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Swarm Robotics for Ultra-Violet Sterilization Robot

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***Abstract*—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. This paper mainly focuses on using a Swarm Robotics System for UV sterilization robots. The most crucial elements in maintaining human health are proper cleanliness and hygiene standards. This system will reduce traditional cleaning costs and also reduces the vulnerability of humankind to infection. The advancements in hardware technology, cooperative approaches in biology, and swarm intelligence in the future will be boosted in the development of swarm robotics systems.**

Keywords—Swarm Robotics; UV sterilization Robot; Multi-robot communication; Mobile robotics simulation.

I. Introduction

Due to the significant advantages of group behaviors of multi-system coordination in lowering cost and energy consumption, cooperative control for Cyber-Physical Systems has gathered a lot of interest over the past years [5].

Swarm robotics focuses on the planning, creation, and deployment of large teams of robots that work together to solve issues or complete tasks. It draws its inspiration from naturally occurring self-organizing systems like social insects, fish schools, and bird flocks that exhibit emergent group behavior based on basic local interaction principles [1]. To create multi-robot systems with comparable capabilities, swarm robotics typically draws engineering ideas from the study of those natural systems. By doing this, it hopes to create robot systems that are more resilient, fault-tolerant, and adaptable than individual robots and that are capable of better adjusting their behavior to environmental changes. Swarm robotics began as an application of swarm intelligence, or the computational modeling of collective self-organizing behavior, which led to various effective optimization algorithms presently utilized in sectors like telecommunications, the simulation and forecasting of crowd behavior [1].

In swarm robotics, we will add a UV sterilization feature. UV sterilization robotic systems will become more common in a wide range of industrial settings for duties like inventory control in warehouses and deep cleaning and sanitization of big spaces. This paper will introduce a swarm robotics system for this UV sterilization robot for operation. It should clean floors and sanitize public areas. Two main benefits of autonomy- First, people are put at risk by the use of stronger disinfectants that robots can employ. Second, their efficiency does not decline as the area increases that need to be sanitized. These robots might replace people who operate in a hazardous environment and put their health in danger [2].

We will be utilizing MATLAB software for swarm robotic communication. We will be doing so by utilizing MATLAB with ROS libraries as well as the Mobile Robot Simulation Toolbox. The mobile robot simulation toolbox is used to simulate 2 and more swarm robots. In that, the robot can map the surface using the Lidar sensor and detect the obstacles. From that 2D simulation, we can see how the swarm robot will work [3].

A communication interface called Robot Operating System (ROS) makes it possible for various robot system components to find one another and exchange data. With the help of a library of functions provided by MATLAB, ROS is supported, allowing you to exchange data with actual robots or robot simulations [3].

II. Literature Survey

It is essential to provide some background information about the Swarm Robotics strategy. An ant colony or a flock of birds are two examples of social creatures whose natural and self-organized activities inspire the developing field of Swarm Robotics. The ideas of self-organization can be used to adapt these social animal behavior models to groups of straightforward, autonomous robots. The robots must not use a complicated algorithm or a sophisticated and intricate system. The basic goal of Swarm Robot is to use emergent behavior, which is how social insects function, to solve complicated issues by taking advantage of small interactions between the robots [1].

The Swarm Robotic strategy needs three key qualities i.e, robustness, adaptability, and scalability, to realize this desired simplicity. Robustness, the first quality, permits the swarm to continue operating as a system without affecting performance even if certain agents stop working. Flexibility is the second quality, which enables the swarm system to adapt quickly to changing environments and also to the levels of difficulties in tasks. The capacity to function with small or large numbers of agents without impacting the system's performance and efficiency is the third attribute [7].

The Swarm Robotics strategy must be created using a set of criteria to attain the Swarm Robotics qualities mentioned above:

- A large group of autonomous robots with the capacity to sense and act in a real environment must make up the robot swarm; Appl. Sci. 2021, 11, 2383 5 of 17.
- The swarm must contain a significant number of robots, at least as many as the control rules permit.
- Robots need to be uniform. Although not overly diversified, the robot swarm may contain a variety of robot kinds.
- The robots must be capable of performing the primary task, they are assigned. They must collaborate to perform better.

