Journal of Electronics and Informatics (ISSN: 2582-3825)
www.irojournals.com/iroei/

UV- C Light Mobile Robotics System

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Abstract

Because diseases are spreading, cleaning enclosed places has become a critical concern. Various methods, including chemical-based solutions in liquid and gas forms, are commonly used for pathogen eradication. However, the environmental damage caused by these methods compounds existing challenges facing humanity. Additionally, UVC light, a promising alternative for disinfection, poses risks to human skin and eyes, necessitating precautions to prevent exposure. Moreover, the effectiveness of UVC disinfection is limited to directly exposed surfaces, rendering it challenging to utilize in occupied spaces where thorough disinfection is crucial. Furthermore, UVC light is less effective on porous surfaces like wood and fabric, further limiting its efficacy. The suggested solution incorporates UVC disinfection technology together with cleaning and drying features to overcome these issues. The objective is to improve the cleaning efficacy and efficiency of enclosed spaces by merging these elements. Both surface disinfection and impurity elimination are the main goals of the mopping and drying functions, which guarantee thorough cleaning. By using clever navigation algorithms to make sure all surfaces have direct exposure to UV-C lamps, the technology also overcomes the shortcomings of existing UVC disinfection. As porous surfaces react less well to UVC disinfection alone, the combination of cleaning and drying activities makes treatment possible. The proposed study provides a brief review of the methods used in sanitation with and without UV rays and the specific range of UV rays utilized in sanitation. It suggests an innovative UV-C sanitation robotic system that overcomes the shortcomings of existing UV-C disinfection systems.

Journal of Electronics and Informatics, March 2024, Volume 6, Issue 1, Pages 1-13
DOI: https://doi.org/10.36548/jei.2024.1.001
Received: 06.01.2023, received in revised form: 03.02.2024, accepted: 15.02.2024, published: 27.02.2024

Keywords: Ultraviolet-C, UV-C radiation, Bluetooth wireless interface, sanitizing system, UVC disinfection technology, cleaning and drying features, cleaning efficacy, UV-C lamps.

1. Introduction

Semiconductors with a stable structure, when doped with precious metals, are utilized in UVC-LEDs. The type and nature of the power supply for these sources determine the emitted light, lifespan, and emission spectrum. These sources can be powered either continuously or pulsed mode. Conventional UVC lamps, primarily medium or low-pressure ones, remain prevalent in disinfection units. However, they come with inherent drawbacks such as mercury usage, low mechanical stability, and ozone production. The lifespan of conventional UVC lamps is typically around 8000 hours, with a peak emission at 254 nm at 30 W power. Short-duration flashes are generated using polychromatic sources employing high-intensity pulsed xenon lamps, providing high-intensity, broad-spectrum UV light with a wavelength of 200–300 nm. UVC-LEDs are emerging as replacements for traditional bulbs, being four to nine times more efficient in water treatment, smaller, and requiring less energy. However, their adoption is still limited due to their higher cost. Several studies have compared the efficacy of various disinfection units. Comparisons have been made regarding surface cleaning and microbe inactivation using pulsed light sources and conventional lamps. In studies examining pulsed xenon systems versus ordinary lamps including mercury lamps, for reducing healthcare-associated microorganisms in hospital rooms, pulsed UV light proved more effective. It has been found that both pulsed xenon and mercury lamps are equally effective in brief exposures, around 10 minutes, in inactivating bacteria in ambulances. Reports indicate that such devices can reduce environmental illnesses within 30 minutes without the need for chemical agents. Despite the trend towards smaller, mercury-free disinfection units, UVC mercury lamps remain popular due to their low cost.

2. Literature Review

Aiming to address health concerns associated with improper waste management, the "Automatic Waste Segregating and Self Sanitizing Dustbin" employs sensor technology to autonomously segregate and sanitize waste. Focused on creating clean, disease-free environments, the system notifies users when the bin is full and prevents the release of toxic gases from decomposing waste. This versatile technology serves both individual homes and communities, facilitating effective trash management to combat health hazards and the spread of infectious diseases. Particularly beneficial for those in public service roles, the innovation strives to enhance overall hygiene and safety in waste disposal, emphasizing the importance of proactive measures in global health crises [1]

Crystalline silicon solar modules using ethyl vinyl acetate (EVA) as encapsulation material commonly face browning and delamination deterioration. In UV testing of mini-modules, UVC EVA exhibited increased browning at higher temperatures, while UV-pass (UVP) EVA showed delamination. UVC modules also displayed increased reflectance (500–700 nm). Characterization identified EVA browning in UVC and delamination in UVP modules as primary degradation mechanisms. EVA, industry-standard for solar modules, contains UV absorbers. UVC EVA turns yellow and brown over time due to degradation, while UVP EVA lacks UV absorbers, avoiding browning. Delamination results from poor adhesion, especially under UV exposure at higher temperatures. The UV preconditioning follows IEC 61215, simulating 45 days of field exposure [2].

