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# C-Remor: UVC-Room Sterilization Mobile Robot

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**Abstract:** Mobile robots can be used in a variety of Internet of Things projects. The sterilization robot is created in the form of a mobile robot by combining two microcontrollers. The Arduino Uno microcontroller provides a sensor acquisition device, while the ESP32-cam provides the actuator controller, which is linked to the Wi-Fi network displayed on the web server. The millis function has been used in the Arduino module programming process because it requires doing tasks at the same time. This modeling system has an accuracy of about 80% for Arduino module settings as sensor controllers and 80%-86% for ESP32-cam modules as user interfaces and actuator controllers. This is due to the sensor's limited range and the Wi-Fi network used.

**Keywords:** Arduino, ESP32-cam, microcontroller, mobile robot, web server

## 1. Introduction

The covid-19 from Wuhan, China, shocked the world in 2019. The virus has infiltrated several countries, including Indonesia. The rate of covid-19 transmission in Indonesia is increasing and has not decreased. As a result, the public is required to limit their activities and refrain from contacting one another in order to break the chain of covid-19 spread. A hospital is a place where people suffer from diseases, and it is necessary to keep each room sterilized so that the disease does not spread or cause pain in patients who are already suffering. A sterilization process is required in the room used by certain patients, such as those suffering from covid-19 so that the next patient who occupies the space is not affected by the previous patient [1].

The sterilization process in the room is still manual, and the room is still cleaned by humans. There are also studies showing that the continuous use of chemical disinfectants can be a factor in chronic obstructive pulmonary disease [2]. This, of course, raises the possibility of transmission to humans who clean the room. To reduce the risk of transmission through this room sterilization activity, a tool that assists humans in carrying out sterilization without direct contact between humans and the room to be sterilized is required. In his efforts it will use remote-controlled mobile robot that can replace human beings in situations of danger [3]. UV light is a sterilization alternative because it does not require a refill process or a change of sterilization material or liquid, such as alcohol or chlorine-containing cleaners. Excessive use of this solution can have a negative impact on the environment and human health because of its reactive nature [4]. UV-C kills 95% of bacteria, viruses, and germs with a modest dose, making it the most efficient UV light type for this purpose [5]. It has a lethal effect on microorganisms [6]. Not only is it effective for disinfecting surfaces, but UV-C light is also effective for disinfecting air and liquids. To be able to use UV-C, radiation distance and light intensity must be taken into consideration because both are important factors in carrying out the sterilization process [7]. Shernoy et al. created a robot named Steriloid in their study, which would be useful during a pandemic to reduce direct contact in the room cleaning process [8]. Their robot would be capable of moving around the room and using sterilizing liquid. In the other study, Pristianto et al. enhanced the system of room sterilization so that it could be done safely and remotely. The type of robot was a fixed robot, using three PIR sensors, UV-C, and Bluetooth connections [9].

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How can the room be sterilized without direct human contact and without having to refill the sterilizing fluid? This study aims to provide an answer to that query. The solution proposed to overcome and prevent transmission in the room sterilization process is a room sterilization robot, which can assist users while avoiding direct contact. This study will begin with data collection as a starting point for robot development. This is the first initial project where the product will be expressed using cheap and simple materials. In its development, it is possible to carry out the development of more complex systems, such as in the second stage, using an autonomous system that allows the robot to move independently without being directed manually. And in the last, more advanced stage, the design will be carried out with an IoT system that allows the robot to be able to register the system and travel from the initial point of charge to the place/room that needs to be sterilized. The hardware components, as well as the IDE used to program the system, will be specified in the product specifications. Before the system implementation, the wiring between components is done as an illustration. The implementation process is carried out by combining already-running subsystems into a single system that can be run in accordance with its function. As the final output, the room sterilization robot will be tested.