The CoV-2 virus may be detectable on hard surfaces for up to 72 hours and in the air for periods longer than three hours, according to research from van Doremalen et al. (2020). Other human coronaviruses have been shown by Kampf et al. (2020) to linger on various surfaces for up to 9 days. UVGI is effective against viruses in the coronavirus family, according to numerous research. Three single-strand RNA viruses, including SARS-CoV-1, were rendered inactive as a result of UV-C irradiation, according to research by Darnell et al. (2020). The 254 nm UV-C inactivation of the MS2 bacteriophage, adenovirus, and MHV coronavirus was demonstrated by Walker and Ko in 2007.

A study by Kesavan et al. (2014) that found aerosolized spores were inactivated more quickly than surface-fixed organisms, even when controlling for variance in irradiation intensity observed in the aerosol chamber, supports the finding that UV-C irradiation neutralizes aerosolized pathogens more quickly than surface-bound pathogens. Fischer et al (2020) more recent research discovered that UV was equally effective as hydrogen peroxide vapor (HPV) at inactivating SARS-CoV-2 on solid, non-porous surfaces.

III. Objective

The objective of the project is given below:

a. The creation of two or more Swarm Robots that will use Swarm Robotics Technology to work as part of a cyber-physical system.

b. The overall disinfection time will be shortened by this system, which operates without manual power.

c. The system's goal is to thoroughly clean the surface using this disinfection robot.

d. The swarm robot will get an obstacle-avoiding feature.

e. If people or animals enter the robot's range of vision, the robot would be able to automatically turn off the UV lamps to prevent any adverse impacts.

IV. Methodology

This section covers the approach used to construct the system.

A. Swarm Robotics Simulation

MATLAB libraries are used for swarm robotics simulation:

1) MATLAB Robotics System Toolbox:
The MATLAB Robotics System Toolbox is a significant toolbox utilized in this project. The toolbox provides several elements that support fundamental robotics methods, such as kinematic, dynamic, and trajectory planning representations of motion. Additionally, the toolbox has features that make operating up to a six-link robot connection straightforward.

For instance, it is simple to analyze the impact of the payload mass on the inertial matrix or the variation in the link's inertia detected by the motor. The toolkit focuses on a specific method for using objects to depict the kinematics and dynamics of manipulators with serial-like motion.

The connection components include a robotic object that may be used to calculate forward and inverse dynamics as well as forward and inverse kinematics. Additionally, the Toolbox provides capabilities for converting between a variety of homogeneous transformations and a variety of point and axis-angle visualizations, as well as providing a category to assist with unit measurements.

2) MATLAB with Robot Operating System (ROS):
Different tools, including packages, nodes, messages, topics, and services, are used by this kind of framework. The nodes of software that can be executed receive data from the robot's detectors and send it to other nodes. When sending data from one node to another, messages are utilized. Topics are the specific ports through which messages are always transmitted [6].

A node that publishes messages about a subject is the talker and the receiving node is the listener. The ability to aggregate and include all nodes in a package that can subsequently be utilized to transfer to another computer when necessary makes packages incredibly helpful. Consequently, the packages are crucial for creating a complete ROS-based autonomous robotic system.

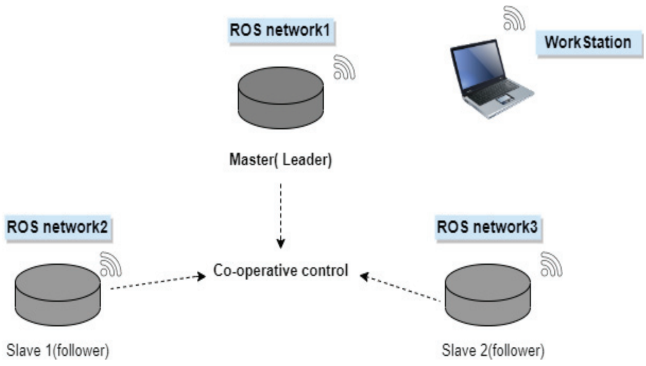

Fig. 1. Swarm Robotics Communication

B. Ultra-Violet Sterilization system

Microorganisms can be destroyed by ultraviolet light with a specific wavelength range of 200-280 nm referred to as the C band of UV radiation. This spectrum of wavelengths is efficient at inhibiting fungus, viruses, and bacteria. Additionally, it works well for disinfecting in the operating room and can be used to sterilize air, water, and surfaces [2] [4].