Cathodoluminescent UV radiation sources, utilizing carbon fiber-based field emission cathodes, have been prototyped with varying UV spectra based on phosphors used. Addressing the limitations of current UV LEDs for focused emission in UV-assisted printing, a UV LED package utilizing MEMS technology was proposed. The design, featuring a stacked silicon reflector and hemispherical quartz lenses, produced a concentrated UV emission with an intensity exceeding 1000 mW/cm^2 at the focal point and a 16° beam angle. Additionally, diverse cathodoluminescent UV sources with field emission cathodes have been developed using a triode lamp configuration [3].

In exploring human-robot interactions, a mixed-methods study employed mobile and stationary robots in various communication scenarios. Participants experienced social, direct, and agent interactions with different forms of robot communication: verbal, open, or silent. Results indicated that allowing social robots to interact with functional ones promoted social behavior and likability. Verbal communication was preferred over covert exchanges [4]. An intelligent watering robot, designed for efficient bonsai tree care, features a stm32f4-based control center, a linear CCD image sensor for line patrol, and a microcontroller-based soil moisture detection sensor. With a wireless transceiver chip for communication, the robot follows predetermined paths, watering bonsai trees as needed. The RPP spray manipulator on its mobile platform, analyzed through dynamic simulation, provides a theoretical foundation for its design and control. As technology advances, robots are becoming integral in daily life, enhancing efficiency across various applications [5].

In a leader-follower interaction study, participants taught a cub robot a musical sequence, adjusting to the robot's varying tap delays. The robot's performance influenced the duration of participants' tapping behavior, indicating human sensitivity to subtle robot behavior in such interactions. The study involved participants using a music pad to teach the iCub robot a preset melody, emphasizing the perceptiveness of humans to robot behavior nuances [6].

Recent research on ultraviolet-C (UV-C) light-emitting diodes (LEDs) addresses previous issues, enhancing optical power and extending device lifespan. Our study focuses on four commercial UV-C LEDs (265 nm) for disinfection systems, subjecting them to a 20,000-minute accelerated lifetime test. Optical and electrical measurements, spectrum characteristics, and gain evaluations were recorded. UV-C LEDs are crucial in combating the COVID-19 virus, offering advantages like compact size, light weight, tunable wavelength, and faster startup compared to traditional mercury tubes. While UV-C LEDs have evolved, challenges like self-heating, spectrum contaminants, manufacturing, and p-doping persist, with aluminum gallium nitride as their fundamental component [7].

The Table.1 below summarizes the different types of methods used in sanitation and robot installation.

Table 1. Comparative Table

Ref. No	Authors	Title	Year	Methodology	Demerits
[1]	P. Sharma P. Kumar R. Nigam K. Singh	Automatic Waste Segregating and Self-Sanitizing Dustbin.	2020	Waste Detection Image Processing For Classification Uv-C Light For Post-Segregation Sanitization In An Automated Waste Management System.	1.Potential Malfunctions 2. High Initial Cost

[2]	H.Gopalakrish P. Arularasu, K. Dolia A. Sinha G. Tamizhmani	Characterization of Encapsulant Degradation in Accelerated UV Stressed Mini-Modules with UV-cut and UV-pass EVA	2019	Preparing Mini-Modules With UV-Cut And UV-Pass EVA Subjecting Them to Accelerated UV Stress Employing Characterization Techniques Like FTIR And DSC.	1.Limited Scope 2.Incomplete Information
[3]	D. I. Ozol E. P. Sheshin, N. Y. Vereschagina, M. V. Garkusha, M. I. Danilkin H.W. Aung	Cathodoluminescent UV-Sources Using Carbon Fiber Field Emission Cathodes	2019	Fabricating UV-Sources with Carbon Fiber Field Emission Cathodes Characterizing Their Emission Properties Testing Performance	1.Energy Efficiency 2.Safety precautions
[4]	X. Z. Tan S. Reig E. J. Carter A. Steinfeld	From One to Another: How Robot-Robot Interaction Affects Users' Perceptions Following a Transition Between Robots	2019	Designing Robot Interactions Collecting User Feedback Analyzing Perceptions to Understand How Transitioning Between Robots Affects Users' Trust and Satisfaction.	1.Artificial Task 2.Short Term Focus
[5]	P. Lv et al	Design of Intelligent Watering Robot	2020	Designing, Integrating Sensors and Actuators, Developing Control Algorithms Building A Prototype, Testing in Various Conditions and Analyzing Results for An Intelligent Watering Robot.	1.Sensor Accuracy 2.Scalability

