

MediCleanX: Intelligent Automated Hospital Cleaning Robot with UV & Spray Sterilization

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Abstract: *The rapid spread of infectious diseases and hospital-acquired infections (HAIs) has highlighted the urgent need for efficient and intelligent sterilization systems in healthcare environments. MediCleanX is an intelligent automated hospital cleaning robot designed to ensure effective and contactless disinfection using a dual-action mechanism combining UV-C light and spray sterilization. The system operates autonomously under microcontroller supervision, utilizing wheels and motors for mobility and ultrasonic/IR sensors for obstacle detection and path correction. A robotic arm equipped with a UV-C light source provides targeted sterilization, while a ground-mounted UV module ensures floor-level disinfection. A PIR motion sensor enables a safety protocol that instantly halts the robot and switches off UV-C light when human presence is detected, preventing harmful exposure. The robot also records distance covered and displays operational data on-screen for monitoring. Powered by a rechargeable battery and controlled via an intelligent algorithm, MediCleanX offers a reliable, efficient, and human-safe solution for continuous hospital disinfection. Its automation reduces manpower, minimizes infection risk, and ensures consistent sanitization, making it a vital step toward smart, hygienic healthcare infrastructure.*

Keywords: Sterilization Robot, Hygiene Technology, Sanitizing Robot, Public Healthcare

I. INTRODUCTION

In modern healthcare environments, maintaining high standards of hygiene and sterilization is critical to preventing hospital-acquired infections (HAIs) and ensuring patient safety. Manual cleaning methods, though widely used, are often time-consuming, inconsistent, and pose health risks to sanitation workers due to exposure to harmful pathogens and disinfectants. To overcome these challenges, automation and intelligent robotics are increasingly being adopted in the healthcare sector.

MediCleanX is an innovative automated hospital cleaning robot developed to provide intelligent, efficient, and contactless sterilization. The system integrates ultraviolet (UV-C) light and disinfectant spray technology to eliminate a wide range of pathogens from hospital surfaces. Its onboard microcontroller coordinates the movement of wheels and motors for autonomous navigation, while ultrasonic and infrared sensors detect obstacles and adjust the robot's path dynamically. The robotic arm with UV-C light enables targeted disinfection of surfaces, and a PIR motion sensor ensures safety by instantly turning off the UV light and halting movement upon detecting human presence.

By combining mechanical mobility, intelligent sensing, and dual sterilization technologies, MediCleanX minimizes manual intervention and enhances disinfection efficiency. It is designed to operate in patient wards, operation theatres, laboratories, and isolation areas where maintaining aseptic conditions is vital. Through automation, MediCleanX not only reduces human error and labor costs but also ensures a consistent and thorough cleaning process, contributing significantly to safer and smarter healthcare environments.



A. Problem Definition

Hospitals, clinics, and public healthcare facilities are vulnerable to the rapid spread of harmful bacteria and viruses due to frequent human activity and high-touch surfaces. Traditional manual cleaning methods are time-consuming, inconsistent, and often fail to eliminate all microbial contaminants. This increases the risk of healthcare-associated infections (HAIs), endangering patients, healthcare workers, and visitors.

To address this challenge, there is a need for an autonomous robotic system capable of disinfecting hospital environments effectively and safely. The proposed UV-C light-based bacteria cleaning robot aims to provide an automated and efficient solution for surface sterilization by utilizing ultraviolet germicidal irradiation (UVGI) technology to destroy or deactivate microorganisms without the use of chemicals or human intervention.

B. Objective

The main objective of the MediCleanX project is to design and develop an intelligent autonomous robot capable of performing efficient and safe hospital disinfection using UV-C light and spray sterilization technology. The system aims to minimize human involvement in the cleaning process, reduce the spread of infections, and ensure consistent hygiene standards in healthcare facilities.

Specific objectives include:

1. To design a mobile robotic platform that can autonomously navigate hospital environments using ultrasonic and IR sensors.
2. To integrate a UV-C light module and a disinfectant spray mechanism for effective dual-mode sterilization.
3. To implement a safety protocol using a PIR motion sensor that detects human presence and automatically disables UV-C light to prevent exposure.
4. To develop a microcontroller-based control system for coordinating movement, sensing, and sterilization operations.
5. To enable real-time monitoring of cleaning activities, including distance covered and operational status, displayed on a screen.
6. To provide a reliable, energy-efficient, and cost-effective solution for continuous disinfection in hospitals and medical facilities.

Overall, the objective of MediCleanX is to enhance infection control, promote hygienic hospital environments, and contribute toward the advancement of intelligent healthcare automation.

