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DESIGN AND DEVELOPMENT OF AUTOMATIC UV DISINFECTION ROBOT WITH REAL TIME MONITORING

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ABSTRACT
This project proposes a fully autonomous mobile robot for cleaning and disinfection of floor surfaces. The robot uses a 360° ultraviolet light source to sterilize floor surfaces and eliminate harmful microorganisms. The robot also includes a floor detergent cleaner unit for improved cleanliness. The robot's central processing unit is an Arduino microcontroller that controls movement and various functions. The robot's H-bridge module is integrated with the Arduino to drive two DC geared motors that enable the robot's locomotion. The UV lamp is strategically placed on the underside of the robot for targeted UV disinfection. The ESP32 camera module allows for live video streaming. Real-time visual feedback is provided by the ESP32 camera mounted on the servo motor, allowing for remote monitoring and operating of the robot during cleaning and disinfection. cleaning area.In short, this project is a 360-degree UV light sterilization and detergent based floor cleaning solution that is strong and efficient in disinfection and cleaning. The combination of an Arduino microcontroller, an H-bridge module and DC geared motors, a UV lamp, a cleaning unit, a suction pump, an ESP32 camera and a servo motor makes it possible to operate autonomously, monitor in real-time, and provide comprehensive floor hygiene.

Keywords:
Autonomous robot, disinfection, UV light, ESP32, 360-degree camera, live video streaming, floor hygiene.

INTRODUCTION

Cleanliness and disinfection of floors is essential in a wide range of environments, including healthcare settings, educational settings, and commercial spaces. Traditional methods of floor cleaning typically involve hand scrubbing and chemical disinfection, which is laborious, time consuming, and potentially dangerous. In this project, we introduce a 360° UV floor sterilization robot specially designed for the floors of Dairy Industry. It has a built-in detergent cleaning unit. Utilizing UV light technology, this autonomous robot eliminates microorganisms on the floor surfaces while using a detergent cleaning unit for improved cleanliness.

An Automated UV Robot is being designed for efficient floor cleaning in Dairy Industries[1]. Of the three types of UV light, UV-C light is the most effective in killing bacteria. UV-C utilizes short-wavelength ultraviolet radiation that is harmful to microorganisms [2]. Moreover it incorporates a webcam, a 360 degree camera, mounted at the beat of the robot. The webcam that is being used is a camera which feeds its images in real time to a computer or computer network, often via USB and there are also uses on sites like video broadcasting services and for recording social videos [3]. This surveillance robot is equipped with a LiDAR sensor for autonomous navigation. The LiDAR sensor gives out light waves in 360 degrees and the light which is bounced back from the objects is used by the sensor to track its path and the robot moves accordingly[4]. The robot is specially built on the use of modernized technology. It has all the features that are required for a floor cleaner [5].

OBJECTIVES

The objectives of floor sanitation in the dairy industry include

- Preventing contamination of milk and dairy by products
- To maintain hygiene standards is a main aim of dairy industries
- To minimize the risk of bacterial growth and ensure a clean environment to comply with regulatory requirements.
- Proper floor sanitation helps safeguard product quality and consumer health.
- To avoid human errors in the practice of floor sanitation which could highly contribute to the

contamination of Dairy products.

- To assist in extending the shelf life of dairy products by minimizing the microbial load during processing and packaging.
- UV sanitation offers an energy-efficient and chemical-free method for microbial control compared to traditional methods like chemical disinfectants.
- It aligns with sustainable and environmentally friendly practices, reducing the reliance on chemical agents that may have negative environmental impacts.
- Thorough cleaning and sanitization of floors and surfaces for each batch of production and processing is very important to remove the dirt, impurities, residues, and other harmful material that could hamper the products.

UV sanitation systems can be integrated into automated processes, contributing to operational efficiency by providing continuous and effective microbial control without significant manual intervention.