## 2. Methodology

### 2.1 Arduino

The Arduino platform was created to provide enthusiasts, students, and professionals with an inexpensive and simple way to develop devices that interact with their surroundings through the use of sensors and actuators [10]. The Arduino Uno microcontroller has been used to carry out the sensing process by the sensor. Sensors are electronic components that convert mechanical, magnetic, heat, light, and chemical quantities into electrical quantities in the form of voltage, resistance, and current. Sensors can be used to detect various conditions and parameters [11]. Arduino will elaborate PIR sensor, sound the buzzer, and turn on the lights under certain conditions in order to build C-Remor. On the Arduino Uno and ESP32-cam boards, the programming medium should be the Arduino IDE (Integrated Development Environment). First, the buzzer would sound 10 times to indicate that the system was ready to start. The light will turn on after the buzzers have stopped sounding. Four PIR sensors will be placed on each side of the robot and will be linked to an Arduino Uno. If there is motion in the surrounding environment, PIR will detect it. If motion has been detected by the PIR sensor, the light that was turned on will be turned off. A relay was installed between the microcontroller and the lamp to provide a switch for turning the lights on or off. Fig. 1 shows the wiring diagram for the Arduino module.

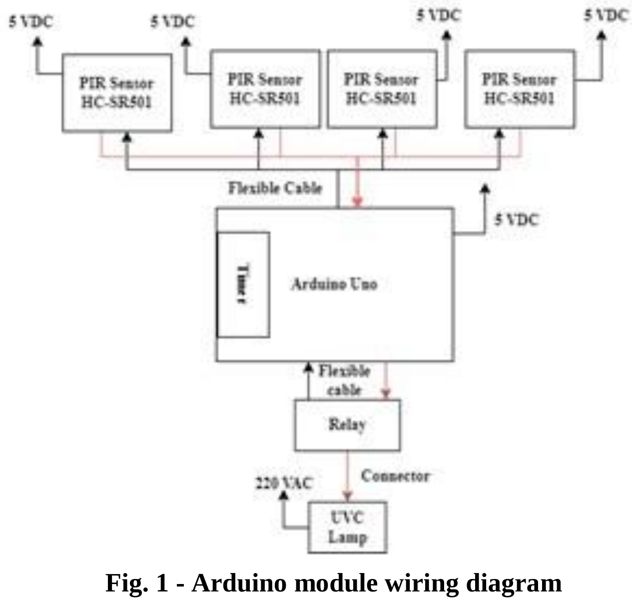


**Fig. 1 - Arduino module wiring diagram**

### 2.2 ESP32-Cam

The ESP32-cam is the product's second microcontroller. The ESP32-cam has been used because its specifications enable Wi-Fi communication. Wi-Fi communication is required as a user interface where the user will direct the robot from a long distance [12]. This ESP32-cam was outfitted with a camera library. The robot's specifications prevent it from being used if there are people or other animals in the room, so the camera sensor is required to replace the eye sensor. This ESP32-cam would also control a DC motor, which would be assisted by a motor driver. During the process, the ESP32-cam would be programmed using the Arduino IDE and additional ESP32 libraries. This program uses the Thinker AI module, which is an ultra-low power consumption technology designed to design IoT programs [13]. Fig. 2 shows the wiring diagram for the ESP32-cam module.

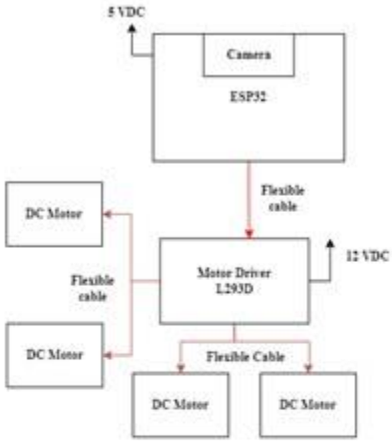


**Fig. 2 - ESP32-cam wiring diagram**

The teleoperation system means operating machine from a distance that has prepared components which are the local controller and the remote site controller [14]. This system utilizes 2 types of applications and teleoperation equipment, namely telerobotics and telepresence. Where telerobotics allows collapsing robots to be controlled remotely, while telepresence uses cameras to capture objects around them and send them to the user or local controller that creating the feeling that both users share fact in the environment [15]. If viewed from a data exchange point of view, this system is included in a 2-way system in which the system exchanges data repeatedly. This system allows the user to be able to control the robot by giving certain commands and at the same time the user will receive data in the form of camera captures.