[6]	F. Ciardo D. De Tommaso A. Wykowska	Humans Socially Attune to Their “Follower” Robot	2019	Observing Participant-Robot Interactions Administering Questionnaires, And Analyzing Data to Understand Human Social Attunement to A "Follower" Robot.	1.Small Sample Size 2.Short Term Interaction
[7]	Francesco Piva Matteo Buffolo Carlo De Santi Gaudenzio Meneghesso Enrico Zanoni Matteo Meneghini Nicola Trivelli	Status of Performance and Reliability of 265 nm Commercial UV-C LEDs in 2023	2023	Evaluating The Performance and Reliability Of 265 Nm Commercial Uv-C Leds Through Optical, Electrical, And Temperature Characterization, Along with Accelerated Life Tests and Data Analysis.	1. Limited Emitted Optical Power and Sudden Failures 2. Wavelength Considerations
[8]	Hsin-Ying Lee Chih-Hsun Lin Ching-Ting Lee	Whole Metal Oxide p-i-n Deep Ultraviolet Light-Emitting Diodes Using i-Ga2O3 Active Emissive Film	2020	Fabricating P-I-N Structure UV Leds With I-Ga2O3 as The Active Layer Characterizing Their Optical and Electrical Properties	1. High Operating Temperature 2. Material Cost
[9]	Maria S. Baltadourou Konstantinos K. Delibasis Georgios N.Tsigaridas	LaUV: A Physics-Based UV Light Simulator for Disinfection and Communication Applications	2021	Developing The Lauv Simulator Based on Physics Principles Modeling UV Light Propagation for Disinfection and Communication Optimizing Parameters, And Validating Against Experimental Data.	1. Complexity of Simulation 2. Energy Consumption
[10]	D. Petrovic L. Kicinbaci F. Petric Z. Kovacic	Autonomous Robots as Actors in Robotics Theatre - Tribute	2019	Designing A Theatrical Script, Programming Robots for Specific Roles	1.Technical Failures 2.Script Adaption Challenges

		to the Centenary of R.U.R		Coordinating Movements with Human Actors	

3. Existing System

The existing system is a robot that disinfects surfaces, especially in homes, offices, hospitals, and other buildings, using ultraviolet-C (UV-C) technology. It is operated by a Bluetooth wireless interface with an Android app. With its three UV-C lamps, this robot can successfully disinfect an area that is 360 degrees around. It also features a self-timer that shuts off the UV-C bulbs automatically. By employing UV-C radiation to damage the DNA of viruses like the coronavirus and other infections, this technology stops their reproduction and the spread of illness. The robot is teleoperated, allowing operators to control it from outside the room, which is crucial for safety during the disinfection process. The technology used in this system includes UV-C disinfection technology and an Android app for control. It has been deployed in various settings, including medical facilities, to sanitize patient rooms and restrooms. The system seems to integrate elements like cryptography, IR communication, keypad testing, transmitters, and receivers, although their specific roles in the system are not detailed in this description.

The potential drawback of the existing system could be the dependence on UV-C technology alone. UV-C radiation can damage people's skin and eyes even if it is useful in disinfecting surfaces. Safety precautions for those present during the disinfection procedure are not specifically included in the existing system. There is a chance of unintentionally being exposed to damaging UV-C radiation if the robot is operated in an area where humans are present or if safety procedures are not effectively explained and followed. This risk increases in the absence of appropriate safeguards or information about how the system guarantees user safety.