REVIEW OF LITERATURE

This project deals with designing and fabrication of a floor cleaning machine. The main aim is to reduce the cleaning time and manual effort. Modern cleaning equipment permits us to finish our household tasks easier and faster[6]. The paper focuses on the development of the autonomous robot UltraBot to reduce COVID-19 transmission and other harmful bacteria and viruses without the use of harmful sprays and chemicals[7]. Swarm robotics is a technical approach of multiple robots working together and solving multiple problems at a time. Enormous and complex work cannot be done using conventional approaches, so this system will help to work in an organized way to deal with this complex work[8]. The robot can automatically detect human and or other types of non-living presence and its main control unit is operated via WiFi using the mobile as a transceiver device allowing for remote safe control of UVC lamp disinfection[9]. CleanBot is essentially a compact remote controlled autonomous floor cleaning device which cleans the floor by a set of commands given from a smartphone using Bluetooth signals given through a Bluetooth module[10]. This robot can perform sweeping and mopping tasks. RF modules have been used for wireless communication between remote (manual mode) and robot and have a range of 50m. This robot is incorporated with an IR sensor for obstacle detection and automatic water sprayer pump[11]. an Automatic Disinfectant Robot which is capable of Cleaning, Sanitizing, and Disinfecting the floor surface by killing harmful pathogens with the help of vacuum cleaner, sanitizer and ultraviolet ray disinfection methodology, respectively without any direct involvement of human beings is becoming an undeniable need[12]. In this study, the proponents employed the capability of Ultraviolet Light in the C band (UV-C) in terminating bacteria[13]. In this examination, we have embraced the actual disinfection strategy by utilizing UVC light as a specialist. The UVC gadgets are examined and characterized concurrently with their sanitizer units, reciprocal gadgets, consolidated disinfection specialists, portability, and request types[14]. Ultraviolet (UV) sterilization technology is used to aid in reduction of microorganisms that may remain on the surfaces after a standard cleaning to the minimum number[15]. The study aims to achieve a safe and high-efficiency disinfection system using a mobile robot. The designed robot comprises a mobile platform and an ultraviolet-C (UV-C disinfection batten). The UV-C lamps are mounted on the end-effector to provide large-scale, accurate manipulation[16]. Construction is simple and easy to operate so that an illiterate person can also be able to operate this machine. The main parts of this machine are moisture cotton mop, sweeping brushes, wiper and vacuum cleaner[17]. In this project we use UV lamp for germ sterilization, IR Sensor for edge sensing and also Arduino UNO microcontroller as the motherboard. By this project, we tried to reduce the cost of mopping robots as compared with other mopping robots[18].

MATERIALS AND METHODOLOGY

The key components used in the Fabrication of this robot include

1. 360° UV light source

A strategically placed UV lamp emits ultraviolet radiation and effectively removes microorganisms from floor surfaces.

2. Arduino microcontroller

This microcontroller acts as the brain of the robot, controlling movement, UV lamp operation and other functionalities.

3. H-bridge module

The H-bridge module integrated into the Arduino effectively controls the DC motor motors, allowing the robot to move.

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4. Floor Cleaning Device
This device dispenses the cleaning solution using a suction pump and a separate container.
5. ESP32 Camera Module
This camera module enables real-time video streaming to facilitate remote monitoring and robot operation.
6. Servo motor
The ESP32 camera is mounted on a servo motor that enables 360° rotation and provides a comprehensive overview of the cleaning area.

Other miscellaneous Components used in the Fabrication and working of this robot include L298 motor driver, 360-degree camera (ESP32 cam), 12V lead-acid battery, Water tank with detergent liquid, Switch for mode control, Fabrication materials for bot structure.

A) System Assembly and Integration

a) *Chassis Construction:* The selected material is cut and assembled according to the designed specifications. This may require drilling holes, bending plates or using fasteners to create a durable and functional chassis.

b) *Integration of motor and wheels:* DC motor motors are mounted on the chassis with suitable transmission mechanisms to connect them to the wheels. At this stage, the motors are also connected to the H-bridge module for controlled movement.

c) *UV Lamp Placement:* The UV lamp is strategically placed under the robot body, ensuring optimal coverage of the floor during use. Safety considerations such as shielding the UV lamp to prevent accidental exposure are critical.

d) *Cleaning Unit Integration:* The cleaning unit, including the reservoir, suction pump, and nozzle system, will be integrated into the chassis design. The suction pump will be connected to the reservoir and the nozzle, and the entire unit will be positioned strategically for effective cleaning coverage.

e) *Electronic Component Integration:* The Arduino microcontroller will be mounted onto the chassis and connected to the H-bridge module for motor control. The ESP32 camera module will be integrated with the Arduino and mounted on the servo motor. Wiring will be done meticulously to ensure proper communication and power distribution between all electronic components.

