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Design and Development of a Sanitization Robot (ROBOSAN V2)

Abstract. *Since the new Corona Virus 19 (COVID19) emerged in December 2019, it has impacted many countries due to its fast infection and is hard to detect, especially with an asymptomatic person. Many new tests and equipment were introduced to the world for us to live in this new normal. The surge of patients infected by the Covid 19 in the hospital itself has exposed our frontliner, such as doctors, while treating the Covid patient. This also includes the cleaner who needs to clean the contaminated room, such as the Intensive Care Unit (ICU) and quarantine rooms. Recent studies show that the virus can last up to 72 hours on surfaces like the floor, plastic, and stainless steel. Therefore, this project uses an ultraviolet C(UVC) as an additional solution on top of the standard cleaning solution to reduce the virus's life expectancy and eliminate it. This sanitization process is equipped in a manually controlled sanitation robot (RoboSan V2). The water pump at the front of the robot is implemented to spray the sanitized liquid and this prototype has a led Ultraviolet-C strip that sterilizes the floor surface after the cleaning. Besides that, the prototype is equipped with a camera for online supervision and controlled via Bluetooth using an application on the smartphone. For extra features this robot can detach the water pump and UVC light for other purpose.*

Streszczenie. *Odkąd nowy koronawirus 19 (COVID19) pojawił się w grudniu 2019 r., wpłynął na wiele krajów ze względu na szybką infekcję i jest trudny do wykrycia, zwłaszcza u osoby bezobjawowej. Wiele nowych testów i sprzętu zostało wprowadzonych na świat, abyśmy mogli żyć w tej nowej normalności. Gwałtowny wzrost liczby pacjentów zakażonych Covid-19 w samym szpitalu ujawnił naszych frontmanów, takich jak lekarze, podczas leczenia pacjenta z Covid-19. Obejmuje to również sprzątaczkę, która musi posprzątać zanieczyszczone pomieszczenie, takie jak oddział intensywnej terapii (OIOM) i pokoje kwarantanny. Ostatnie badania pokazują, że wirus może przetrwać do 72 godzin na powierzchniach takich jak podłoga, plastik i stal nierdzewna. Dlatego ten projekt wykorzystuje ultrafiolet C(UVC) jako dodatkowe rozwiązanie poza standardowym roztworem czyszczącym, aby skrócić oczekiwaną długość życia wirusa i go wyeliminować. Ten proces sanityzacji jest wyposażony w ręcznie sterowanego robota sanitarnego (RoboSan V2). Pompa wodna z przodu robota służy do rozpylania odkażonej cieczy, a ten prototyp ma pasek LED Ultraviolet-C, który sterylizuje powierzchnię podłogi po czyszczeniu. Poza tym prototyp wyposażony jest w kamerę do nadzoru online i sterowany przez Bluetooth za pomocą aplikacji na smartfonie. Aby uzyskać dodatkowe funkcje, ten robot może odłączyć pompę wodną i lampę UVC do innych celów.* (***Projektowanie i rozwój robota odkażającego (ROBOSAN V2***))

Keywords: Sanitization, UVC-Light, Robot, COVID-19
Słowa kluczowe: robot odkażający, światło UVC

Introduction

Due to the present COVID-19 illness outbreak brought on by the SARS-CoV-2 new coronavirus, a large influx of COVID-19-infected patients has flocked to the hospital for treatment. Because it needed to be cleaned at least once a day, numerous staff members, including healthcare workers, were exposed to this virus. Combining sanitizer fluid and UVC light can improve the effectiveness of killing Corona Viruses. Manual cleaning methods are risky for humans, although they are equipped with full PPE [2]. Besides that, using auto sanitization may miss some parts of the room or area. Furthermore, the design before (RoboSan V1) was good but consumed a lot of power and was also heavy because of the numerous components. It was hard to change the power supply because it used a non-rechargeable battery.