4. Proposed System

The proposed robot operates autonomously, utilizing ultrasonic sensors for obstacle detection and avoidance. This choice is made due to the longer operating range of ultrasonic sensors compared to IR sensors. The robot incorporates ultraviolet LEDs for sanitization, effectively eliminating viruses, and is also equipped with a sanitizer spraying mechanism. Motor control is facilitated by a dual-channel motor driver connected to a Node MCU, enabling both remote operation and autonomous navigation. An inverter, managed by a relay switch connected to the Node MCU, regulates the power supply to the UV lights from the battery. The primary function of the robot is sanitation through ultraviolet germicidal irradiation (UVGI), which helps prevent the transmission of infectious diseases. UVGI typically utilizes low-pressure mercury discharge lamps or LEDs emitting shortwave ultraviolet-C radiation, often at a wavelength of 254 nm. The UVGI using LEDs or the pressure mercury discharge lamps are shielded to ensure proper ventilation, and ultrasonic sensor are employed to detect human presence and automatically turn off or deactivate the UVGI system when people are in the vicinity in order minimize the risk of unintended exposure during operation The robot is equipped with mopping and drying capabilities, enhancing its cleaning solutions. A dedicated motor controls the water reservoir and mop attachment for mopping operations. To ensure thorough mopping coverage, the robot intelligently dispenses water and cleaning solution while traversing the floor. The robot also features a drying system that utilizes hot air and airflow to accelerate the drying process. This drying mechanism activates once the mopping operation is complete, ensuring the floor remains dry and free of moisture. The robot's autonomous navigation system seamlessly integrates with both the mopping and drying functions. Depending on user preferences and detected cleanliness levels, the robot automatically switches between mopping, drying, and sanitization modes. By combining mopping, drying, and sanitization functions, the robot provides a comprehensive cleaning solution. This guarantees that floors are thoroughly cleaned, dried, and sanitized, promoting a sanitary and germ-free environment.