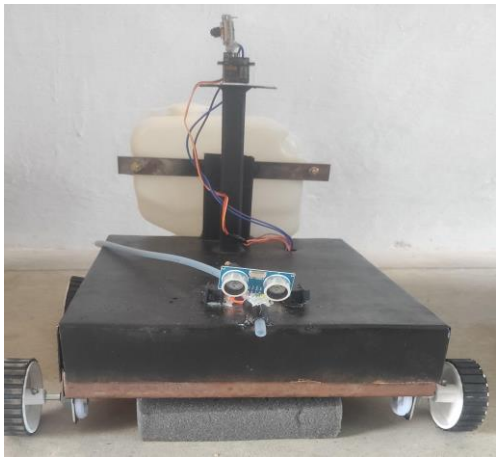

Figure 1 Automatic UV Disinfection Robot(A Prototype)

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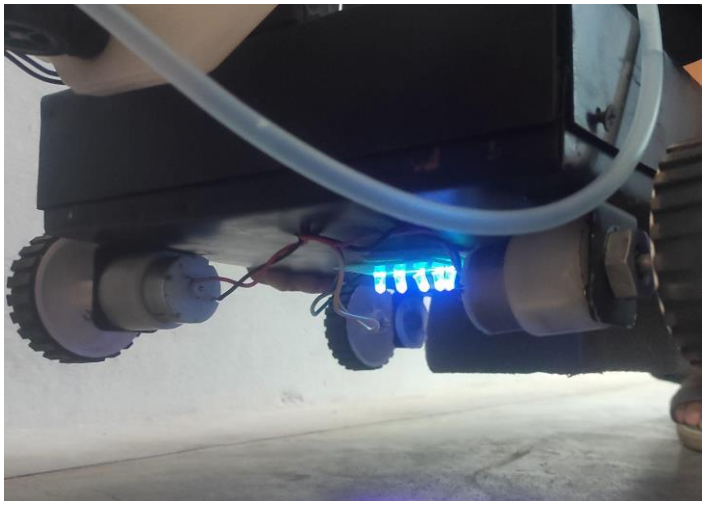

Figure 2 UV-C Light beneath the Prototype

B) Software Development and Programming

In this phase, the software that controls the operation of the robot is developed

a) *Arduino programming:* Using the Arduino IDE, code is developed to control the robot's movement patterns, UV lamp activation and general functionality. The code controls the speed and direction of the motors with the H-bridge module. It also controls the timing and operation of the UV lamp according to predefined parameters or sensor inputs (if available).

b) *Programming the ESP32 camera module:* The ESP32 camera module is programmed to capture and transmit video. This may require the use of ESP32 platform-specific libraries or frameworks to establish a reliable video streaming connection.

c) *Servo Motor Control:* The Arduino code is programmed to control a servo motor that allows the ESP32 camera to rotate 360° to get a comprehensive view of the cleaning area during operation.

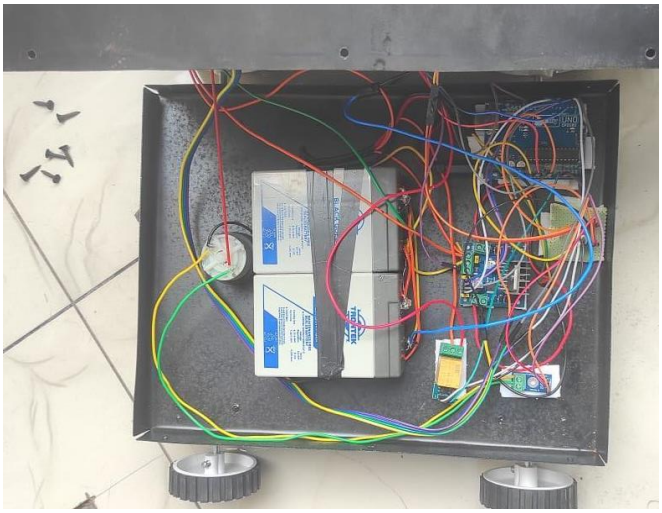

Figure 3 Internal Components of the Prototype

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BLOCK DIAGRAM:

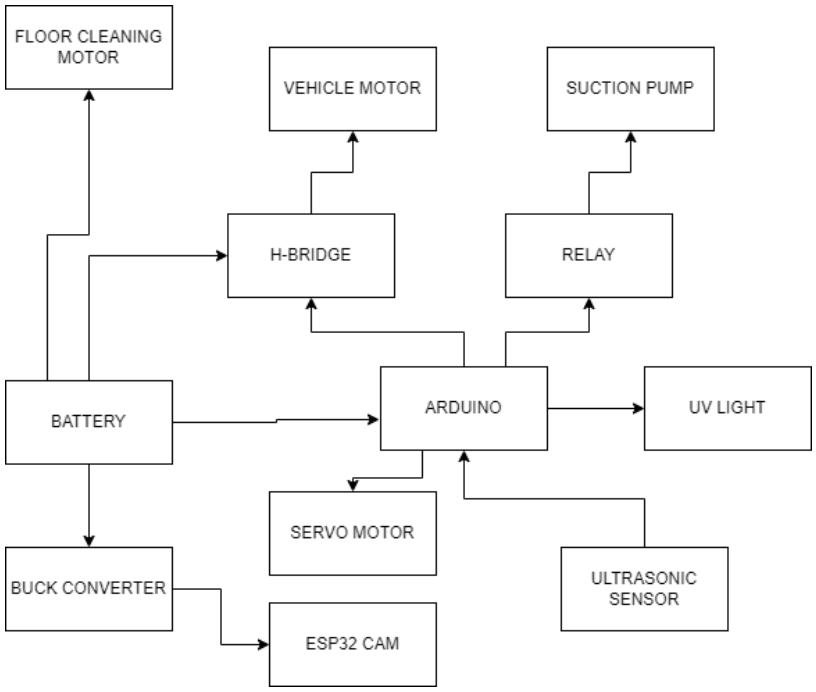

Figure 4 Block Diagram of 360° robot for UV disinfection

The included Arduino code is designed to control the movement of the robot using an ultrasonic sensor to detect and avoid obstacles. Let's break down the work process step by step:

A) Initialization:

The code starts by including the necessary libraries: "NewPing" to connect to the ultrasonic sensor and "Servo" to control the servo motor.- Sets of pins are set up for the ultrasonic sensor (trigger and echo pins), motors and servo.

B) Setup function:

In the `setup() function, the pin modes are initialized, the serial monitor is started, and the motion start time is saved.

C) Loop function:

Within the Loop() function, the distance between the ultrasonic sensor and the nearest obstacle is measured by the sonar.ping_cm() function and stored in the 'dist' variable.

- The code then checks if it's time to change the motion state based on the elapsed time. When the previous time is exceeded, it rotates left and right alternately.
- If an obstacle is detected nearby (less than 10 cm), both motors will be stopped to avoid a collision. Otherwise, the robot will move forward, turn left or right according to the current movement state.
- The code also reads analog input pin A1 to detect the signal. When a signal is detected above a certain threshold, it triggers an action that is performed after a certain number of counts.
- Additionally, the code controls the servo motor to oscillate between two positions (0 and 180 degrees) every 800 milliseconds.

D) Movement functions:

"moveForward()", "makeLeftUTurn()" and "makeRightUTurn()" control the movement of the robot. They assign the appropriate motor pins to achieve forward, left or right movement.

E) Servo control:

A servo motor is used to sweep the object detection sensor. It oscillates between 0 and 180 degrees every 800 milliseconds.

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F) Serial Output:

The code outputs sensor readings, analog input readings and detected distance to a serial monitor for debugging and monitoring.

G) Control flags:

The variables `flag` and `gt` are used as control flags to control the vibration of the servo motor and the rotation direction of the robot, respectively.In short, the code continuously cycles through detection, decision making, and movement execution. It effectively controls the movement of the robot, detects obstacles, avoids collisions and performs additional functions based on sensor inputs. Using modular functions improves readability and maintainability, which makes the code easier to understand and modify for different applications.

RESULTS AND DISCUSSION

A) DETERMINATION OF UV INTENSITY:

Determination of the intensity of UV radiation is done to determine the value of the UV dose, its accuracy and sanitary accuracy. When the UV-C lamp is on, the detector should be placed as close as possible to the UV-C source (lamp) at the same distance as when it is used to disinfect surfaces or objects.
The intensity of UV radiation is µW/cm2.