## 2.3 Mobile Robot

C-Remor is presented as a mobile robot because it is necessary to have a robot that can move around rather than just remain in one location. The required movement is also smooth. An actuator in the form of a wheel has been used in the construction of a robot [16]. The robot will be used exclusively indoors. As a result, the robot is not required to perform strenuous tasks such as passing rocks, swimming, or jumping. C-Remor does not necessitate complex movements. The user could also easily control the mobile robot. The user would control this robot manually from a distance that is still within Wi-Fi range. The C-Remor manages to stand about 180 cm tall, with wheels at the bottom and an ESP32-cam at the top. The height of this UV-C lamp post in the shape of a TL lamp is approximately 120 cm. A chassis provides a container for robot components. The component that will be used is also a component that is quite common in making simple projects. Fig. 3 shows the design of the robot.

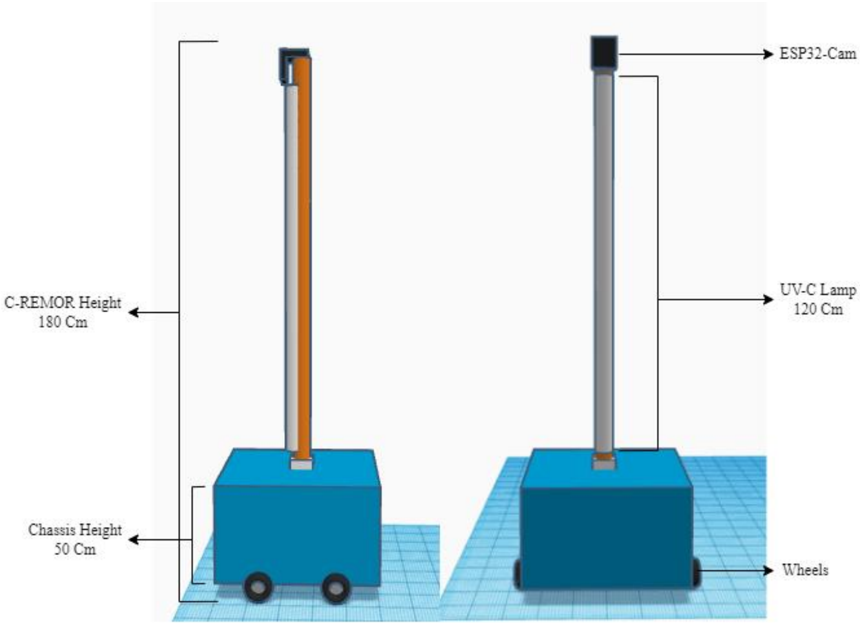


**Fig. 3 - Mobile robot design**

Components will be placed on the robot's body, which includes a 12V Accu as a power source. DC to DC step down is used to convert the voltage from the power source to the working voltage, namely 5V DC. Motor Driver L298N is a driver that will assist in controlling the speed and direction of DC motor rotation. The 5V relay will become a switch during the process of turning on and off the UV-C lamp. The Arduino Uno is one of the system controllers. Inverter as a converter of DC electricity into AC electricity, which will be used in lamps. The charger is placed on the outside of the robot body, and the voltmeter is used to display the voltage source as well as the buzzer. The ESP32-cam will be placed at the top of the UV-C lamp stand as it will be used as a camera sensor. The placement of components on the robot body can be seen in the Fig. 4.

