Developing a Pathogen Sterilization Robot based on Ultraviolet Radiation

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Abstract:

The role of robots for disinfection and sterilize purposes is increasing with time, due to the challenge of the global Covid-19 pandemic, which led to a shortage in the availability of traditional surface disinfectants due to their extensive use also because of the poor efficiency in sterilizing using the normal methods of cleaning. All that considered and after we have studied the effect of ultraviolet radiation on viruses, we proposed to develop a pathogen sterilization robot based on Ultraviolet radiation. This project is designed to develop a sterilization robot using Hector_SLAM technology for navigation. The aim of our work is to contribute to combating the spread of Covid-19 in hospitals, public transportation, airlines and any closed areas and to develop a new method for sterilizing. The sterilization robot sterilizes pathogens and viruses in rooms. The robot move around autonomously and it is equipment with ultraviolet rays, and it turns off automatically when humans are around to keep them safe due to the danger of radiation.

Keywords: Autonomous robot, Service robot, Mobile robot, Indoor sanitizing, SLAM, Automation.

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روبوت تعقيم باستخدام الأشعة فوق البنفسجية

الملخص:

يتزايد دور الروبوتات في أغراض التطهير والتعقيم بمرور الوقت، بسبب التحدي الذي يمثله وباء كوفيد- 19 العالمي، والذي أدى إلى نقص في توافر المطهرات السطحية التقليدية بسبب استخدامها المكثف أيضًا بسبب ضعف الكفاءة في التعقيم باستخدام طرق التنظيف العادية. كل هذا في الاعتبار وبعد دراسة تأثير الأشعة فوق البنفسجية على الفيروسات، اقترحنا تطوير روبوت لتعقيم مسببات الأمراض يعتمد على الأشعة فوق البنفسجية. تم تصميم هذا المشروع لتطوير روبوت تعقيم باستخدام تقنية Hector_SLAM للملاحة. الهدف من عملنا هو المساهمة في مكافحة انتشار Covid-19 في المستشفيات ووسائل النقل العام وشركات الطيران وأي مناطق مغلقة وتطوير طريقة جديدة للتعقيم. يقوم روبوت التعقيم بتعقيم مسببات الأمراض والفيروسات في الغرف. يتحرك الروبوت بشكل مستقل وهو عبارة عن جهاز مزود بالأشعة فوق البنفسجية، ويتم إيقاف تشغيله تلقائيًا عندما يكون البشر في الجوار للحفاظ على سلامتهم بسبب خطر الإشعاع.

الكلمات المفتاحية: روبوت مستقل، روبوت خدمة، روبوت متحرك، تعقيم داخلي، SLAM، أتمتة.

1. Introduction

Sterilize has emerged as an increased area of concern after the spread of the global epidemic COVID 19 it has imparted us a lesson, that the threat is not a one-time phenomenon and that now it is always worth worrying about sanitizing and personal protective equipment, mainly in distinctly populated areas. These locations consist of restaurants, hospitals, hotels, airports, football stadiums and faculties to call a few. Because of this, we're seeing increasingly corporations and establishments turning to automation for sterilizing rooms and public spaces. To deal with this problem, most hospitals and restaurants may have employees manually wipe down and sterilize high-contact regions. This is problematic, thinking about there's constantly the hazard of employees contacting with the virus, and studies has proven that not all high-contact regions have a tendency to be cleaned. Studies show that COVID-19 stays on various surfaces for up to 80 hours and touchable surfaces, e.g., door handles, handrails, office furniture, and etc., represent a high risk of transmitting the virus.

Another problem in enclosed spaces is that COVID-19 is airborne and highly transmittable, and it remains in the air in the form of particles for up to 3 hours [1]. The main problem in the struggle for sterilization is that in most places, at the moment, stationary methods are used, or manual methods of cleaning and sterilizing the surface. Even though manual sterilization is quite effective, since many inaccessible places are cleaned, these methods are also dangerous for the operators. If they are not indoor sterilization devices, stationary methods also require operators, which increases the risk of their use, as they have to be constantly moved according to the sterilization schedule. To deal with this dilemma the ultraviolet light has been used as it has a powerful approach to killing dangerous bacteria, viruses in hospitals for decades. The UV-C light has been formerly used to fight different coronaviruses together with SARS, MERS, and in addition to the Ebola virus. Therefor building a robotic vehicle with the ultraviolet light attached to it will create a modern technique of sterilizing which is thorough, quicker and much less labor intensive than manual sanitizing [1].

