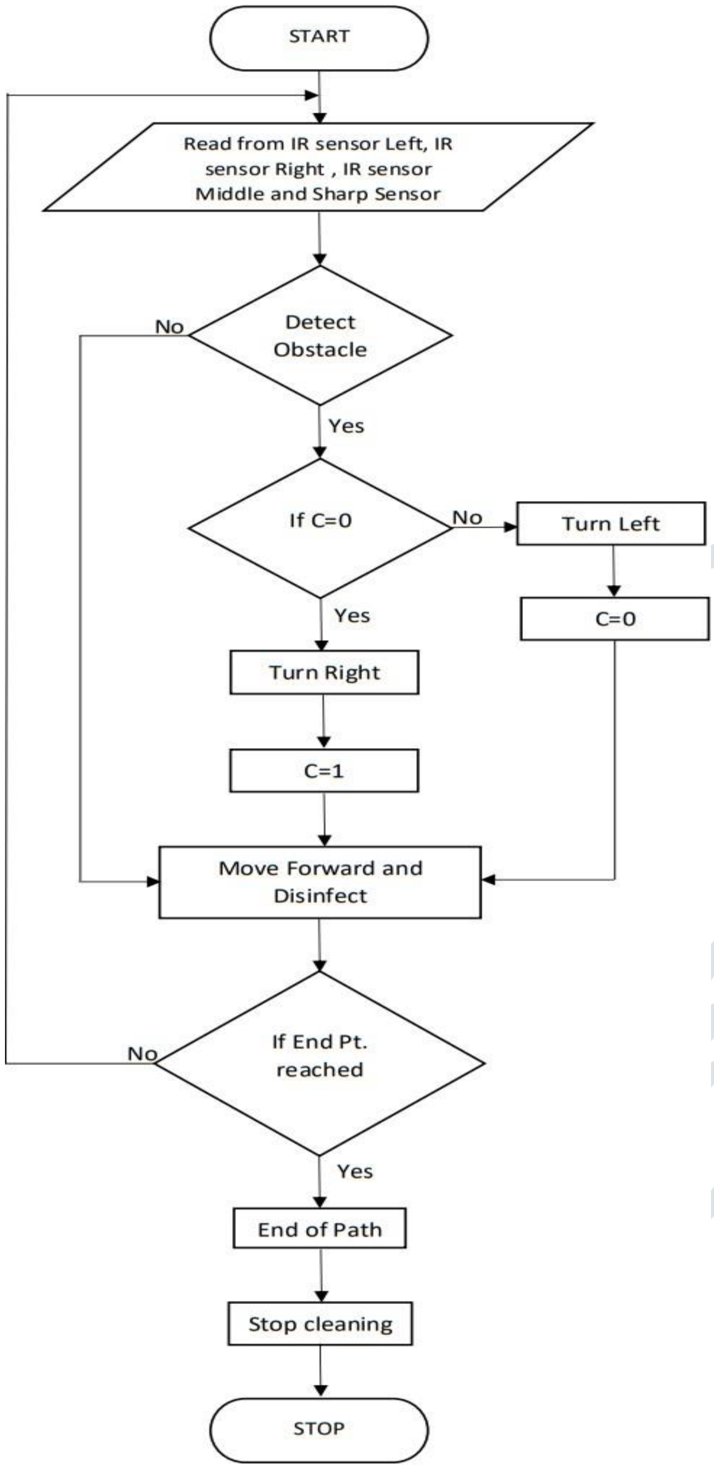

Fig. 5: Flowchart of the implemented system.

III. RESULTS AND CONCLUSION

3.1 Result

The robotic floor cleaner moves in forward, backward, and takes left and right turn to get full coverage of the room including obstacle avoidance to complete zig zag pattern. Unlike many other UVC robots which are stationary and follow a 360^o direction, our robot is autonomous and moves in a zig zag pattern without an oversight. The robot disinfects the floor using 254nm wavelength UVC light, with optimum dosage of 1 to 3 J/cm^2 for the calculated exposure time. From the given values of dosage and power of the UV light, The exposure time is calculated. The speed of the robot is changed accordingly to the exposer time per cm^2. The advantage of the built application is that we can select the UVC lights with different power and length depending on the application.

3.2 Conclusion

The robotic floor cleaner moves in forward, backward, and takes left and right turn to get full coverage of the room including obstacle avoidance to complete zig zag pattern. Unlike many other UVC robots which are stationary and follow a 360^o direction, our robot is autonomous and moves in a zig zag pattern without an oversight. The robot disinfects the floor using 254nm wavelength UVC light, with optimum dosage of 1 to 3 J/cm^2 for the calculated exposure time. From the given values of dosage and power of the UV light, The exposure time is calculated. The speed of the robot is changed accordingly to the exposer time per cm^2. The advantage of the built application is that we can select the UVC lights with different power and length depending on the application.

IV. ACKNOWLEDGMENT

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