A considerable amount of literature has been published on sanitization devices such J. Hu et al., (2021) presented an automated device for public elevator control panel UVC sanitization [3]. The paper highlighted the use of UVC light to deactivate SARS-CoV-2 on a control panel in the public elevator [3]. However, the article only focuses on the control 19 panels, which are one of many possible infected areas. Therefore, for this project, RoboSan will use UVC LED Strip light to disinfect germs and pathogens in a larger area which is a floor. Next, M.Bentancor and S.Vidal, (2018) published on Programmable and low-cost ultraviolet room disinfection devices [4]. The paper stated a disinfection device that is designed for the periodic conditioning of culture rooms which is a wide-ranged area. It also said that experimental tests showed the very high effectiveness of this device in eliminating high bacterial inocula, and it has several advantages with respect to chemical-based sanitizing methods [4].

Table 1 Comparison of Previous Research that have been patent with Robosan V2

Patent	Patent features	'RoboSan V2' focus features
Autonomous floor mopping apparatus [8]	This cleaning robot may be remotely controlled or Autonomous [8].	Simple wet mopping and sterilizing using UVC Led Strip.
Autonomous surface cleaning robot for wet cleaning [9]	An autonomous floor cleaning robot includes a transport drive and control system arranged for autonomous movement of the robot over a floor for performing cleaning operations [9].	This prototype uses a mop pad attached to the underside of the robot to absorb cleaning solution as it moves forward. This process is the same as mopping the floor by hand.
Autonomous cleaning robot [10]	The autonomous system uses a series of ultrasonic sensors to calculate the position of the robot relative to obstacles which allow for safe autonomous movement.	This prototype used wet mopping system, while UVC Led strip was used to disinfect the cleaning surface from bacteria and microorganism.
Sterilization system with ultraviolet emitter for eradicating biological contaminants [11]	The robotic mobile platform being configured to neutralize biological contaminants by using the ultraviolet light source to emit ultraviolet light on a surface [11].	Simple UVC light system that combine with Wet mopping system to ensure that the cleaned area is thoroughly cleaned.
Patent	Patent features	'RoboSan V2' focus features
System and method for autonomous mopping of a floor surface [12]	The robot includes a controller for managing the movement of the robot as well as the treatment of the surface with a cleaning solvent [12].	Manually controlled using smart phone and the webcam installed on the prototype's front allows users to detect and control the prototype's direction.

But then again, the device can only be installed in one location, and installing it in each room will cost extra. Hence, in this project, a mobile robot can help to reduce costs, which is even critically crucial in this pandemic era. Thus, Table 1 presented a list of patented robots compared to the features that this project proposed.

Another intriguing paper from Pacharawan Chanprakon (2019) which is an ultraviolet sterilization robot for disinfection. The paper highlighted UV robots for sterilization [5]. The most exciting feature of this robot is it has UV lamps mounted on top of the UV bot platform covering 360° direction where it can cover more area [6]. Even so, the lamp's distance from the floor is too much to achieve proper sterilization. For that reason, RoboSan has been set to clean the floor area where the UVC light is placed under the robot. Furthermore, an exciting project involving a sanitization device is from Tang-Jen Liu and Shi-Hao Liu (2021), which presented A Self-Sterilizing Toilet Seat with UVC Radiation [5]. The research study focused on A toilet set with UVC LEDs radiating 275 nm for sterilization which also includes a system that can switch off automatically using detection [6]. On the contrary, this project also can only be installed in one location for each device. To this end, RoboSan is a mobile robot that can be controlled manually and a low-cost sanitization device that will help to ease human work and provide safety during cleaning works.

Riki Patel (2022) presented an article on an Autonomous robotic system for ultraviolet disinfection. The paper highlighted a method of using Ultraviolet (UV) sterilization technology to reduce the microorganisms that may remain on the surface after a standard cleaning to the minimum number. However, the paper only focuses on reducing the microorganism that remains on the surface [7]. Hence the primary aim of this research is to develop a manually controlled robot using for sanitizing a Covid patient's room by using Bluetooth. An additional UVC light was added to reduce the contamination of virus in a room. Furthermore, the project also aims to design a low-power consumption robot.

Methodology

In this project, the method incorporates a few vital techniques. After a rigorous literature search, the circuit is constructed on the breadboard, which helps for more accessible assessment before developing the prototype.