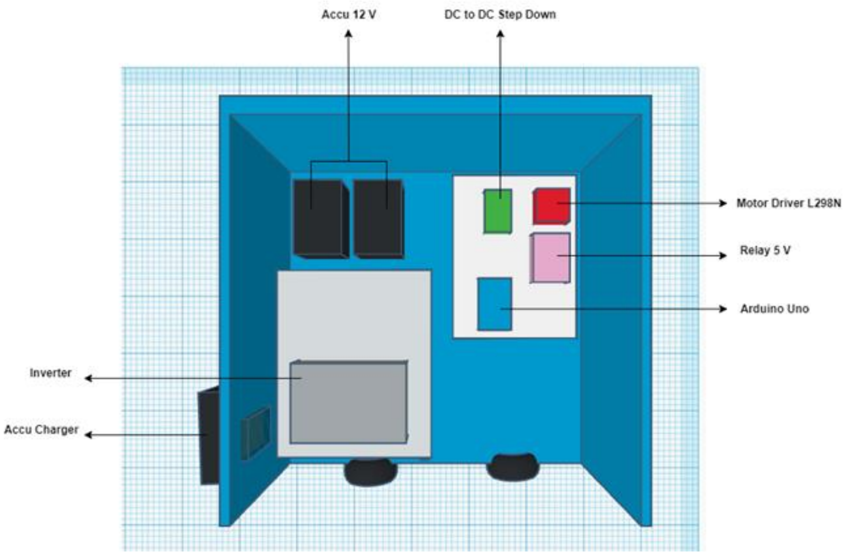


**Fig. 4 - Placement of the components**

There are 2 types of circuits in this robot, namely AC circuits and DC circuits. The AC circuit will be used to turn on UV-C lamps which have lamp specifications that turn on AC power. The DC circuit is used as a useful circuit as a working circuit, the majority of which operate at a working voltage of 5 V. This 5V circuit will be used on both microcontrollers, PIR sensors, buzzers, relays, working voltage on motor drivers, but for the DC motor used 12V DC to move the motor. The complete DC circuit can be seen in Fig. 5.

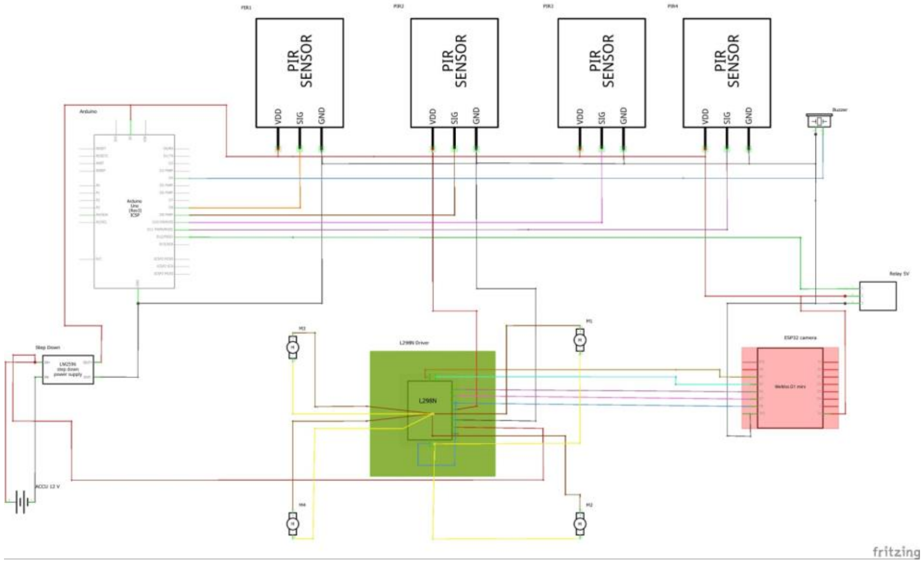


**Fig. 5 - DC circuit diagram**

The use of this robot will be ideal if it is used in single patient medical/surgical room around 4,6 m x 6,1 meters [17]. In the ideal working scope of the robot for a single patient/surgical room, the duration of cleaning is around 1 hour with a configuration of 1 lamp with irradiation of around 180 degrees. The configuration of this robot is still in its early stages, which would be ideal if the irradiation is from 360 degrees with a total of 4 UV-C lamps used. In a small standard room/practice room, if the coverage is too large, then the robot has to walk to every corner of the room and carry out the sterilization process for +- 10 minutes for 1 corner. In the process the efficiency of UV-C light is affected by the UV-C power used, irradiation time, and irradiation distance [18].

