Development of Android-Controlled Ultraviolet Floor Sanitizer Robot

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***Abstract*—Ultraviolet (UV) light radiation is very dangerous as it can irritate human skin and eyes in which long and direct exposure can lead to skin and eyes cancer. However, Ultraviolet C (UVC) light with a wavelength between 207nm-222nm could sanitize in which inactivate the bacteria such as superbug (the pathogen that already built immunity against chemical sanitizer) and contribute to the fight against Covid-19 viruses. Therefore, this development of UV sanitizer is to sanitize surface area effectively with a human alert system in which will activate the buzzer, turn off the UV light and stop moving when human motion is detected. The notification also will be sent to the user whenever a human motion is detected as a precaution to avoid any accident. The device is equipped with one UVC light which provides a 360◦ sanitization area to inactivate pathogens. Then, the body has ultrasonic sensors to detect obstacles and provide autonomous movement to the device while the PIR sensor is used to detect human motion and activate the human alert system. As the result, the UVC light effectiveness is determined based on the bacteria growth in the petri dish. After the sanitization process, the bacteria are significantly reduced and killed effectively in low areas such as floors but reduce their efficiency to the high area. Thus, this device is time efficient and able to reduce the cost of sanitization compared to chemical sanitizer.**

Keywords—UV sanitizer, UVC radiation, cross-contamination

I. INTRODUCTION

Nowadays, Covid-19 virus can be a threat to mankind due to its ability to be transmitted thru respiratory droplet whether its direct or indirect contact from infected person. The virus from respiratory droplet as the Covid-19 patient coughing or sneezing can be spread to the surface area such as table, floor, bed and doorknob [1]. Furthermore, it is very harmful as Covid-19 virus can last up to 72 hours on plastics and 48 hours on stainless steel [2]. This will increase the diseases spreading to the patients, healthcare workers and their relatives.

Moreover, disease such as HAI that is cause by superbug should not be taken lightly as it can cause pneumonia, skin infection and blood-stream infection. This superbug or pathogen that has already built immunity against chemical sanitizer such as methicillin-resistant Staphylococcus aureus (MRSA) has cause danger especially for older patient aged more than 60 years as it has cause 11.7% mortality rate in Malaysia (2018) [3].

Standard cleaning by cleaners has many blind spots or unreachable spots that can be growing spots for the pathogen. Constantly exposed to the chemical sanitizer but does not get killed, will help the HAI pathogen grow immunity against chemical sanitizer provided in the standard cleaning such as Hypochlorite and Accelerated Hydrogen Peroxide. Moreover, the cleaner is also prone to be infected by the Covid-19. If the cleaner gets Covid-19 virus infection, the hospital area can be a dangerous space. Thus, standard cleaning seems unreliable compared to the UV light sanitization that can be operated autonomously [4].

Therefore, by utilizing UVC light radiation with wavelength 207nm-222nm or in particularly the UVC germicidal light at 254nm is a great solution, as it can rupture the DNA or RNA of the pathogen which will kills them effectively [5], [6]. Thus, the pathogen unable to replicate and infect [7].

Since the device will move autonomously, it is more efficient to reduces the human contact that can cause cross-contamination of the Covid-19 viruses during sanitization compared to the traditional method. However, precaution need to be taken as UVC light radiation is very dangerous to human skin and eyes as it can trigger cancer. So, precaution such as avoiding direct skin exposure to UVC radiation and never look directly into UVC light is taken. Consequently, human alert system is installed in this device, as whenever human is detected, notification is sent to the user thru Blynk apps, buzzer is turned on, UVC light turn off and device will stop moving for 20s. This will alert the interrupter about the danger and user to chase out the interrupter from the sanitization area.