The block diagram in Fig.1 explains how the system connect and works. First, to make the prototype is working, both prototype and handphone need to be turned on. For the phone, it needs to open the Bluetooth RC Controller application that can be obtain by downloading the apps in the Google Play store and connect it with robot via Bluetooth. The app has button for moving the prototype and switch for turning on the UVC lamp and water pump. Furthermore, in the prototype, it has STM 32 that connected to component HC-05 Bluetooth Module. The phone will send the information to STM 32 and then it will transfer an instruction to the next component to make the next step. When the phone is clicked on the Bluetooth button, it will find the HC-05 Bluetooth Module's id and connect with it by Bluetooth. Whenever the UVC lamp or water pump button is clicked on or off the component will turn on or turn off. The cleaning solution will flow out from the water tank to the nozzle when the water pump is turned on. For the movement, the STM 32 will send the instruction to the Motor driver, and it will make sure which motor is turned on. Finally, to observe the room in a safe distance, another phone will need to be used to be connected to camera also via Bluetooth.

All the components and modules used for creating the system are in Table 2, and Fig. 2, Fig. 3, & Fig. 4 schematically displayed the listed components.

Table 2 – List of components used.

No	Module/Component
1	STM32F103C8T6 Blue Pill
2	HC-05 Bluetooth Module
3	L298N DC Motor Driver Module
4	Geared DC Motor
5	DC Water Pump Motor
6	UVC LED Strip
7	Mini Webcam
8	Rechargeable Lithium-ion Battery

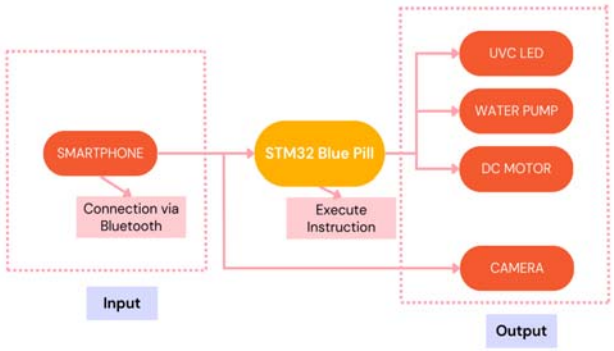

Fig. 1 – Block Diagram of the System

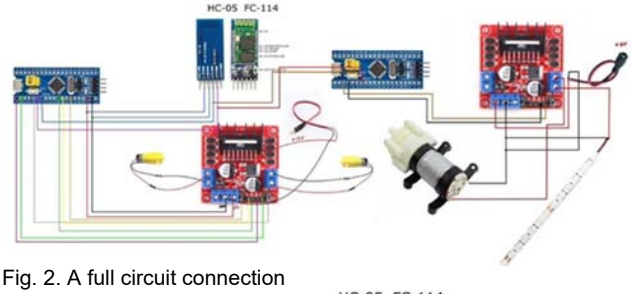

Fig. 2. A full circuit connection

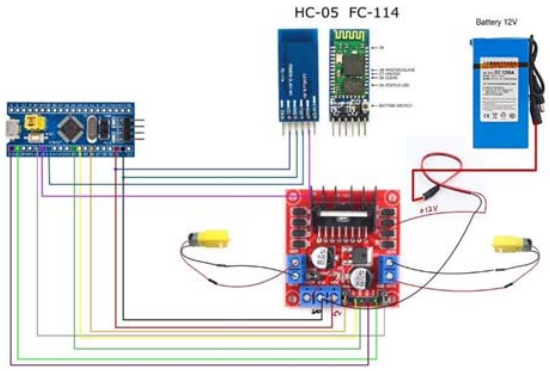

Fig. 3. First part circuit connection (Robot Movement).

The entire circuit implemented for RoboSan V2 is demonstrated graphically in Fig.1, which joins the two circuits using one power supply and one Bluetooth module. For this circuit, the output Rx and Tx from the STM32 of the water pump and UVC Light part are connected to the same connection of Rx and Tx from the STM32 of the Dc motor and directly connected to the Bluetooth module HC-05. Both STM32 have their code, and if necessary, to split it can still function properly. But the water pump and UVC light part need their Bluetooth module to transmit their data controlled by the application from the smartphone. The water pump needs a voltage supply of 12V to smooth the operation and maximise functionality.

