IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 5, May 2025

DOI: 10.17148/IARJSET.2025.125393

AUTO-STERILE (UV-STERILIZATION ROBOT)

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Abstract: The ongoing need for enhanced hygiene and infection control, especially in the wake of global pandemics, has driven innovation in autonomous sanitization technologies. This survey paper explores the development and application of an Auto Sterilization Robot designed to autonomously disinfect environments such as hospitals, offices, schools, and public transport facilities. The robot integrates various technologies including UV-C light, chemical spraying systems, obstacle detection, and autonomous navigation using sensors and microcontrollers. The paper reviews existing solutions, compares key design methodologies, and evaluates performance metrics such as coverage efficiency, disinfection effectiveness, and energy consumption. Emphasis is placed on the role of automation in reducing human exposure to pathogens and improving the consistency of sterilization processes. The survey concludes by identifying current challenges and proposing future directions for improving autonomy, safety, and adaptability in sterilization robotics.

INTRODUCTION

In recent years, especially following global health crises like the COVID-19 pandemic, the importance of hygiene and sterilization has become more critical than ever. Conventional disinfection methods often require manual labor, which is not only time-consuming but also poses a health risk to cleaning personnel due to potential exposure to harmful pathogens. To address these challenges, this project introduces an Auto Sterilization Robot using UV Light, designed to autonomously disinfect indoor environments such as hospitals, schools, offices, and public transportation hubs.

Ultraviolet (UV-C) light, particularly in the 254 nm wavelength range, has been scientifically proven to destroy the DNA and RNA of viruses, bacteria, and other microorganisms, effectively rendering them inactive. Unlike chemical disinfectants, UV light leaves no residue and can disinfect without direct human intervention. By integrating UV-C lamps with a robotic platform capable of autonomous navigation, the system offers a safe, efficient, and contactless method for sterilization.

The proposed robot utilizes sensors for obstacle detection and path planning, allowing it to navigate autonomously while ensuring optimal exposure of surfaces to UV light. Safety features, such as motion detectors or infrared sensors, are included to turn off the UV light if a human is detected nearby, thereby preventing accidental exposure. This project aims to improve public hygiene standards while minimizing human involvement and maximizing efficiency.

LITERATURE SURVEY

Pacharawan Chanprakon et al. developed a UV contraceptive robot to eliminate viruses. This robot utilizes ultrasonic sensors to avoid collisions, and a webcam is used to direct its movement. With three UV lamps, the robot covers a wide range for disinfection. Operators can control the robot's mobility and speed, along with UV light intensity.

Thomas Rubaek, Merima Cikotic, and Simon Falden evaluated a UV disinfection robot. Their practical robot features Bluetooth control and sanitizes surfaces through a pre-defined path without worker intervention. The UV robot requires approximately a minute to disinfect the surrounding area. O. Hachour's work focuses on path planning for autonomous mobile robots. The paper discusses the autonomy of robots in automated fields and emphasizes optimal planning for autonomous actions based on tasks.

Jui-Hsuan Yang et al. explored the effectiveness of an Ultraviolet-C Disinfection System against healthcare-associated pathogens. The study highlights the system's impact on reducing infections caused by NTM (Non-Tuberculous Mycobacteria) and other pathogens.

Aladin Begic et al. proposed sanitizer robots for sterilization in medical institutions. These semi automated systems reduce bacteria and MRSA on room touch surfaces, contributing to infection control measures.

Noriyuki Yagi et al. worked on a disinfection robot using high-wavelength UV-LED. Their project demonstrates the efficacy of UV-LED in eradicating microbial contaminants, suggesting its cost effectiveness and efficiency compared to traditional mercury light.

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The paper by Ishaan Mehta review discusses the mechanisms of UV disinfection, including the effectiveness of UV-C light in sterilization and the limitations of classical UVGI systems. It highlights the integration of UV robots with SLAM for autonomous navigation and the challenges of shadowing and human safety.
This paper presents a UV-C disinfection robot designed for hospitals, capable of killing 95% of bacteria within 20 seconds from a distance of 0.5 meters. It also functions as a dispenser for transporting medicines and samples, thereby reducing healthcare-associated infections and human error.
This study explores the use of a mobile manipulation robot equipped with UV-C light to disinfect horizontal surfaces. The robot autonomously plans and executes disinfection tasks, ensuring effective coverage and minimizing cross-contamination.
Ultra Bot is an autonomous robot designed to reduce COVID-19 transmission and other harmful bacteria and viruses. It utilizes UV-C light for disinfection and employs optimal trajectories for effective sterilization.
This paper introduces a cost-effective germicidal system utilizing Far-UVC excimer lamps for disinfection. The system comprises a team of mobile manipulators with end-effectors designed for disinfecting high-contact surfaces.

PROBLEM IDENTIFICATION

Many disinfection processes involve chemicals that can be harmful to humans and the environment. Prolonged exposure to these chemicals may cause health issues. Manual cleaning is time-consuming and labor-intensive. It also increases the risk of human exposure to contaminated surfaces. High-touch areas in hospitals, offices, and public places require frequent and thorough sterilization. However, maintaining consistent hygiene in such spaces is challenging.

APPLICATIONS

Hospitals and Healthcare Facilities – Used in patient rooms, ICUs, and operation theaters to prevent the spread of infections.
Offices and Workplaces – Ensures a sanitized environment by disinfecting desks, meeting rooms, and common areas.
Educational Institutions – Helps in maintaining hygiene in classrooms, libraries, and laboratories to protect students and staff.
Public Transport and Airports – Disinfects buses, trains, airplanes, and waiting areas to reduce the risk of disease transmission
Hotels and Restaurants – Keeps dining areas, kitchens, and guest rooms free from harmful bacteria and viruses

CONCLUSION AND FUTURE SCOPE

The development of an Auto Sterilization Robot using UV light presents an effective, automated solution for disinfection in high-risk environments such as hospitals, public spaces, and offices. By leveraging UV-C technology, the robot can efficiently eliminate a wide range of harmful microorganisms without the need for chemical agents, reducing both human labor and exposure risk. The integration of autonomous navigation, human detection sensors, and safety mechanisms ensures that the system operates reliably and safely in real-world environments. While challenges like shadowing and limited power supply remain, this project demonstrates significant potential to enhance hygiene standards and support infection control protocols. Future improvements can further optimize coverage, energy efficiency, and remote monitoring capabilities.

Improved Navigation and Mapping
Future versions can incorporate advanced **SLAM (Simultaneous Localization and Mapping)** algorithms, allowing the robot to more efficiently navigate complex environments and cover hard-to-reach areas with precision.
Integration with IoT and AI
Integrating IoT capabilities will allow remote monitoring, control, and real-time status updates. AI algorithms could also enable predictive maintenance, ensuring the robot's optimal performance over time.
Collaborative Multi-Robot Systems
By using **swarm robotics**, multiple UV sterilization robots could work together, effectively covering larger areas and ensuring faster and more thorough disinfection.
Enhanced Safety Features
The inclusion of **advanced sensors** to detect human presence and movement can lead to even safer operation, ensuring UV light is only emitted in empty spaces, avoiding harm to humans.
Reduction of UV-C Light Shadowing
Improving the design to minimize **shadowing effects** areas where UV light cannot reach will ensure that all surfaces receive adequate exposure for complete disinfection.

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