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II. Methodology

A. Block diagram of UV Sanitiser

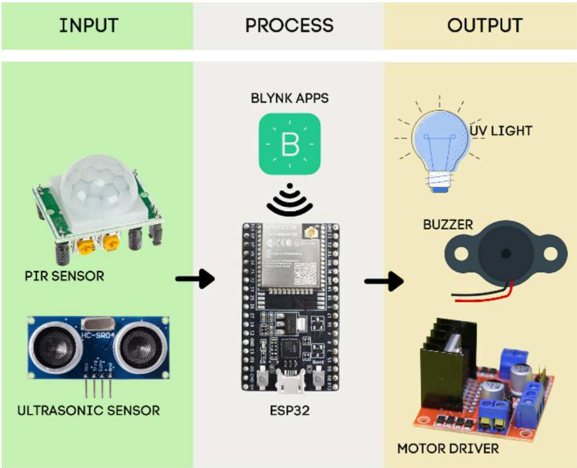

Fig. 1. The block diagram of UV Sanitiser system.

Figure 1 represent block diagram that is divided into input, process and output. The block diagram helped to explain the workflow in the device.

NodeMCU-32 is used as microprocessor as it has a built in Wi-Fi module that will be connected to the Blynk apps to control the device.

The ultrasonic in input is used to measure the distance from the obstacles and the information will helped to avoid collision with obstacles as it can provide automated movement for the device which showed by the motor driver. The PIR sensor then is used as human alert system input as it able to detect human motion by using infrared radiation radiated by the human body. After human is detected, UV light will turn off, the buzzer will turn on and the device will stop moving for 20seconds to alert the human of the danger.

B. Block diagram of UV Sanitiser

Based on the flowchart in figure 2, firstly the device is connected to an AC power supply. The microcontroller will start to initialize and connect to Wi-Fi. Then the user needs to press the "UV light" switch in Blynk. If the "UV light" switch is turned ON, the UV light is turning on and the ultrasonics in the front, left, and right will start detecting the distance from obstacles.

Then the ESP32 will control the movement depending on the ultrasonic inputs as the device needs to move forward and close to the right wall. Firstly, the device will consider the front side, as if there are no obstacles within 40cm, the device will move closer forward but closer to the right wall. However, if there is an obstacle on the right, the device will move to the left and vice versa.

Next, if the front side is blocked, the device will move either to the right or left but if there is an obstacle on the right side, it will move to the left and vise versa. However, if the front, left and right were blocked in which the device encounter dead ends, the device will stop, move backward and rotate itself.

Meanwhile, once the "human alert" is pressed, the PIR sensor will detect any human motion within 7m (120 degrees). If the PIR sensor detects a human motion, the microcontroller will send a notification to the phone, activate the buzzer, turn off the UV light and stop the car's movement for 20 seconds. Then, the PIR sensor will detect human presence again before turning on the UV light. This helped to prevent any hazards from happening during the sanitization process.

Once the sanitization process is done, the user needs to turn off the "UV light" and "human alert" switches in the Blynk apps. The power supply needs to be turned off to avoid overheating the device.

