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AI-powered Automated UV Sterilization System for ICU Hygiene and Surgical Tool Disinfection

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ABSTRACT: Hospital-acquired infections (HAIs) are a persistent challenge in critical care environments like Intensive Care Units (ICUs) and operating rooms. This paper presents a novel AI-powered automated UV sterilization system designed to enhance ICU hygiene and ensure effective surgical tool disinfection. The system utilizes artificial intelligence for real-time detection of surface contamination and dynamic control of UV-C light exposure. It integrates environment mapping, object recognition, and dosage calibration to maximize disinfection while minimizing exposure to sensitive materials. The automated operation reduces human error and ensures a consistent, sterile environment crucial for patient safety.

KEYWORDS: UV Sterilization, ICU hygiene, Surgical Tool Disinfection, Artificial Intelligence, Automation, HAIs

I. INTRODUCTION

Healthcare-associated infections (HAIs) are a major cause of morbidity, mortality, and increased healthcare costs, particularly in vulnerable patient populations within ICUs [1]. The complex environment of an ICU, with its high density of patients, medical equipment, and frequent staff interactions, creates numerous opportunities for pathogen transmission. Similarly, effective sterilization of surgical tools is paramount to prevent surgical site infections (SSIs) [2]. While manual cleaning and disinfection protocols are standard practice, their efficacy can be inconsistent due to variations in technique and human error [3].

Ultraviolet-C (UV-C) radiation has proven to be a potent germicidal agent, capable of inactivating a wide range of microorganisms, including bacteria, viruses, and spores, by disrupting their DNA and RNA [4]. Automated UV-C disinfection systems offer a potential solution to overcome the limitations of manual methods by providing consistent and contactless disinfection. The integration of Artificial Intelligence (AI), specifically computer vision and object detection, can further enhance the precision and efficiency of these systems by enabling targeted disinfection of high-risk areas and objects [5].

This paper presents the development and evaluation of an AI-powered automated UV sterilization system designed to address the challenges of ICU hygiene and surgical tool disinfection. The system comprises a mobile robotic platform equipped with a UV-C light source and an AI-powered object detection module for autonomous disinfection within the ICU. Additionally, a dedicated module incorporating AI-assisted tool recognition for enhanced surgical tool disinfection in a controlled environment is described. The effectiveness of the system in identifying target objects and reducing microbial contamination is evaluated through experimental studies.

II. LITERATURE SURVEY

Numerous studies have investigated the efficacy of UV-C disinfection in healthcare settings. Nerandzic et al. [6] demonstrated the effectiveness of an automated UV-C device against *Clostridium difficile* and other HAIs on environmental surfaces. Cadnum et al. [7] explored the use of UV-C for the disinfection of N95 respirators, highlighting its potential for PPE reprocessing during shortages. These studies establish the foundation for UV-C as a viable disinfection modality.



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The field of AI has seen significant advancements in image recognition and object detection, largely driven by deep learning [8]. Xiao et al. [9] proposed an AI-based real-time object detection and sterilization system, showcasing the

potential of integrating AI with disinfection technologies. Mobile robots equipped with UV-C lamps for autonomous disinfection have also been explored [10], demonstrating the feasibility of automated room disinfection. However, the integration of sophisticated AI-powered objects detection for truly targeted disinfection of specific high-touch surfaces and surgical tools within a comprehensive system remains an area of active research.

III. METHODOLOGY

The proposed system comprises three core modules:

- 1. Environment Scanning and Mapping:
 - A depth-sensing camera maps the ICU or surgical bay in real-time. The AI module detects high-touch surfaces, medical tools, and potential contamination zones.
- 2. Object Detection and Classification:

Using a convolutional neural network (CNN), the system identifies objects and classifies them based on sterilization requirements. Items such as monitors, bed rails, and tools are flagged for UV exposure with tailored dosage.

3. UV-C Dosage Control and Actuation:

The robotic system is equipped with UV-C emitters. An AI-based control unit calculates optimal angles, durations, and intensities for each object. Safety features like motion detection and shielded emission ensure compliance with UV exposure standards.

The entire process is automated, with feedback loops allowing real-time adjustments based on environmental changes.

IV. EXPERIMENTAL RESULTS

Prototype testing was conducted in a simulated ICU setting. The AI system successfully mapped the environment and identified 95% of common hospital objects. Pathogen reduction tests using *E. coli* and *S. aureus* on surfaces showed a >99.9% kill rate after calculated UV-C exposure.

Compared to manual UV sterilization, the automated system achieved more uniform coverage and reduced cycle time by 30%. The AI module's reactivity to dynamic object repositioning improved overall safety and efficacy.



V. CONCLUSION

This paper presented the design, implementation, and evaluation of an AI-powered automated UV sterilization system for enhancing ICU hygiene and improving surgical tool disinfection. The integration of deep learning-based object

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detection with a mobile UV-C platform enables targeted disinfection within the complex ICU environment. The dedicated module for surgical tool disinfection leverages AI for instrument recognition, potentially leading to optimized sterilization protocols. Experimental results demonstrate the system's effectiveness in identifying target objects and reducing microbial contamination. Future work will focus on further optimizing the AI algorithms, enhancing the robustness and adaptability of the robotic platform, and conducting real-world clinical trials to evaluate the system's impact on HAI rates and workflow efficiency. The AI-powered automated UV sterilization system demonstrates significant potential in enhancing hospital hygiene, particularly in high-risk environments like ICUs and operating theaters. By combining artificial intelligence with UV-C technology, the system delivers efficient, adaptive, and safe disinfection, mitigating the risk of HAIs. Future work will focus on integrating cloud analytics and real-time monitoring dashboards for hospital management.

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