## 2.4 Web Server

The medium used to connect C-Remor and its users is a Wi-Fi network. The frequency of the transmitter or receiver is about 2.4GHZ, which is suitable for a web server to download data from an SD card using any phone or tablet with Wi-Fi [19]. When the ESP32-cam is connected to Wi-Fi, it will generate an IP address that can be used to access the web server. The web server can display images captured by the camera of the ESP32-cam [20]. A web server can move the robot via Wi-Fi as the user interface. The robot can be navigated by pressing any one of five buttons on the web server display. When the "Forward" button is pressed, the robot moves forward. Pressing the "Left" or "Right" buttons would cause the robot to turn left or right, respectively. The robot could be rotated by holding down one of the "Left" or "Right" buttons for a long enough period of time. When the "Backward" button is pressed, the robot can move backward. There is also a "Stop" button that will force the robot to stop. The mock-up of the web server can be seen in Fig. 6.

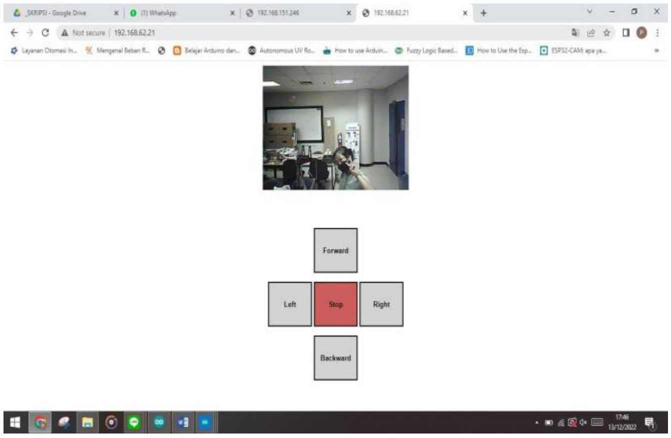


**Fig. 6 - Web server mock-up**

The ESP32-cam and Arduino subsystems will be combined into a whole system whose performance will be evaluated using the flowchart in Fig. 5. There is no communication between ESP32-cam and Arduino Uno because both of them will only run together according to certain procedures. The procedure for running the robot is as follows.

1. Turn on the Wi-Fi network to be used.
2. Turn on the button of the robot system.
3. Connect supporting devices with the Wi-Fi network used and enter the IP address.
4. The test will produce 2 sensor outputs which will be used as determining variables for decision-making on Arduino Uno, namely as Movement and No Movement.
5. When movement is detected, the lamp will respond in the form of turning off the previously set lamp to light up as the initial condition.
6. In testing the entire system, the camera sensor will capture images as a sensor.
7. The captured image will be broadcast via a web server in the form of a video stream that is displayed on the device that has entered the IP address.
8. On the web there will be several buttons that can be pressed by the user to determine the direction of the robot which can only be pressed 1 type every time an order is given.
9. There are several commands that the user can choose to determine the direction of the robot, namely forward, backward, right, left, and stop/stop. 10. The motor will run according to the type of command given to the robot via buttons pressed via the web.

As soon as the robot is turned on, a buzzer will start to sound. In order to direct the robot, the second step assembles the control device and robot on the same Wi-Fi network. The UV-C lamp will then activate, and if motion has been detected, it will turn off. Workflow of the robot can be seen in Fig.7.