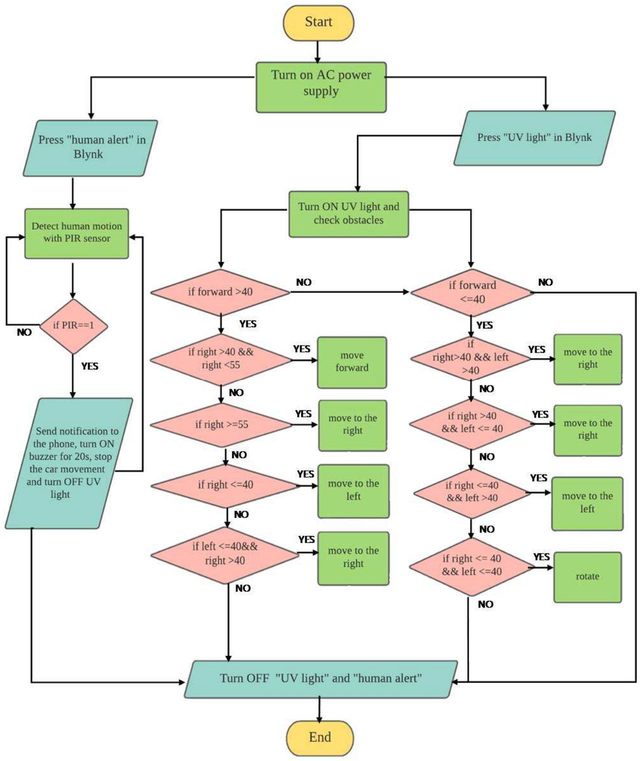

Fig. 2. The flowchart of UV Sanitiser system.

The overall design is based on figure 3, which consist of body, UV light, DC motor, ultrasonic and PIR sensor. The body consist of ESP32, L298N motor driver, voltage regulator, relay, ballast and AC-to-DC converter. The body is made from Perspex plastic to ensure its sturdiness and stability when device is moving.

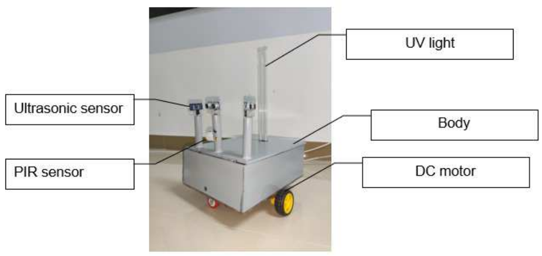

Fig. 3. The prototype of UV Sanitiser

The device is powered by an AC power supply to turn on the UV light. Then the power supply is converted to DC voltage which is 12V 10Amp to supply the L298N motor driver. The 12V is stepped down to 5V to power up the ESP32, ultrasonic sensor, PIR sensor and buzzer.

III. RESULT

The device required Blynk apps to act as switches to start the sanitization process and human alert system. Once the "UV light" switch is turned ON in figure 4, the ultrasonic sensor will start to measure the distance from obstacles. So that, the device can move forward and closer to the right wall showed in figure 5.

Moreover, when the "Human alert system" switch is turned on in figure 4, the PIR sensor will start detecting human motion. Once the human is detected, a notification will be sent to the user, the device will stop moving, the UV light will turn OFF and the buzzer will turn on for 20 seconds. This helped to alert the human about the danger of the device and avoid hazard. The simulation can be seen in Figure 6, after 20 seconds alert, the PIR sensor will sensing human presence again before turning on the system back.

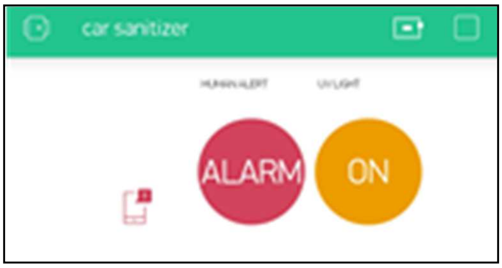

Fig. 4. UV light and human alert switches using Blynk apps

Fig. 5. Testing of UV Sanitiser prototype

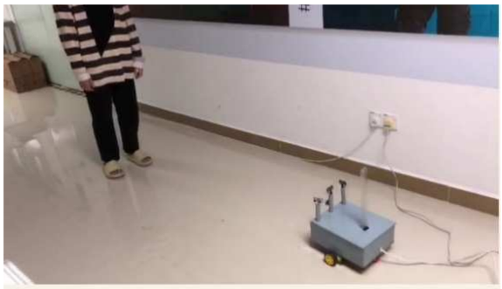

Fig. 6. Device stop moving, turn on buzzer and turn off UV light for 20 seconds.

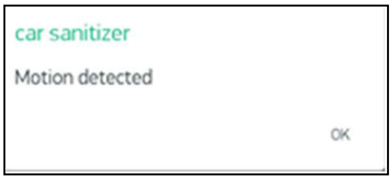

Fig. 7. Notification received by the user to alert the user about human presence.