Based on Fig. 2, the circuit has now been controlled by STM32 Blue Pill as a microcontroller that controls the movement of the DC motor through the L298N motor driver and then transfers to the DC motor. Using data from the HC-05 Bluetooth module, pin A9 for Tx and A10 for Rx, it will receive and send data from a host system via the application controller interface, which in this project is known as the RC Bluetooth Controller. Pinout B3, B4, B12 & B13 from STM32 are connected to the input pin DC motor driver and enable pin to make movement for both DC motor and control the PWM DC motor speed. From the motor driver, the power supply is connected to the battery 12V, and this module supplies the voltage to the STM32 board with an operating voltage is 5V. The output pin for the DC motor was connected to the output pin on the L298N motor driver, which outputs 1 and 2 for the right motor and outputs 3 and 4, respectively, for the left motor. The Bluetooth module HC-05 is independent of this part of the circuit only. Apart from that, this circuit only controls the DC motor part.

The front part of RoboSan V2 contains the 12VDC Motor pump, UVC LED, L-928 Motor driver, 7.2V power source (rechargeable lithium-ion), and HC-06 Bluetooth module, which is connected to the microcontroller of STM32F103C8(Blue Pill) as seen in Fig.3.

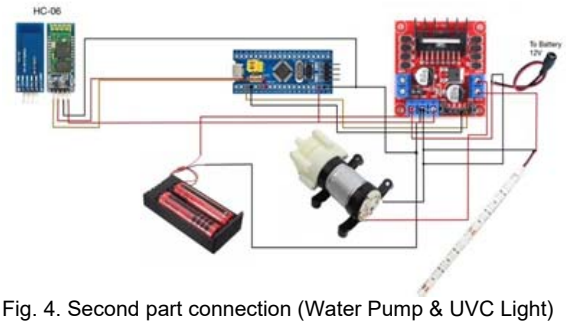

Fig. 4. Second part connection (Water Pump & UVC Light)

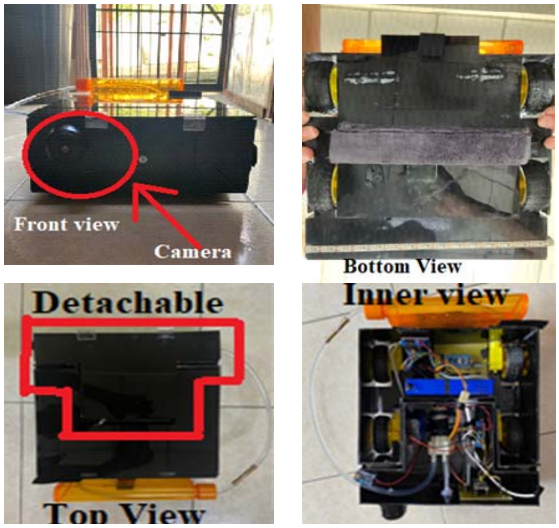

Fig. 5 –RoboSan V2 full prototype

The purpose of the component on this part was able to load the sanitizer fluid and generate mist spray. Other than that, with the help of UVC LED it will create two layers of germ extermination. The HC-06 Bluetooth module can be connected to 3 points of Tx-Rx connectivity which are PA9-PA10, P10-PB11, and PA2-PA3. The connection between Blue Pill and Bluetooth module must be a cross-connection in which the Rx's Bluetooth module goes to Tx's Blue pill and vice versa. The power source of 7.2V does not go directly to Blue Pill, but it is connected to the Motor driver as the Motor driver can receive two types of DC voltage which are 12V and 5V. Which, it will allow the Motor driver to take advantage of excess voltage. Also, 5V input on the Motor driver was used to power up Blue Pill. Since there are not many components on the front part, 7.2V with 1200mAh capacity was enough to power up the front part of RoboSan V2. Both the 12V Motor pump and UVC LED were powered up by the Motor driver. The current output from the Blue Pill was too low and not enough to even power up the UVC LED; that is the reason UVC LED was not powered up directly from the blue pill which can be seen in Fig. 3.