II. LITERATURE SURVEY

Jaimeel Shah, Arun Kumar Marandi, P T Sivasankar, Ketan Chande, Rahul Kanekar, Devvret Verma (2023). Development and Construction of an Automated Sanitizing Robot Incorporating Ultrasonic Sensor and Sanitizer Level Detection Sensor. In this study, we present the design and implementation of an autonomous sanitizing robot equipped with a camera, and we compare it to a floor cleaning robot. Group sample sizes are determined using G power software, with its default settings optimized for optimal performance within a 5% margin of error. For statistical purposes, we will always use a total sample size of 20 from each group.

P. Vimala; R. Gokulakrishnan (2021). Implementation of IOT Based Automatic Disinfectant Robot. It is important to clean crowd gathering areas due to the spread of the covid 19 diseases. Nowadays, disinfecting operations in different locations are performed by humans, which can be harmful to humans. This paper presents an engineering approach to the issue by using an automated disinfecting robot to sanitize crowd gathering areas automatically using chemical disinfectants to control the spread of the covid-19 diseases.

Anusha Madan, Arati Ganesh, Preethi N, Sahana Bandekar, A.N. Nagashree (2021). Mobile Covid Sanitization Robot. As the second wave of the Novel Coronavirus hits the world, a staggering number of COVID-19 cases have been reported. The COVID-19 cases in India also are substantially high. Most of the existing systems require a human to be physically present to manually disinfect the surfaces. To reduce and limit the COVID-19 cases, person-to-person interaction, cleaning and sterilization from time to time is the demand of the present day.



Additionally, the system integrates IoT-based monitoring to track the robot's performance, battery status, and disinfection coverage through a mobile or web interface. A safety mechanism is included to automatically turn off the UV-C light when human presence is detected to prevent harmful exposure. This proposed system aims to minimize manual cleaning efforts, reduce the spread of healthcare-associated infections (HAIs), and ensure a safer and more hygienic hospital environment through efficient, chemical-free sterilization.

A. System Features

- **Autonomous Navigation:** The robot can move independently within predefined areas. It uses sensors to detect obstacles and adjust its path in real-time for safe operation.
- **UV-C Disinfection Control:** The software controls the intensity and duration of UV-C light. Ensures effective sterilization of all surfaces without human intervention.
- **Scheduling and Remote Operation:** Users can set cleaning schedules via desktop or mobile interfaces. Allows operation during non-working hours for maximum safety.
- **Scalability and Multi-Robot Coordination:** Multiple robots can be integrated and coordinated in large facilities. Enables faster disinfection over extensive areas.
- **Environmentally Friendly Operation:** Uses UV-C sterilization instead of chemical disinfectants. Reduces environmental impact and promotes sustainable hygiene practices.

B. System Requirement

- **Hardware Requirements:** Microcontroller or embedded board (Raspberry Pi/Arduino), UV-C lamps, sensors (ultrasonic/infrared), battery, wireless modules.
- **Software Requirements:** Programming languages (Python, C/C++), database (SQLite/MySQL), GUI framework (Tkinter/PyQt/web interface), and operating system (Windows/Linux/Android/iOS).
- **Communication Requirements:** Wi-Fi, Bluetooth, or MQTT protocols for remote operation and real-time monitoring.
- **Performance Requirements:** Real-time navigation and disinfection without delay. Efficient energy management for prolonged operation.
- **Safety Requirements:** Emergency shutdown on human detection or obstacle collision. Protection against accidental UV-C exposure.

C. System Model

The System Model of the Hospicare UVC Robot describes how the software and hardware components interact to perform autonomous disinfection tasks. It provides a conceptual representation of the system, helping stakeholders understand its functionality and data flow.

Context Diagram The context diagram shows the robot as a single system interacting with external entities:

- User sends schedules and commands; receives status updates and alerts.
- Power supply and battery provide energy for operation.
- Sensors detect obstacles and guide navigation.

Use Case Model

Key actors include:

- **User/Administrator:** Schedules operations, monitors status, and reviews logs.
- **Robot System:** Performs navigation, disinfection, and safety operations.
- **Maintenance Staff:** Handles maintenance and troubleshooting.

Main use cases:

- Schedule Cleaning, Start/Stop Cleaning, Monitor Status, Receive Alerts, Review Logs.



Data Flow Overview

Data moves as follows:

- User inputs schedules/commands.
- Robot processes commands and collects sensor data.
- UV-C lamps operate based on area, distance, and time.
- Logs and alerts are sent back to the user interface.