The prototype has been tested in the lab for two different area size to monitor the performance in term of disinfection time without human control.

The time of disinfection in different area as shown in Table I are measured to ensure its efficiency. The time taken needed to sanitize is highly depends on the human presence and room area. The longer time needed with human presence and its highly depends on the human movement as the longer the human stay near the device, the longer time needed to sanitize. The time also can be affected when the device got stuck with bumpy stuff on the floor.

TABLE I. DISINFECTION TIME WITH OR WITHOUT HUMAN PRESENCE IN DIFFERENT LOCATION.

Situation	Sanitization time 3mx4m (minutes)	Sanitization time 5mx5m (minutes)
Without human	20	50
With human presence	37	76

To determine the effectiveness rate of UV sanitizer, agar sample is used as it provides nutrient and solid growth surface for the bacteria.

Therefore, few experiments are conducted to observe the effectiveness rate of the UV light device at different height.

1) Choose 4 different places with different heights from the floor to collect bacteria samples such as table (76cm), chair (44cm), floor (0cm) and bed frame (23cm).

2) Prepare 5 self-made agar in petri-dish.
3) Set 1 control agar sample before the sanitization process occurs to observe the bacteria growth.
4) After 50 minutes of the sanitization process, swap the selected places onto the agar sample. Then observed bacteria growth after 4-5 days. Repeat the experiment in 5 different rooms to determine UVC effectiveness.

Based on the above experiment, the result on the agar is observed in table II.

TABLE II. RESULT OF THE AGAR SAMPLE

Agar sample	Height from the floor	Rate of UV effectiveness
Table	76 cm	40%
Bedframe	23 cm	80%
Floor	0 cm	100%
Chair	44 cm	80%

IV. DISCUSSION

Based on the result, the device reduces its effectiveness as the object increases its height from the floor. The device is the most effective on the floor as it showed no bacteria growth compared to others. This is because the time of sanitization is highly dependent on the distance from the UV light. Therefore, the UV light will reduce its effectiveness at a certain height as the device is moving continuously across the room. As the result, the floor at the lowest height has 100% UV effectiveness while the table is the furthest away from the UV light has only 40% UV effectiveness.

The UV light is shorter than the table causing the UV light unable to sanitize the whole tabletop. Thus, it reduces the UV light ability to kills bacteria on the table rather than the floors that are more exposes to the UV light.

These problems can be solved by increasing disinfection time per area or increase the size of the UV light. By decreasing the speed of the device, the time for the UV light exposure per area increases. Therefore, the UV effectiveness will increase as the UV light able to radiate the whole room effectively. In addition, increasing the light size cause the UV light able to radiate the whole room effectively. This is because, the UV light radiation reduce exponentially over distance. Thus, by increasing the UV light size, more area able to be sanitize at short amount of time which will increases sanitization effectiveness.

In other way, ultrasonic sensor is compared to decide its error. Experiment was done by comparing the actual data and measured data of the ultrasonic sensor on horizontal surface.

TABLE III. COMPARISON OF THE ULTRASONIC READING ACCURACY WITH ACTUAL DATA.

Actual data (cm)	Measured data (cm)	Error (%)
10	10	0.00
20	19	5.00
30	31	3.33
40	38	5.00
50	52	4.00

The experiment is done to ensure the movement of the device is smooth. Based on the result, the error can become up to 5% which has 2cm difference from the actual data. Furthermore, the effectiveness also reduced as the detection angle increase.

Thus, to minimize the error, three sensors are used which significantly increase the detection angle and made it possible to simultaneously detect distance from front, right and left angle. This helped the device to efficiently move forward but closer to the right wall effectively rather than move in random direction.

V. CONCLUSION

To conclude, a UV sanitizer is designed with an alert system integrated with an Android app. This can be seen as the prototype is using Blynk apps as an interface to receive notifications whenever an intruder is detected. This helped prioritize the safety of the human in the surrounding area as the user was able to control the UV light via Wi-Fi connection. Different experiment was done to prove the device system and be concluded.