In Fig.4 presented the full view of the RoboSan V2 prototype with the total cost of RM 395 only. The front of the robot is equipped with a camera and the detachable microfiber mop is placed on bottom part of the robot that can be easily replaced. As mentioned, Robosan V2 can be detached from its original body meaning the part with the cleaning solution and UVC can be an additional accessory to any autonomous robot that anyone has at home.

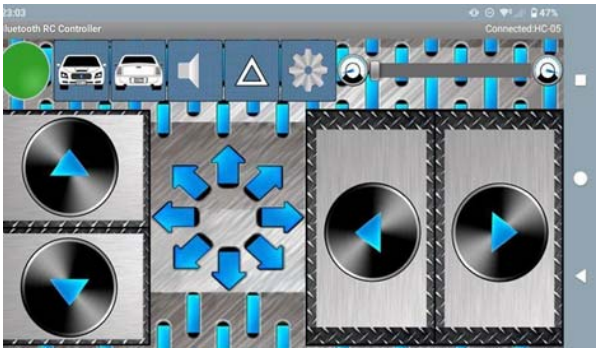

Fig. 6. Bluetooth RC Controller app's view

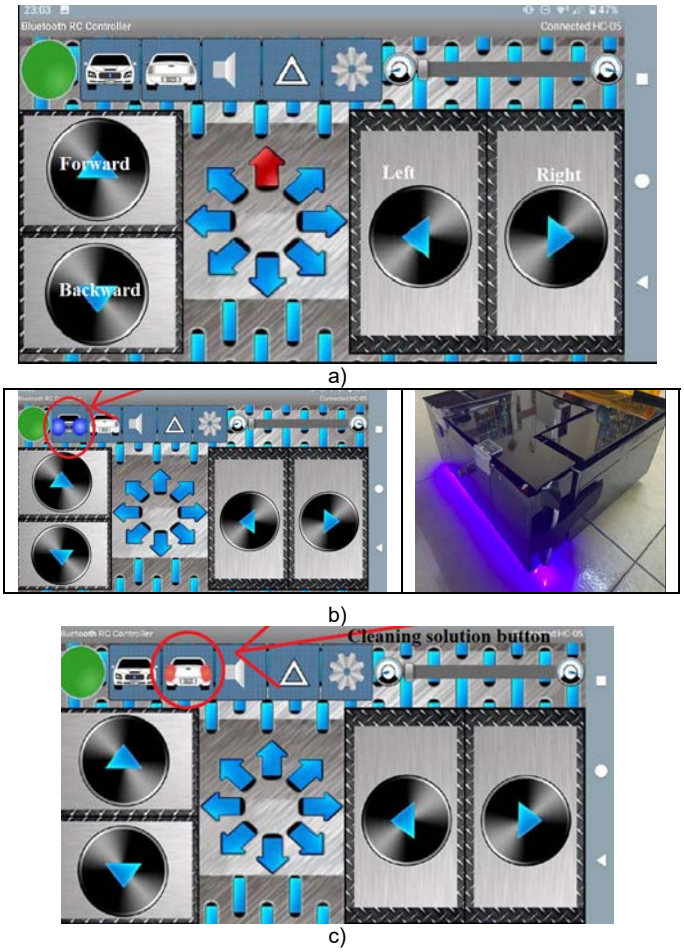

Fig. 7 – a) Movement direction controller in the RC Controller apps b) the button to turn on the UVC light c) Cleaning solution controller button.

Robosan V2 uses a remote-controller app which connected via bluetooth and can be install in any Android phones or tablet as seen in Fig.5.

After the robot is turned on, the HC-05 Bluetooth Module becomes discoverable and able to connect to the application Bluetooth RC Controller; the green light on the top left corner indicates the software is connected to the robot. The application will send the command to the robot to be executed by clicking the button.

The main parts of RC Controller apps that connected to the Robot are shown in Fig.6. For the robot direction to moved forward, backward, turning left and right seen in Fig.6 a). For the features of sanitize solution dispersion button shown in Fig.6 b). And in Fig.6 c) to turn on the UVC light.