Description The system model ensures integration of users, software, hardware, and environment. It enables safe, reliable, and efficient autonomous disinfection in healthcare and public spaces.

D. Performance Requirements

The Hospicare UVC Robot is designed to operate efficiently, safely, and reliably in healthcare and public environments. The software and hardware must meet the following performance requirements:

- **Real-Time Operation:** The robot must process sensor data and control navigation in real-time without delays. Ensures smooth movement and effective obstacle avoidance.
- **UV-C Efficiency:** UV-C lamps must provide sufficient intensity and duration for effective sterilization. The robot should maintain consistent coverage across all surfaces.
- **Battery Management:** The robot must monitor its battery level and return to the charging station automatically. Ensures uninterrupted operation for scheduled cleaning sessions.
- **Navigation Accuracy:** The system must accurately detect obstacles and room layout. Minimizes collisions and guarantees complete area coverage.
- **Data Logging Speed:** Cleaning logs, alerts, and system status must be updated and transmitted without delay. Ensures real-time monitoring and reporting.
- **System Uptime:** The robot should operate continuously for multiple hours with minimal failures. Supports long-duration disinfection in large facilities.
- **Scalability:** The software should handle multiple robots operating simultaneously in large areas. Enables coordinated cleaning for faster disinfection.

These performance requirements ensure that the Hospicare UVC Robot operates effectively, safely, and efficiently, delivering consistent disinfection while minimizing HUMAN intervention.

IV. SYSTEM FLOW & ALGORITHM

A. Algorithm/Methodology

Start and Initialization

1. The robot system is powered ON.
2. Microcontroller initializes sensors, motors, and UV-C lamps.
3. Battery level and sensor status are checked.

Movement Control

1. Robot starts moving forward along the floor.
2. Distance and motion are continuously monitored.

Obstacle Detection

1. Ultrasonic and IR sensors detect obstacles.
2. If an obstacle is found → robot stops → changes direction → continues movement.

Disinfection Process

1. UV-C lamps (ground and arm-mounted) are activated during movement.
2. Surfaces and surroundings are sterilized by UV-C radiation.

Human Detection and Safety Control

1. PIR sensor continuously checks for human presence.
2. If human detected → UV-C lamps turn OFF → robot halts immediately.



3. Once the area is safe → system resumes operation.

Data Logging

1. Distance covered, disinfection time, and operation status are recorded.
2. Data displayed on LCD screen for monitoring.

End or Recharge

Robot stops operation or returns for recharging when cleaning is completed or battery is low.

B. FlowChart

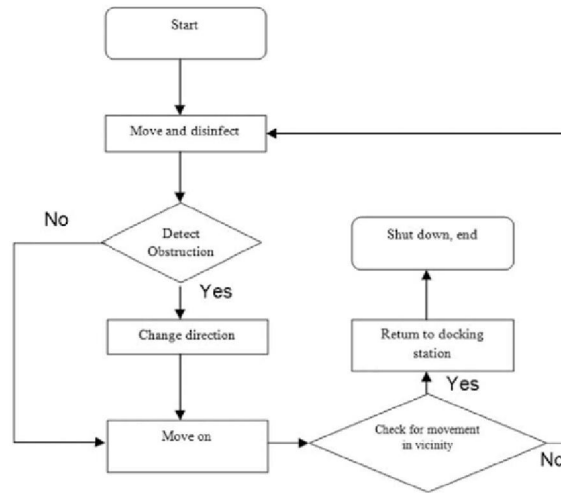


Fig. 2: Flowchart

V. CONCLUSION

The reviewed research papers collectively highlight the significant advancements in UV-C disinfection robot technology and their transformative impact on modern healthcare and sanitation systems. These studies demonstrate that UV-C robots are highly effective in reducing microbial contamination, minimizing human exposure to pathogens, and ensuring consistent disinfection standards in various indoor environments.

Furthermore, the integration of autonomous navigation, real-time monitoring, and cost-effective design approaches has made these robots practical and scalable for widespread adoption. In conclusion, UV-C disinfection robots represent a promising step toward safer, cleaner, and more automated hygiene management systems in the post-pandemic era.

- UV-C disinfection robots have proven highly effective in reducing microbial contamination and preventing the spread of infectious diseases.
- These robots minimize human involvement in high-risk disinfection tasks, ensuring greater safety for healthcare and cleaning personnel.
- Integration of autonomous navigation and sensor-based mapping enhances accuracy and coverage during disinfection operations.
- Cost-effective and compact designs have made UV-C robots suitable for diverse environments, including hospitals, offices, and laboratories.

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