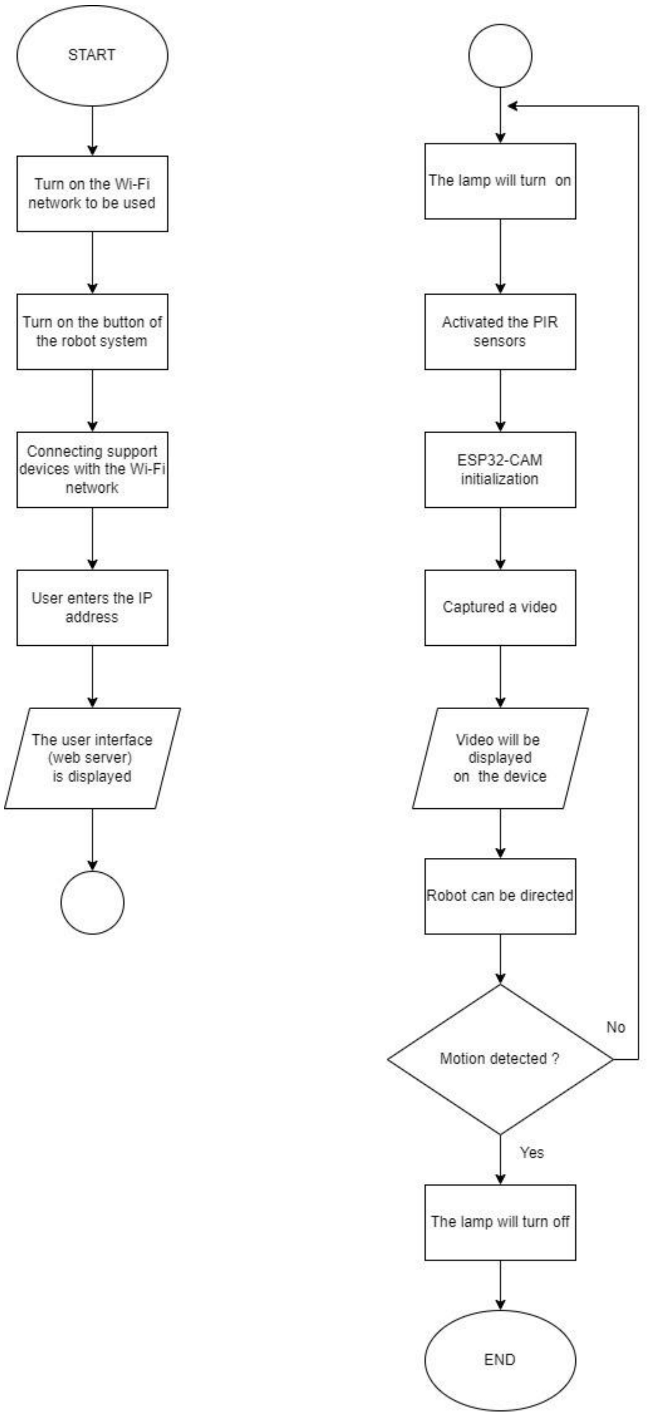


**Fig. 7 - Flow diagram**

## 3. Results

## 3.1 Robot Appearance

C-Remor robot had a relatively small appearance for its robotic body and a relatively tall height for the lamp's irradiation effectiveness. The process for accomplishing the robot's appearance is as follows; it requires some adjustments, particularly to balance the height of our moving robot. When the robot moves, the robot pole sways as well. As a result, a support rope is attached to each side of the robot to reduce movement on the pole. The robot body is built using acrylic which is supported by angle iron as the framework. The appearance of the robot can be seen in Fig. 8.


**Fig. 8 - Robot appearance**

## 3.2 Actuators and Camera Sensor

The C-Remor robot was propelled by an actuator system. There is also a camera that has been used to detect robots. This test scenario is repeated 15 times, during which the robot is instructed to use a web server connected to a Wi-Fi network. The robot will run forward, backward, right, and left during the process This robot is intended to be moved manually by the user with the remote displayed on the device connected to the Wi-Fi network. Robot control is carried out in real-time. The following Table 1 is the movement of the robots for one press on the controlling device.

**Table 1 - Movement of the robot**

| Position | Forward | Backward | Left | Right |
|---|---|---|---|---|
| Left Actuator | 4 cm | 3,5 cm | 4 cm (-60°) | 3,5 cm (50°) |
| Right Actuator | 3.5 cm | 4 cm | 3.5 cm (-60°) | 4 cm (50°) |

The integration and programming of this system uses C++ which functions to regulate actuator movements which will then also be transferred into HTML because it uses a web browser as an interface. If the user gives orders through the interface. So, the command will be conveyed to the sterilizing robot that is connected in the Wi-Fi range used. The data transferred via the web browser/interface will then be received by the robot and processed in such a way that it can move the robot according to orders in real-time. The Wi-Fi communication between the user interface and robot can be seen in Fig. 9.