There are various usage restrictions on the fixed UV sterilization system at the moment. For instance, those who are exposed to UV for an extended period or a significant amount may suffer negative effects. It may affect eye infections and skin rashes. To reduce this problem, we can use the ultrasonic sensor, which will detect human beings. When humans or animals come within the range of the robot the UV lights will automatically turn off.

C. *LiDAR Mapping*

The term "Light Detection and Ranging," or LiDAR, refers to a remote sensing technique that uses pulsed laser light to take measurements that can be used to build 3D models and maps of various objects and settings. Essentially, a LiDAR system determines the amount of time it takes for the laser to reach a surface or object and return to the scanner. From there, distances may be calculated using the speed of light via "time of flight" data.

LiDAR involves the use of active sensors with built-in lighting. Sensors detect and quantify the energy that is reflected when an energy source hits an item. The duration between sent and backscattered pulses is measured, and the distance to the object is calculated using the speed of light. Due to the camera's capacity to generate a bigger flash and sense the spatial relationships and dimensions of the region of interest with the returned energy, flash LiDAR enables 3-D imaging. Because the technology is not sensitive to platform motion and the collected pictures do not need to be patched together, this enables more precise imaging. Less distortion is the outcome of this. We can map the entire room in this project using the LiDAR sensor. To avoid obstacles while working.

D. *Obstacle Avoidance*

Intelligent technology known as "obstacle avoidance" can detect obstacles in its path automatically and avoid a lot of them by reversing directions. A direction requirement for any autonomous robot is the ability to avoid collisions when navigating in an unfamiliar area. The usage of the obstacle-avoiding robot is popular in military organizations today, and it enables the performance of several dangerous tasks.

In this robot, we can use Ultrasonic Sensor. The ultrasonic sensor constantly sends ultrasonic waves from its sensor head while the robot travels along the targeted path. The ultrasonic waves are reflected by obstacles whenever they are in their path, and the microcontroller is informed of this when it occurs. Based on ultrasonic signals, the microprocessor manages the motors to the left, right, rear, and front. Each motor's speed is controlled via pulse width modulation (PWM).

V. CONSTRUCTION

The following sensors and components will be utilized for the robot construction:

The radiation of UVC light is a well-known surface, water, and air disinfectant. Because UVC radiation has been used for many years to prevent the spread of germs and viruses and to destroy them.

For area mapping, a LiDAR sensor will be used. It takes measurements using a laser light that may be used to map different objects and surfaces.

To determine the distance between a target item and the sensor, ultrasonic sound waves are emitted. The target item is hit by this ultrasonic sound wave, and the distances are measured. This sensor is used to recognize the human presence and avoid obstacles.

In this, ESP32 with a cam module will be used. The ESP32 series is a low-cost, low-power microcontroller with built-in Wi-Fi and dual-mode Bluetooth.

An IR LED that emits and a light detector for reflection detection make infrared proximity sensors. To find surface edges, it has a set of certain parameters. In this, we'll make use of this sensor to find the edges of the surface.

The rotation of a Robot is directly provided by the gyroscope sensor. However, this includes the earth's rotation, which causes gyroscopes to wander over time.

The wheel's rotating velocity will provide via a wheel encoder. To measure we may include this into the wheel's rotating angle to measure our progress if the robot has turned, we may compare this distance to that of the opposite wheel. We need to poll the encoder very quickly or set up interrupts when operating at high speeds.