Results and Analysis.

There are several analysis made to tested the robot.

Table 2 Distance covers to refill 10 times using 420ml of bottle

No. of Bottle (420 ml)	Distance Covered (m^2)
1	99
2	198
3	297
4	396
5	495
6	594
7	693
8	792
9	891
10	990

First Analysis: Cleaning solution storage capability per area

First analysis shows the robot capability to cover 9m x 11m area with a single filled solution tank. The lecture room is estimated 9m x 11.4m area. Therefore, it took only a single full tank to finish the whole room. The result in Table 3 summarize how many bottle needed to cover up to 990 m^2.

Second Analysis: Glow Powder as bacteria to determine the UVC effectiveness.

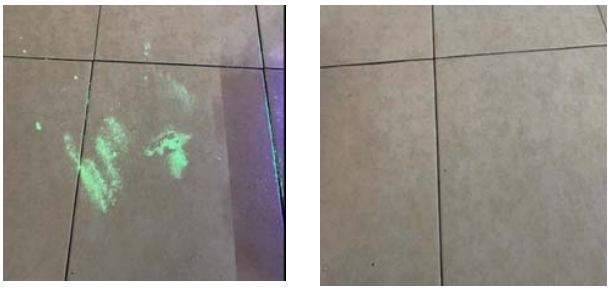

Fig. 8 – Show the floor tile before (left) and after (right) sanitizing by RoboSan v2.

As seen in Fig.7, the effectiveness of the prototype was tested by using glowing powder acts a bacteria/virus. This analysis aims to determine the function of the cleansing solution and mopping process used in figure. The study has proven that the cleansing solution used is valuable and can clean an area well. This experiment succeeded because when the glowing powder was exposed to UVC Light, the glowing powder glowed to show the powder interacting correctly. After the cleaning session with microfiber mop and UVC light treatment, Fig. 7 (right) shows the floor clean from the glow powder on the floor.

Third Analysis: Range of the Bluetooth connection and battery lasting.

In this analysis, the range of the prototype could reach via bluetooth was tested in the faculty walkaway as shown in Fig. 9.

Fig 9 Testing the Bluetooth connection between smartphones and prototype.

For straight walkaway, Fig.9 indicates the robot bluetooth range able to reach as far as 35.2meter. The further the robot is from the phone, the slower the information is sent into the robot. Hence, with 420ml of cleaning solution and almost 36 meter of ranges, the battery for the motor could last for an estimated 7 hours, for the UVC light an estimated 6 hours, and for water pump it is estimated 5 hours. The robot moves slowly when the battery is low and keeps moving until the battery is run out.

: Conditions

1 = moving, 0 = non-moving

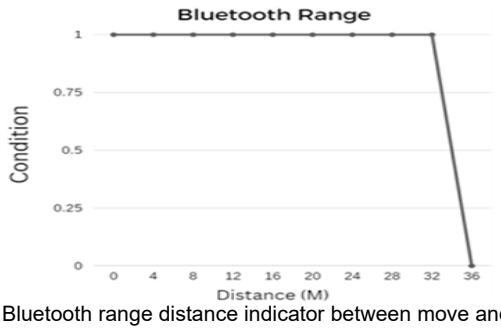

Fig. 10 Bluetooth range distance indicator between move and static

Fourth Analysis: STM32 and Motor Driver sustainability

In our previous design (RoboSan V1), the prototype has lack of heat tolerance due to the microcontroller keeps overheating due to high power usage. Hence, for this design, the STM 32 is chosen due to low power consumption, but the motor driver was getting too much heat caused by the 12V battery.