This paper is organized as follows. Section 2 problem analysis. Section 3 related work. Section 4 explains the structure, components, and the working principle of the system. Section 5 describes the hardware and software design of the system. Testing the system is presented in section 6. Finally, conclusion and future work are summarized in section 7.

2. Problem Analysis

The robot is designed to work in large areas, possibly with people. These can be mosques, warehouses, shopping centers, offices. To accomplish this task, the problems we are going to solve with this project are the following:

- Wide spaces that need to be sterilize in short amount of time.
- The dangerous of sterilizing materials.
- The cost for sterilizing materials.
- The efficiency for sterilizing the surfaces.
- The dangerous of contacting directly with the diseases like the Covid-19.

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3. Related Work

An Engineers working with the Intelligent Space Robotics Laboratory, Space CREI, Skolkovo Institute of Science and Technology, Moscow, Russian Federation. developed a UV sanitizer robot they called it UltraBot, UltraBot technology has the potential to offer the most optimal autonomous disinfection performance along with taking care of people, keeping them from getting under UV-C radiation. The paper highlights UltraBot's mechanical and electrical structures as well as low-level and high-level control systems. The conducted experiments demonstrate the effectiveness of the robot localization module and optimal trajectories for UV-C disinfection. The results of UV-C disinfection performance revealed a decrease of the total bacterial count (TBC) by 94% on the distance of 2.8 meters from the robot after 10 minutes of UV-C irradiation [2].

4. The structure, components, and the working principle of the system

In this section, a complete comprehension of building the hardware is presented and it talks about function of tools that have been used in the project. Also, this chapter talks about the software of the project. photos and block diagram of the project are presented.

Figure 1 below shows the general block diagram of the System.

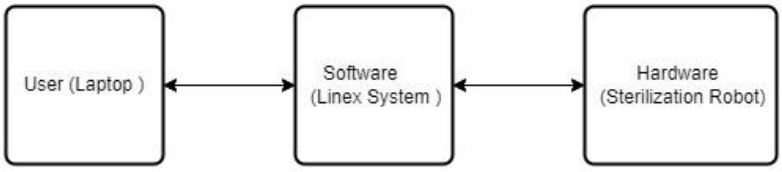

Figure 1: General system block diagram

This system only contains three main blocks: User, Software and Hardware.

The user in this system will be the one who runs the Linux system through the laptop and controls the whole system and monitor it by running a few codes of programs in the ROS environment which is integrated with the Linux system.

4.1 Hardware

Project wiring was done as shown in Figure 2.

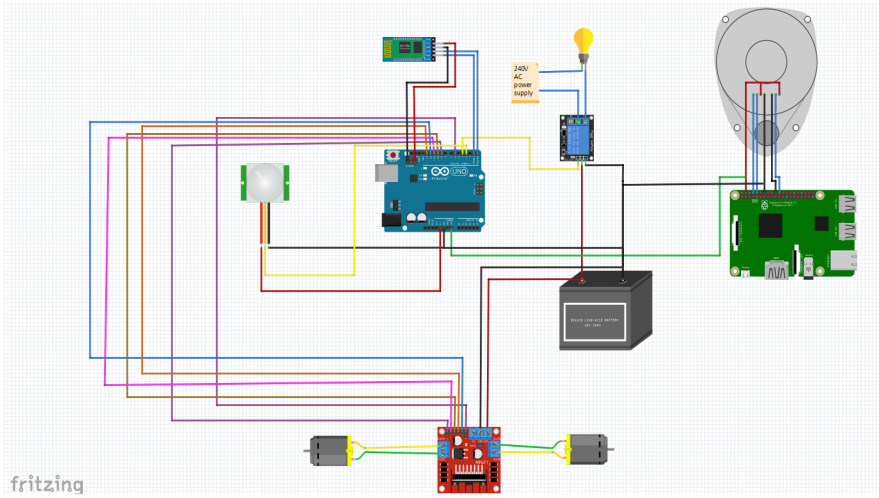

Figure 2: Project Wiring

The main components of the system were:

Raspberry pi 3: It is the main controller. It is responsible for the navigation by sending commands to the motor after processing the data from the RpLidar sensor.

RPLiDAR sensor: It is the sensor responsible for drawing the 2D map using the infrared radiation and sending the data to the Raspberry pi 3 for processing.