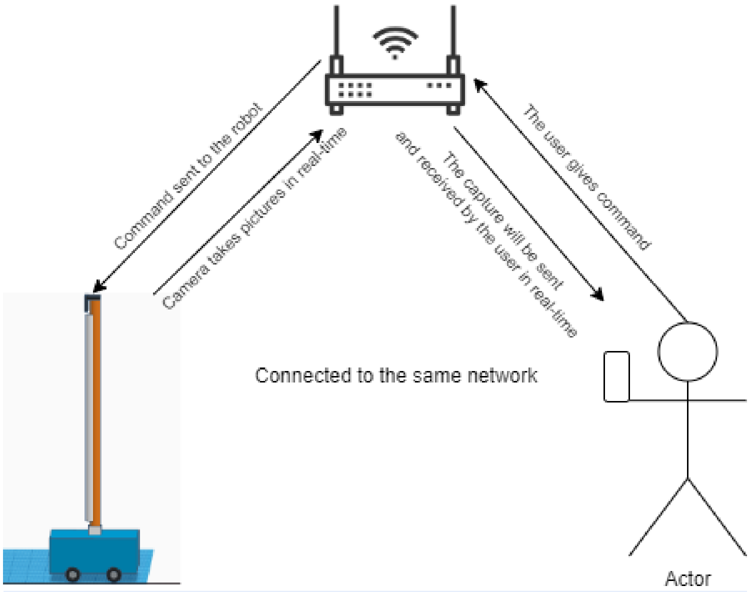


**Fig. 9 - Communication between user and robot**

Furthermore, the camera would also detect its surroundings, which would be displayed on the web server in the form of fast image capture, giving the appearance of a video. The web server had access to the actuator buttons and camera images. A view of the web server is shown in Fig. 10.

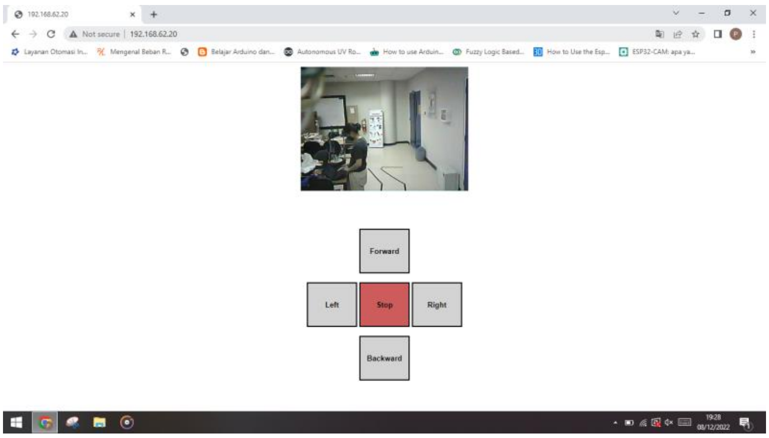


**Fig. 10 – Web server view**

The robot could function effectively with an accuracy rate of about 80%. This is possible because there are no significant obstacles between the robot and the web server that prevent the Wi-Fi network from functioning properly. However, there is a 20% performance inaccuracy. On the 7th, there was an unexpected problem: the signal was being lost during the testing process. On the 13th test, the connection was constrained when the user gave the command "left," causing the robot to continue rotating to the left. And on the 14th trial, the robot was completely disconnected from the web server due to a change in the IP address used to access the web server. The information is presented in Table 2.