Conditions: 1 = move, 2 = overheat, 3 = resting

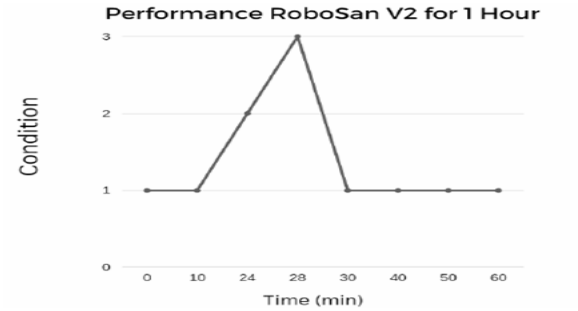

Fig. 11 Motor performance for 1 hour of operation

Table 3 Comparison specifications between Arduino Uno & STM32 Blue Pill

Microcontroller	Arduino Uno	STM32 Blue Pill
Operating voltage	5V	3.3V
Analog input	6	10
Digital I/O pin	14	37
DC source from I/O pins	40mA-50mA	6mA
Flash memory	32kB	64/128kB
SRAM	2kB	20kB
Clock speed	16MHz	72MHz

As presented in Fig.10, the motor driver can hold from overheating and can only last 24 minutes, and it needs to rest for just 4 minutes to back in good condition. This is because the motor driver has a heatsink to absorb the heat from components.

Comparison between RoboSan V1 and RoboSan V2

Based on previous design, (RoboSan V1) and this RoboSan V2, V1 used plywood as the body design, and V2 used acrylic sheets laser cut for the body structures. Plywood can affect the quality of the structure because the spilled water solution will affect the plywood. So acrylic sheets are better to use as structure prototypes because they are waterproof and light. For the brain of the prototype, which is the microcontroller, the previous version used Arduino Uno, and this version used STM 32 Blue Pill. Their specifications and comparison are shown in Table 3.

By referring to the Table 3, it proves that the Blue Pill uses a lower operating voltage of 3.3V than the Arduino Uno, 5V. Besides that, the Blue Pill output pin gives only 6mA of output current, which is also lower than the Arduino Uno, 40mA to 50mA. From the table above, most of the variable sides of Blue Pill prove the Blue Pill has more advantages than the Arduino Uno. So, the power consumption for V1 is higher than V2.

Besides that, the performance for V1 is not very smooth, and it has been delayed a few seconds after the button in the application is clicked. This is because the Arduino Uno easily overheats, so the robot's movement cannot be controlled well. Different from V2, which uses STM 32 that performed well and was not delayed. This is because the STM32 is not directly connected to a 12 V power supply, but it is from the motor driver that has a step down the voltage to 5V. So, the STM 32 will not burn and overheat like Arduino Uno.

The battery V1 used is not rechargeable, unlike V2, which uses 12V DC Rechargeable Battery Polymer Lithium-ion Battery, which is good for the environment. V1's battery is not centralized because it uses a different battery, different components, or one battery for one component and functions. V2 only used two batteries, 12V two controlled all the components when part one and part two of the prototype were merged, and another battery for the water pump and UVC lamp when the prototype was separate from the motor. So, the functions of the water pump and UVC lamp can be used, although the 12V battery in the motor runs out.

Furthermore, the area covered by V1 is less than V2. This is because the previous prototype only used 250 ml as shown in Fig. 11, and this prototype used 420 ml. For example, RoboSan V1 needs to refill a few times to sanitize the lecture room thoroughly, but RoboSan V2 only requires a full tank to complete the lecture room. Another reason the previous prototype needs to refill a few times is that the nozzle cleaning solution does not work well from this prototype in that the nozzle mist and functions well.

Fig. 12 Robosan V1 prototype

Lastly, the features of the RoboSan V2 are that the prototype can be separated into two parts which are the first part has the motor, and the second part contains a water pump and UVC lamp. These features develop because when the motor has a problem such as broken or the main power supply 12V runs out, the second part can be used in other robots because it was only connected with Velcro tape that can be easily use. Then the others feature is that this prototype has camera surveillance. The camera used can be viewed even when the robot is moving, and it is effortless to use and, the camera is rechargeable.

Discussion

In this project, RoboSan V2 is a robot that has the function of cleaning a quarantined room without any need for a person to be near that room. This way, it can reduce the risk of virus infection in that person. This project can clean places that are hard for humans to reach because their size fits this assignment. This prototype can last long enough to cover a quarantine room due to its external source. The Bluetooth connection also has no problem regarding the range of the area covered because it can reach far enough to cover a room. The motor's battery could last for an estimated 7 hours, the UVC light is 6 hours, and the water pump is 5 hours. The solution tank is enough to use for big cleaning areas. The power sources are rechargeable, so it is upgraded from the previous version of RoboSan. Plus, the prototype efficiently cleans a room because of its features.