UV Dose = UV Intensity (µW/cm2) x Exposure Time (seconds)
= 860 x 8
= 7040 µW/cm2s
= 704 µW/m2s (Safety Range)

B) DETERMINATION OF PRECISION OF RESULT:

This is done to check the error percentage of UV Sanitation Robot that is done by parking the Bot in such a way that the Camera and the motion sensor is pointed at a particular height to experiment trials and determine consistency.

S.no	Floor	Distance (Sq.ft)	Trail	Time taken	Efficiency	Overall Efficiency
1	Cement Floor (milk area)	10	1	10 min	59.22	**73.86**
		20	2	20 min	63.87	
		30	3	30 min	88.76	
2	Tiles (Lab area)	10	1	10 min	58.76	**72.11**
		20	2	20 min	69.74	
		30	3	30 min	87.82	

3	Normal Floor	10	1	10 min	56.78	**71.28**
		20	2	20 min	65.78	
		30	3	30 min	89.76	

Table 1 Determination of Precision of Result

Speed = 10 rpm
Overall Machine Efficiency **= 73.60 %**

C) DETERMINATION OF MICROBIOLOGICAL COUNT (E. coli, Fungi and Bacteria):

Determining the number of microbes helps determine the effectiveness and also helps compare the UV bot with existing floor cleaning methods. Samples are collected using swab collectors and then the swabs are cultured, incubated and then the filter is examined for microbial activity.

MICROBIOLOGICAL ANALYSIS (SWAB)

SL. No	NAME OF THE SAMPLE	UNIT	SPECIFICATION	TOTAL BACTERIAL COUNT (TBC)	TEST METHOD
1.	Sample-1 (Before passing UV)	CFU	Max 100/Sq cm	70	IS 5402
2.	Sample-2 (After passing UV)	CFU	Max 100/Sq cm	15	

Table 2 ***Determination of Microbiological Presence***

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Figure 5 Swab Sample Collection for testing

Figure 6 Total Bacterial Count of Sample 1

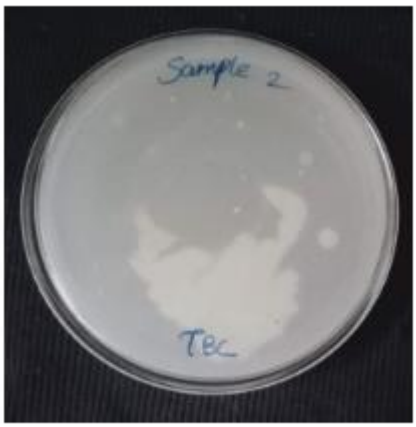

Figure 7 Total Bacterial Count of Sample 2

- The total bacterial count (TBC) of a material is a quantitative estimation of the number of microbes present in a sample.
- This measurement is expressed as the count of colony-forming units (CFU) per gram of sample.

AREAS OF FUTURE RESEARCH AND IMPROVEMENTS

Sensor integration: The functionality of the robot can be improved by adding different sensors to it. For example, floor sensors can automatically adjust cleaning parameters for optimal results on different surfaces. In addition, obstacle detection sensors can allow the robot to navigate around obstacles and clean more complex environments**.**

Map and Navigation: The integration of a map and navigation system allows the robot to autonomously clean larger areas and create cleaning schedules. This would further reduce manual intervention and improve the efficiency of the robot.

Advanced cleaning techniques: Research into alternative cleaning methods such as steam cleaning or vibrating brushes can be integrated to provide a more complete cleaning.

Self-cleaning and maintenance functions: Introducing functions such as automatic emptying of the dust container or self-cleaning mechanisms for UV lamps can improve the user-friendliness of the robot and reduce the need for maintenance.

Remote Control and Timing: Developing a robust remote control system and timing capabilities can allow the user better control and flexibility in using the robot.

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CONCLUSION

The proposed 360° UV floor sterilization robot with detergent cleaning can revolutionize the practice of floor hygiene in various environments. This project offers an all-in-one solution that combines the disinfection efficiency of UV light with the cleaning power of detergent use. The autonomous nature of the robot reduces labor costs and cleaning time, while the 360° UV lamp ensures thorough disinfection of floor surfaces. In addition, the integration of real-time video streaming enables remote monitoring and control of the cleaning process.The successful development and implementation of this project can bring significant benefits to healthcare, educational and commercial facilities. By promoting a more effective and efficient approach to floor hygiene, this robot can help create a cleaner and healthier environment for everyone..

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