Arduino Uno: in this project it was implemented as the interface driver with the motors also as the protection system with the conjunction of the passive infrared sensor.

PIR sensor: Passive infrared sensor is a motion sensor that was used to prevent the ultraviolet lamps from working when sensing a heated body in the area.

Ultraviolet Lamps: it is the main source of radiation for killing the viruses.

12V Battery: it is the main power source of the entire system.

Gera Motors: They are the actuators of the Robot to navigate inside the rooms.

Bluetooth shield: used with Arduino to control the ultraviolet lamps remotely using an app installed in Smartphone or Laptop.

Laptop: it the main monitor of the robot operations and controls the robot wirelessly.

Besides, Figure 3 below shows the physical wiring.

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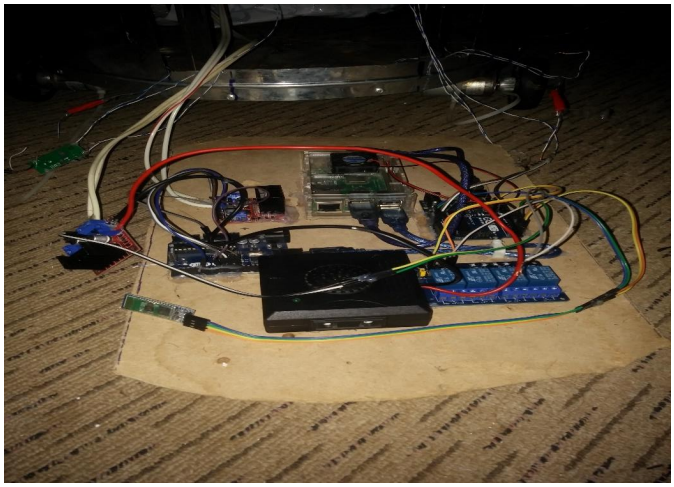

Figure 3: Physical wiring of the robot

4.2 Software

The main system the was used is Linux but the main environment that was used for control, monitor and navigate was ROS (Robot Operating System) [3].

Python and Arduino IDE were used in the project all of these languages were held by the ROS kinetic (Robot Operating System) environment, which is one of its advantages [4] that can compile and run many programming languages and coordinate between all of them.

4.3 Block Diagram

Figure 4 below shows the relation between every component in the system.