5.1 Proposed Block Diagram

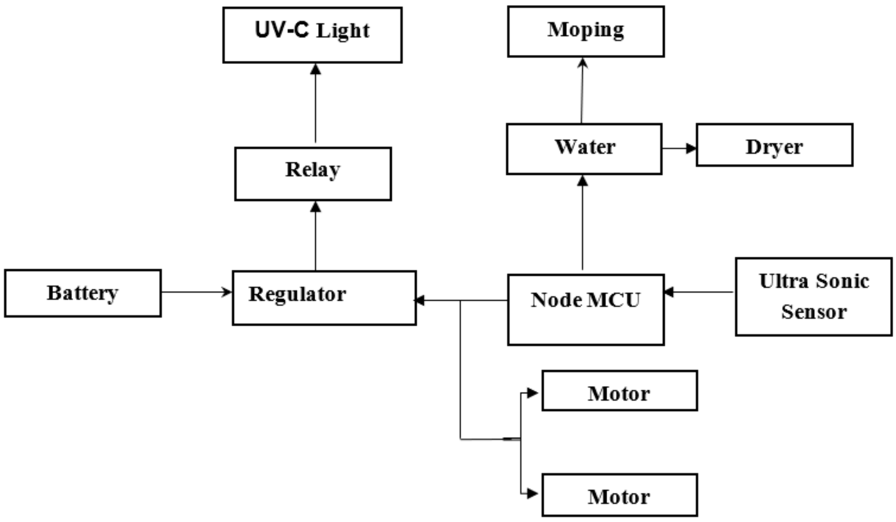

Figure 1. Proposed Block Diagram

5. Discussion

The proposed UV sanitization robot is indeed a cutting-edge solution designed to address the challenge of disinfecting environments efficiently while reducing reliance on harmful chemicals. UV-C rays have long been recognized for their potent germicidal properties, effectively neutralizing bacteria and viruses by disrupting their DNA. By harnessing UV-C rays, the robot can efficiently sanitize surfaces, thereby lowering the risk of infectious diseases spreading. The incorporation of live video streaming capabilities enhances the robot's functionality, allowing operators to remotely control its movements and target specific areas for sanitization. This feature significantly improves usability and adaptability, particularly in complex environments where precise navigation is essential. Utilizing ultrasonic sensors for obstacle detection provides distinct advantages over conventional IR sensors, including higher accuracy and reliability. This ensures the robot can navigate safely and autonomously, avoiding collisions with objects or individuals in its path. Moreover, the integration of UV LEDs offers a compact and energy-efficient solution for delivering UV light, thereby facilitating effective sanitization. The addition of a sanitizer spraying mechanism further enhances the robot's ability to thoroughly disinfect surfaces, providing a comprehensive cleaning solution. The Node MCU serves as the central control unit, orchestrating the operation of the robot's motors and other essential components. Paired with a dual-channel motor driver, this setup enables precise control over movement and functionality, ensuring optimal performance during operation. The relay switch, managed by the Node MCU, regulates the connection between the UV lights and the battery through an inverter, extending the UV light source's lifespan and ensuring efficient power management. In alignment with recommendations from the World Health Organization (WHO), which advises minimizing the use of toxic disinfectants, the UV sanitization robot offers a safer and more sustainable alternative by relying on UV-C rays for sanitization. Reports of successful deployment in diverse settings, including hospitals and public spaces, underscore the effectiveness and versatility of the UV sanitization robot. Its ability to adapt to different environments highlights its potential to significantly contribute to efforts aimed at preventing the spread of infectious diseases. Incorporating mopping and drying capabilities into the robot further enhances its functionality, providing a comprehensive cleaning solution. By combining UV sanitization with mopping and drying, the robot ensures surfaces are not only disinfected but also thoroughly cleaned and dried, fostering a hygienic and sanitized environment. This multifunctionality enhances the robot's utility across various settings, from healthcare facilities to public spaces, where maintaining cleanliness is paramount for public health and safety.

5.1 Specification Table

Component	Technical Specification	Specification
UV-C Light Source	UV- C 254 nano meter(nm)	High-intensity UV-C LEDs for germicidal disinfection
Sanitizer Sprayer	Capacity 250 ml	Mechanism for dispensing disinfectant solution
Ultrasonic Sensors	HC-SR04, Working Frequency: 40Hz, Range: 2cm – 400cm/4m, Resolution: 0.3 cm	High-accuracy obstacle detection and navigation assistance
LiDAR Sensors	Range beyond 100 meters, Wavelengths around 850 nm or 905 nm.	Advanced environmental mapping and obstacle detection

Node MCU	ESP8266 Wi-Fi SoC	Central control unit for coordinating robot functions
Dual-Channel Motor Driver	RM0402.,2 DC to 12 VDC	Precise motor control for movement and functionality

6. Future Enhancement

The future work would proceed with the prototype development and the implementation of the work for real time use. The suggested model could be further improved with the UVD Robotics, a Blue Ocean Robotics affiliate, that uses mobile robots fitted with lidar sensors and short-wavelength ultraviolet-C (UVC) lamps to sanitize operating rooms and hospital patient rooms. The robot is controlled by a computer, and once it is in place, it uses lidar to scan the surroundings and produce a digital map. To designate regions that the robot should not clean, operators can annotate the map. The robot employs simultaneous localization and mapping (SLAM) for navigation. As it moves, the UV sanitization robot captures live video of its surroundings and utilizes UV beams to eradicate bacteria and germs. By use of WiFi connectivity, hospital rooms can be remotely navigated by operators using a graphical user interface (GUI) to manage the robot.

7. Conclusion

The UV sanitization robot offers an efficient solution for destroying bacteria and germs using ultraviolet (UV) light. Its capability for remote control via the MCU and provision of a live video stream of its surroundings make it particularly valuable for sanitizing hospital rooms without requiring human presence. This feature enhances flexibility and allows for tailored sanitization according to specific needs. The mechanism by which UV radiation kills germs involves interfering with their ability to reproduce, thus preventing their multiplication. By dissolving the DNA structures of bacteria, viruses, and other harmful organic entities, UV radiation effectively disinfects the environment. Integrating mopping and drying functionalities into the UV sanitization robot further enhances its utility and provides a comprehensive cleaning solution. This multifunctionality ensures that not only are surfaces disinfected but also thoroughly cleaned and dried, contributing to a hygienic and sanitized environment. Moreover, the use of UV robots offers a cost-effective approach to implementing disinfection practices in public areas. Traditional techniques, such as misting disinfectant liquids, often based on alcohol, have drawbacks including potential respiratory problems, skin irritation, and environmental disturbance due to strong fragrances. Recent guidelines from the World Health Organization (WHO) advise against frequent use of such liquids in public settings. Therefore, the UV robot presents a safer and more environmentally friendly alternative for general disinfection. The effectiveness of UV robots has been demonstrated in various settings, including hospitals, offices, and public transportation systems, in numerous countries. Their successful deployment in future work would underscore their potential to significantly contribute to efforts aimed at preventing the spread of infectious diseases while also promoting sustainability and public health.

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