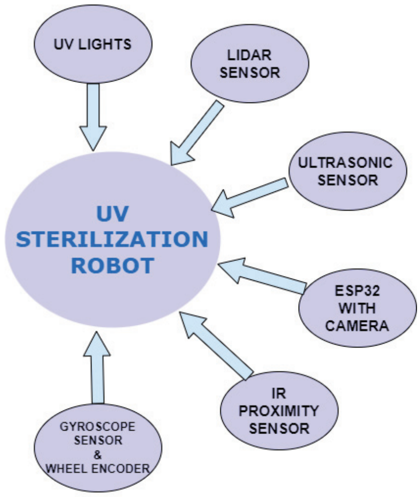

Fig. 2. Block diagram of UV sterilization robot

VI. SWARM COMMUNICATION NETWORK

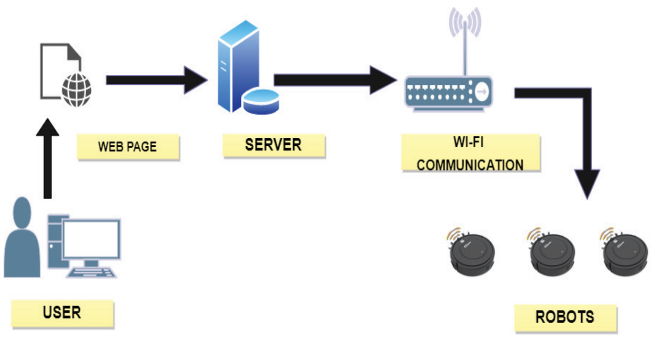

Fig. 3. Block diagram of a networking

There are several ways to communicate in swarm robots. The main determining elements are the project's budget or cost, the surroundings, the size of the robots, and any limitations placed by the project's designers or other circumstances. There are several methods of communication, including wireless LAN and Bluetooth. In this project, we choose Wi-Fi communication. Here, MATLAB will be the first used for simulation purposes. We simulate the disinfect robots using the mobile Robotics simulation toolbox.

Additionally, Simulink for graphic design. In this, we created an environment for swam behavior. In the peer-to-peer network, the user accesses a web page, which sends data to a server, which in turn sends the data to the end node swarm robot through Wi-Fi.

We will use Wi-Fi as the primary means of communication between the robot server and the robot swarm. Wi-Fi will be chosen because it allows us to use two different channels of communication without much to no additional hardware costs. We may incorporate a range of communication protocols over Wi-Fi, designed on top of the fundamental Wi-Fi protocol like IEEE 802.11.

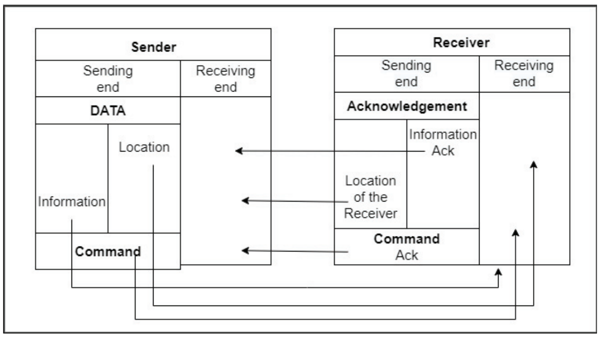

Fig. 4. Block diagram of peer-to-peer communication

In a peer-to-peer network of robots (agents). From the sending end, the sender will send the location to the receiving end, and from the sending end, the acknowledgment will be sent back to the receiving end of the sender. The acknowledgment package will change in this instance. In this case, the acknowledgment packet essentially contains the receiver's or any other node's location. The node's or agent's location serves as an acknowledgment packet. Any information regarding the location will therefore comparable to the acknowledgment packet, and we will send the information to the recipient while simultaneously getting the acknowledgment from the receiver to the sender.

VII. MATLAB SIMULATION AND RESULTS

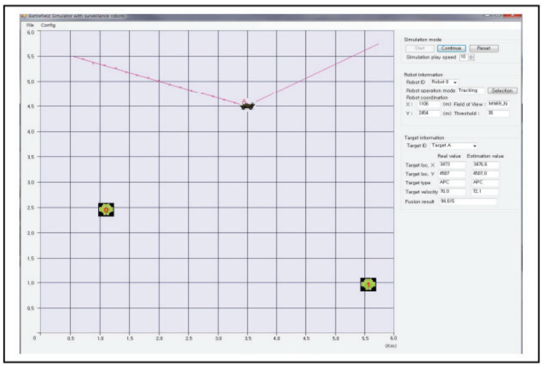

Fig. 5. Battlefield scenario with two surveillance robots and one target. (Existing system)