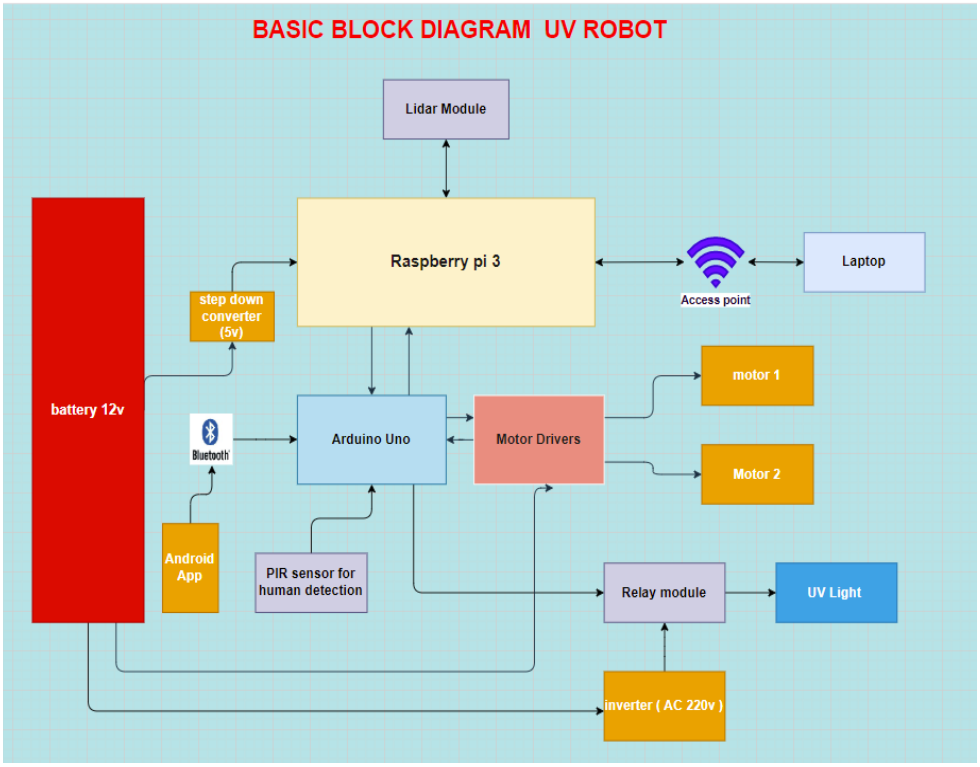

Figure 4: Components Relations

5. Working Principle and System Algorithm

The working principle of the project is in the beginning we run the system and control the motors manually from the laptop we began to scan the room and create a 2D map using the lidar sensor after that we set the target for the robot to navigate to. Finally, we activate the ultraviolet lamps and leave the room for sanitizing.

The protection measurements were set by the PIR (Passive Infrared) that if it detects anybody that emits infrared and sends a signal to the control system and immediately shuts down the motors and the UV (Ultraviolet) lamps until the body levers the range of detection.

The flowchart in Figure 5 demonstrates the general algorithm used in this Robot.

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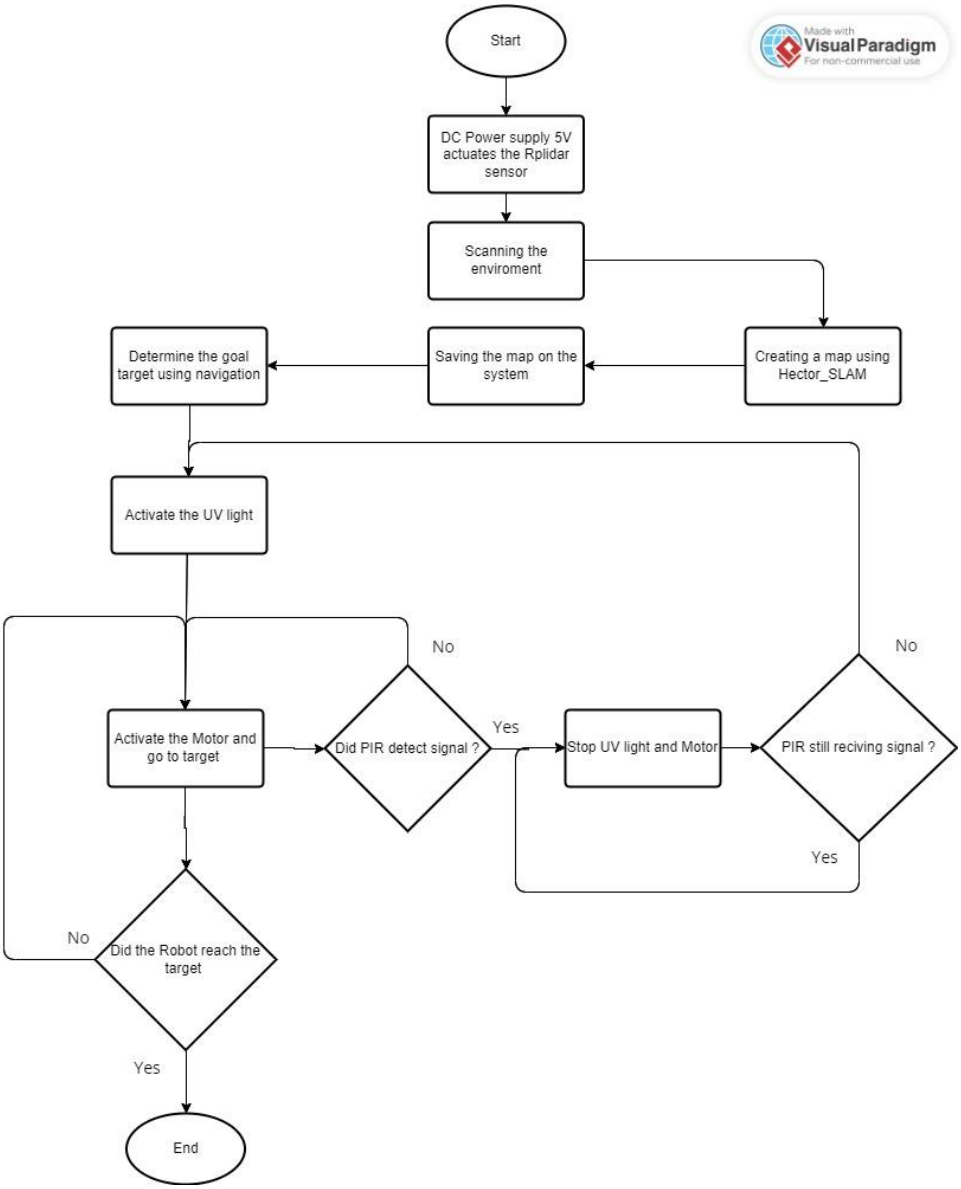

Figure 5: System Algorithm

6. Testing the System

We started to recorded a map using the RpLidar and the result of the map accuracy was shown in Figure 6.