Firstly, more ultrasonic sensors are used to provide fast obstacles detection system and wider detection angle rather than using only one ultrasonic. In this case, three ultrasonic sensors are used at different angles which indicates that when 40 cm away from the obstacles, the device will alternate its direction accordingly to avoid a crash and move seamlessly.

Secondly, the time needed to sanitize the room is highly dependent on the presence of the human. The longer the human stays within the detection range of the PIR sensor, the longer time is needed to sanitize the area. The PIR sensor sensitivity is reduced to provide better detection as the higher the sensitivity, the device will likely confuse between human's movement and device's movement.

Thirdly, the experiments are done using agar samples to indicate UV effectiveness at different heights. The result showed that the UV effectiveness reduce as the height increased which proved that UV light radiation reduce exponentially over distance. Therefore, to increase the sanitization area, the UV light needs to elevate over a distance without reducing its effectiveness, the time of sanitization must be increased whereas the device will stop after a certain distance to provide a better sanitization process.

However, future recommendations can be done to improve the device for future society such as using LiDAR sensor to replace the ultrasonic sensor to provide autonomous movement. This is because, it can produce a 2D/3D image of the rooms whereas the device is able to move effectively throughout the rooms. Next, by upgrading the human alert from the PIR sensor to the thermal camera. Better human detection and fewer false alarm can be achieved. Lastly, to reduce confusion to the user, a data system that is able to calculate the time needed per sanitization session and able to localize a correct room is more convenient to the user. This helped to avoid double-sanitizing rooms in a close time range.

REFERENCES

[1] DG OF HEALTH, "Kenyataan Akhbar KPK 5 Jun 2020 – Situasi Semasa Jangkitan Penyakit Coronavirus 2019 (COVID-19) di Malaysia – From the Desk of the Director-General of Health Malaysia." https://kpkesihatan.com/2020/06/05/kenyataan-akhbar-kpk-5-jun-2020-situasi-semasa-jangkitan-penyakit-coronavirus-2019-covid-19-di-malaysia/ (accessed Jun. 21, 2021).

[2] N. van Doremalen *et al.*, "Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1," *N. Engl. J. Med.*, vol. 382, no. 16, pp. 1564–1567, Apr. 2020, doi: 10.1056/NEJMC2004973/SUPPL_FILE/NEJMC2004973_DISCLOSURES.PDF.

[3] S. Elhariri, "Annals of Clinical Surgery 2020 | Volume 1 | Issue 2 | Article 1008 MRSA Infection in General Surgical Wards in a Malaysian Tertiary Hospital: A Retrospective Study," *Ann Clin Surg*, vol. 1, no. 2, p. 1008, 2020.

[4] C. McGinn *et al.*, "Exploring the Applicability of Robot-Assisted UV Disinfection in Radiology," *Front. Robot. AI*, vol. 7, Jan. 2021, doi: 10.3389/frobt.2020.590306.

[5] M. Bentancor and S. Vidal, "Programmable and low-cost ultraviolet room disinfection device," *HardwareX*, vol. 4, p. e00046, 2018, doi: 10.1016/j.ohx.2018.e00046.

[6] A. Vyshnavi, A. Manasa, C. Hamsika, and P. Shalini, "UV Disinfection Robot with Automatic Switching on Human Detection," *EAI Endorsed Trans. Internet Things*, vol. 6, no. 23, p. 166364, 2020, doi: 10.4108/eai.25-9-2020.166364.

[7] T. Pacharawan Chanprakon and P. H. and W. P. Sae-oung, Treesukon Treebupat-chatsukal, "An Ultraviolet sterilization robot for disinfection," vol. 5, pp. 44–47, 2019, [Online]. Available: https://sci-hub.do/downloads/2019-08-29/c4/chanprakon2019.pdf?rand=60afe4e1a3ba3#view=FitH.