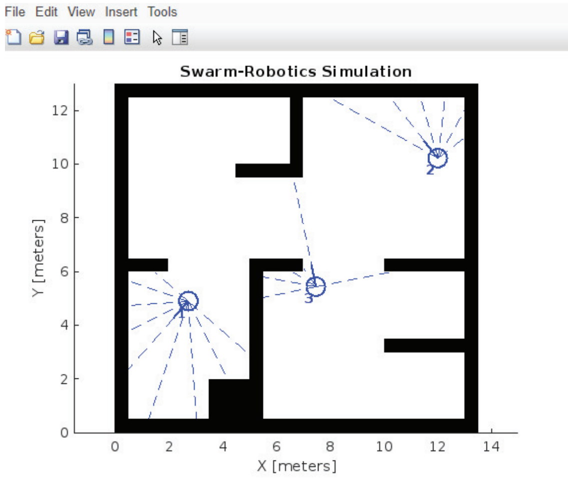

Fig. 6. MATLAB simulation using LiDAR (purposed algorithm)

The above fig. 6. It's our simulation results, we have used MATLAB software. In this MATLAB software, we used the Mobile robotics simulation toolbox. Mobile robotics simulation toolbox has a SwarmTeamMain.m MATLAB file and Simulink has a MultiRobotAvoidance.slx file for simulation purposes.

TABLE I. COMPARISON OF SWARM ROBOTICS AND OTHER SYSTEMS

Parameters	Multi-robot system	UV Disinfection robot	Swarm robotics for UV sterilization robot
Population size	Small	Bulky	Compatible size
control	Centralized or remote	remote	Decentralized and autonomous
Flexibility	Low	Medium	High
Scalability	Low	Medium	High
Environment	Known and unknown	Known	Unknown
The range for 1 robot	IR range 30m	RP LiDAR range 2.8 m	LiDAR range 100 m x n (n= no. of robots)
Typical Application	Transportation and sensing	Surface and Air disinfect	Surface disinfection and medical application

In the above table I, we did a comparison between the existing multi-robot system as shown in fig 5, as the result of the surveillance robot [16], UV disinfection robot [2], and our proposed Swarm robotics for UV sterilization robot. The multi-robot existing system had limitations in size while our proposed system will have no limitations in size. The control parameter is centralized or remote for existing systems but in our system, it is decentralized and autonomous. Parameters like flexibility and scalability increase from low (existing system) to high in our system. The existing multi-robot system used an IR sensor having a range of 30m. And UV disinfection robot which used an RP LiDAR sensor has a range of 2.8m. In our system, we will use a LiDAR sensor for multiple robots, each sensor having a range of 100m.

VIII. FUTURE SCOPE

In the future, swarms of Nano-bots may develop into a unique and effective tool in precision medicine, enabling targeted treatments inside the human body like slightly forward operation or the administration of poly-therapy directly to tumor tissue. The swarm robotics method will, however, be forced to its limitations when it comes to coordinating large numbers of robots with extremely limited processing and communication capacities, requiring the creation of new conceptual tools in addition to microscopic hardware or robotics devices [1].

Defense organizations all across the globe are looking to use robot swarms because they find a system that cannot be quickly shut down to be very attractive. Particularly when robots are replaceable and, to some level, disposable, an adversarial system that is fault-tolerant to external attacks can support operations. But in this case, the role of the human being is still crucial. Therefore, advanced HSI (Health Service Indicator) strategies will be essential for successful deployment and the person in the loop must be taken into account in defense applications.

IX. Conclusion

Manufacturing is a key requirement for the development of swarm robotics systems, and cooperative algorithms are necessary for the swarm to provide control over it. The size of robots will be decreased because of advancements in swarm robotics technology in the areas of communication systems, sensors, actuators, and electronic components.

We believe that the development of swarm robotics systems will be boosted by advancements in hardware technology, cooperative approaches in biology, and swarm intelligence in the future. The robot will be capable to handle the primary task which focuses on issues related to human health. Essentially, people are put at risk by the use of stronger disinfectants that robots can employ. Second, their efficiency does not decline as the area increases that need to be sanitized. These robots might replace people who work in a hazardous environments and put their health in danger. To show the swarm robotics behavior we have used the Mobile robotics simulation toolbox in MATLAB for simulation purposes. We have created a scenario of a room with an obstacle, it results in how the multiple disinfect robots will work. Hence the range of disinfection areas increased which reduced the vulnerability of humankind and improve the quality of healthy life.

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