The first idea for UVC is to use the T5 Anti-Virus Bulb UVC Quartz Tube 8Watt but to use. The prototype needs to have an inverter because the lamp needs 220V, and it was an AC supply. The prototype uses a DC supply. The experiment was carried out, and the inverter 40W DC-AC Boost inverter 12V 220V Step up power Modules exploded, and the lamp was unable to have a good source. Therefore, UVC LED strippers were used because they can use a DC supply.

The analysis took place in lecture room 4 at the Faculty of Electronic Engineering and Computers. In this experiment, the prototype can completely clean the lecture room before the motor driver overheats. But the prototype just needs 4 minutes to rest before the temperature of the motor driver returns to normal. Not the same as the previous prototype, which needs to wait up to 8 minutes to rest. Besides that, the solution tank can cover the whole lecture room, which is 9m x 11m. The Bluetooth connection between the camera and the robot does not have any problem in the experiment because the connection range is good. The camera can be viewed clearly even when the robot is moving, and it is effortless to use and rechargeable. For the last analysis, the glowing powder acts as bacteria. It is suitable for the examination because when the glowing powder is exposed to UVC light, it will glow up, indicating that the analysis succeeded. The wiping mope also absorbs all the powder to clean the floor.

This prototype is used for low power consumption because the microcontroller has only a 3.3V operating voltage and the power supply is rechargeable. Due to the longer intervals between battery changes, low power design leads to longer battery life, enhancing user experience. A product with a longer battery life may also require fewer trips to change batteries, resulting in cheaper maintenance expenses. Besides that, RoboSan V2 uses fewer components than the previous design, which uses four relays, four motors, and many batteries with two supply voltage to each component. Unlike RoboSan V2 are used only two motors and has the capacity of a 12V 8000Mah rechargeable battery to supply the components. Plus, the STM 32 will not overheat because the voltage entered is

only 5V from motor drivers that support 12 V. So, this prototype uses low power to consume and support the components. It is environmentally friendly, unlike the previous version RoboSan V2 that used lead acid battery and other non-rechargeable batteries.

Conclusion

In conclusion, the RoboSan V2 is a cutting-edge robot designed to clean quarantine rooms and reduce the risk of virus infection in human cleaners. The robot is able to clean places that are hard for humans to reach due to its size and the use of an external source. With its long battery life and the capability to cover a large area, this prototype is suitable for cleaning quarantine rooms. Additionally, it uses a Bluetooth connection which ensures coverage of the area with no range problem. The prototype is designed to last long enough with the use of rechargeable power sources, making it more efficient and cost-effective than its predecessor. The robot is designed to use UVC light to disinfect the room, it uses UVC LED strippers to enhance the cleaning process. In experiments, it was found that the robot can completely clean a room within a short time, with 4 minutes of rest required before the temperature of the motor driver returns to normal. This prototype uses a solution tank that is sufficient to cover large areas, and it has a Bluetooth camera that can be viewed clearly, making it easy to use. Furthermore, the prototype is designed to be environmentally friendly, as it uses low power consumption and has a longer battery life. This leads to cheaper maintenance expenses and less trips to change batteries. Additionally, this prototype uses fewer components and consumes less power than the previous design, which makes it more energy efficient. The use of a microcontroller with 3.3V operating voltage and a 12V 8000mAh rechargeable battery ensures that the components are supplied with power without overheating. This leads to a longer lifespan for the product and a more user-friendly experience. In conclusion, the RoboSan V2 project is a promising solution in the field of cleaning and preventing the spread of viruses. It effectively disinfects and cleans quarantine rooms while being cost-efficient and environmentally friendly. The success of the experiment shows that the prototype can be used to clean large areas and can be used to prevent the spread of viruses, 68 making it a valuable tool in various situations. The RoboSan V2 is a great example of how technology can be used to create safer and healthier environments.

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