**Table 2 - Data of actuators and camera sensors**

| No | Forward | Backward | Left | Right | Video |
|---|---|---|---|---|---|
| 1 | Forward | Backward | Left | Right | Can be seen |
| 2 | Forward | Backward | Left | Right | Can be seen |
| 3 | Forward | Backward | Left | Right | Can be seen |
| 4 | Forward | Backward | Left | Right | Can be seen |
| 5 | Forward | Backward | Left | Right | Can be seen |
| 6 | Forward | Backward | Left | Right | Can be seen |
| 7 | - | - | - | - | Didn’t move |

| | | | | | |
|---|---|---|---|---|---|
| 8 | Forward | Backward | Left | Right | Can be seen |
| 9 | Forward | Backward | Left | Right | Can be seen |
| 10 | Forward | Backward | Left | Right | Can be seen |
| 11 | Forward | Backward | Left | Right | Can be seen |
| 12 | Forward | Backward | Left | Right | Can be seen |
| 13 | - | - | Left | - | Didn’t move |
| 14 | - | - | - | - | Didn’t appear |
| 15 | Forward | Backward | Left | Right | Can be seen |
| Total Accuracy | 12 | 12 | 13 | 12 | 12 |
| Accuracy Percentages | 80% | 80% | 86,67% | 80% | 80% |

## 3.3 Distance, PIR Sensors, and Lamp

PIR sensors have been used in this product to detect motion. Within a certain range, the PIR sensor will detect motion. The UV-C lamp would be turned off if the motion had been detected; otherwise, the lamp would be turned on as the output. The millis function has been used in the programming, and if motion has been detected, the delay will not stop the entire system clock. When a motion has been detected, the millis function calculates the length of time the treatment has been in effect. If the conditions are met, millis will execute another function. Due to the UV-C technology used, this product was created to function indoors, away from people and animals. When a person is exposed to UV-C for an extended period of time, it can cause serious health problems. As a result, the PIR sensor serves as a safety feature for this product. When there is no motion detected in the room, the UV-C lamp will turn on. However, the system would turn off the lights when the PIR sensor detected motion because this was a sign that there were living things close to the robot. The data on the distance, PIR detection, and lamp are presented in Table 3.

**Table 3 - PIR detection data in distance for lamp response**

| No | Distance | PIR Pin | Movement | Lamp Off |
|---|---|---|---|---|
| 1 | 10 Cm | 8 | No | No |
| | | 9 | Yes | Yes |
| | | 10 | Yes | Yes |
| | | 13 | Yes | Yes |
| 2 | 10 Cm | 8 | No | No |
| | | 9 | Yes | Yes |
| | | 10 | Yes | Yes |
| | | 13 | No | No |
| 3 | 10 Cm | 8 | Yes | Yes |
| | | 9 | Yes | Yes |
| | | 10 | Yes | Yes |
| | | 13 | Yes | Yes |
| 4 | 1 M | 8 | Yes | Yes |
| | | 9 | Yes | Yes |
| | | 10 | Yes | Yes |
| | | 13 | Yes | Yes |
| 5 | 3 M | 8 | No | No |
| | | 9 | Yes | Yes |
| | | 10 | Yes | Yes |
| | | 13 | Yes | Yes |
| | Total Accuracy | | 16 | 16 |
| | Accuracy Percentages | | 80% | 80% |

## 4. Conclusions

C-Remor results show that the robot could be executed successfully. The robot accuracy for the actuators was 80% - 86% due to the limitations of the Wi-Fi network used in this system. The robot could experience problems if the network is down. The sensor could even detect motion at least 80% of the time. The remaining 20% is determined by the PIR sensor's physical limitations. As a result, the product is still highly dependent on the Wi-Fi network and also has sensor detection limitations beyond a certain distance. In this study, the effectiveness of UV-C irradiation was not emphasized because we did not have a pathway for testing the effectiveness of UV-C in the virology lab. However, it can be estimated that the quality of the lamp used affects the efficiency and power of the lamp in carrying out the sterilization process. Product development can be done not only as a sterilizing robot but also to replace human work that has a risk of being exposed to certain substances/objects, for example, fogging or extinguishing fires. Making this robot uses cheap materials so that even in the scope of business, this robot can become a robot that is still affordable when compared to the price of robots in general.

## Acknowledgement

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