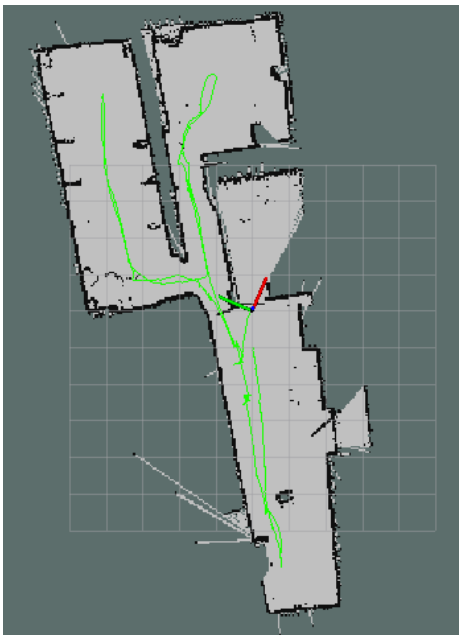

Figure 6: A 2D map of a first floor of an apartment

after that we opened Rviz (the platform that shows the map) and set a 2D pose estimate after that set a navigation goal. We turned on the UV (Ultraviolet) lamps and the robot starts to move according to the goal pos and orientation by avoiding the obstacles that exist and start the sanitization process

6.1 Protection test

In the protection we used PIR sensor to detect the heat signature of humans or animals we succeeded to a point that in approximately 1.5 meter the sensor can effectively detect the presence of someone and shut down the UV light for 25 seconds and also stops the motor using the relay but we canceled the motor idea due to the PIR (Passive Infrared) unreliability most of the time. But in general, it worked as desired.

6.2 Power test

On the power test we measured the current drawing from the battery using a multimeter device and we found out the following measurements:

in Standby: 0.5 Amp

With Motor running without load: 0.9 Amp

With the whole system running (including lamps and sensors): 3.2 Amp

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7. Conclusion and Future work

The purpose of this thesis was to document the progress we made toward the project that would contribute to the growing body of open-source work with ROS and the Mobile Robot. In the UV sterilizing robot project, the aim was to develop a system that sanitize any premises autonomously without the intervene of human being We have found that the system worked successfully both hardware and software we have finished our robot and make it able to localize and create a map for its environment and move to any point and the work of the UV light to sanitize while its moving towards the goal target while having the security measurements to avoid effecting a human with the UV light radiation. Although the work of the PIR wasn't accurate but it was a start towards improving the protection system of the UV robotics machines. Further, some of the aforementioned unsolved problems are currently under consideration in order to improve performance of the UV sterilizing robot one of them is that we had some issues in the navigation process due to the lack of time and resources and the structure of the robot wasn't built accurately causing a vibration while its moving. But overall, we could call it a successful project hoping in the future our colleges could finish and built a fully autonomous robot.

Our future work on this project is as follows:

1) Changing the raspberry pi 3 to raspberry pi 4 which has more RAM there for it makes it smoother in executing commands and more stable than the pi 3.

2) Upgrading the ROS version from ROS Kinetic to ROS Melodic because the ROS Kinetic is no longer supported from the ROS.org

3) Adding 3D lidar scanner will be more effective in visualizing all of the surfaces that can be maneuvered or sanitized in a 3D dimensional point of view.

4) Replacing the current UV tube with a UV pulsed light tube which is more powerful energy for radiation. It can save time and have an excellent efficiency in sanitizing.

5) Building a charging house so that whenever the battery is running low the UV Robot return to the charging house to recharge the battery autonomously without the need of charging it manually (Automated process).

6) Building an application to view the Robot status like battery percentage UV light status and PIR status.

7) Replacing the PIR detection sensor with IR imaging Camera because it is more reliable and accurate than the PIR sensor.

8. References

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