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DEVELOPMENT OF AUTONOMOUS MOBILE ROBOT ON ROS2 FOR DIS-INFECTION APPLICATION

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Abstract - ***This project established a robust and autonomous robotic system utilizing ROS2 to address the need for effective and automated disinfection in various environments. Leveraging ROS2 as the primary robotics framework, it was integrated with a virtual simulation platform to facilitate risk-free experimentation with advanced navigation and disinfection strategies. This innovative setup enabled safe testing and validation of autonomous mobility, sensor integration, and control algorithms without exposing hardware to potential damage. The core focus of this project was a requirement-based disinfection process tailored to predefined zones and schedules for optimized sanitation tasks. A user interface was developed to enhance user interaction and real-time monitoring, allowing the operator to define disinfection areas, select operation modes, and monitor system status. Upon receiving user commands, the robot autonomously navigated to designated areas using LiDAR-based mapping and localization and performed precise disinfection through a controlled spraying mechanism. In the virtual simulation environment, the autonomous mobile robot demonstrated accurate mapping, obstacle avoidance, and systematic disinfection task execution, replicating real-world conditions. Additionally, the project bridged virtual and physical realms by enabling the real robot to mirror actions performed in the simulation, allowing the autonomous robot to navigate and disinfect physical spaces based on input from the user interface. Comprehensive system validation confirmed that the integrated platform met all performance, safety, and reliability requirements in practical scenarios before full deployment. The optimized workflow and efficient resource utilization supported innovation in autonomous robotics, advancing applications in healthcare facilities, industrial premises, and public areas for reliable and automated disinfection solutions.***

Key Words: **Autonomous Mobile Robot, ROS2, Virtual Simulation, LiDAR Mapping, User Interface, System Validation, Automation, Disinfection Process.**

1.INTRODUCTION

An Autonomous Mobile Robot (AMR) is a self-navigating robot designed to move and perform tasks in dynamic environments without direct human control. It uses advanced sensors, cameras, LIDAR, and onboard computing to perceive its surroundings, plan paths, and make real-time decisions for obstacle avoidance and task execution. AMRs are capable of adapting to changing environments, allowing them to operate efficiently in spaces shared with humans or other machines. These robots rely on algorithms for simultaneous localization and mapping (SLAM), autonomous navigation, and task planning, typically running on platforms like ROS2. AMRs are widely used in industries such as logistics, manufacturing, healthcare, and disinfection, where they improve operational efficiency, safety, and accuracy by automating transportation and other repetitive tasks.

1.1 INTRODUCTION TO THE PROJECT

This project focuses on developing an integrated autonomous mobile robotic system for disinfection tasks using ROS2 as the core framework. Leveraging ROS2's advanced capabilities in robot control, mapping, and communication, the robot operates autonomously in defined zones, carrying out systematic disinfection tasks.

The virtual environment allows for risk-free testing of autonomous navigation, path planning, and disinfection mechanisms before physical deployment. The system is designed with a custom-built user interface through which users can define disinfection areas, set schedules, and initiate tasks. Upon user input, the robot autonomously navigates to the specified location, performs precise spraying through its disinfection module, and confirms task completion, simulating real-world operation.

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Beyond simulation, the project bridges virtual testing and real-world deployment through seamless integration between simulated and physical environments. Using ROS2, along with SLAM algorithms and real-time feedback mechanisms, the autonomous mobile robot replicates simulated actions in physical spaces, ensuring accurate performance. System validation confirms the robot's ability to navigate, disinfect, and report with precision, optimizing efficiency and resource utilization in sanitation and safety-critical applications.

1.2 HISTORY

In recent decades, autonomous robot development and simulation environments have rapidly advanced, particularly with the evolution of ROS (Robot Operating System) and ROS2. In 2007, Willow Garage introduced the first version of ROS, enabling modular development for robotic applications. By 2010, ROS gained widespread adoption, with research institutions using it to build complex autonomous systems. In 2017, ROS2 was released, offering improved real-time performance, security, and distributed computing support, making it ideal for industrial-grade applications.

By 2018, ROS2-based autonomous disinfection robots began to emerge, notably during the COVID-19 pandemic, when hospitals and public spaces adopted robots for contactless sanitation. Companies such as Blue Ocean Robotics introduced the "UVD Robot" using ROS-based frameworks to perform autonomous disinfection in healthcare environments. In 2020, Clearpath Robotics leveraged ROS2 for enhanced indoor navigation and obstacle avoidance in industrial settings.

In 2021, researchers from the Massachusetts Institute of Technology (MIT) demonstrated ROS2-integrated autonomous robots capable of performing complex mapping and task execution for disinfection in laboratories. The same year, companies like Siemens and Honeywell started incorporating ROS2-based robots in smart manufacturing and warehouse sanitation applications.

Today, in the 2020s, ROS2 continues to evolve as the backbone for autonomous mobile robots used in disinfection, logistics, and surveillance, with companies like OTSAW Digital and Fetch Robotics leading developments in large-scale deployments of autonomous disinfection solutions.

1.3 DYNAMIC ARCHITECTURE OF THE INTEGRATED ROBOTIC CONTROL SYSTEM

The dynamic architecture of this integrated autonomous robot system is designed to enable seamless operation, real-time control, and robust communication between the robot, sensors, and the control interface. At its core, ROS2 operates as the computational engine for handling autonomous navigation, dynamic obstacle detection, disinfection task scheduling, and system monitoring. LiDAR sensors and onboard cameras provide environmental feedback, allowing for continuous localization and path planning.
The architecture is built around a multi-node ROS2 framework where navigation, mapping (via SLAM), disinfection control, and user communication nodes function in parallel. Using ROS2's DDS communication protocol, the robot interacts with external interfaces to receive instructions and send task completion updates.

The simulation environment, powered by Gazebo, is used to test this architecture by modeling real-world disinfection scenarios and navigation paths.
For real-world application, the simulated environment mirrors the physical world, and the robot transitions seamlessly from virtual testing to actual deployment.

Feedback loops in both simulation and physical operation ensure that sensor data is continuously analyzed for adaptive path correction and efficient task execution. This architecture minimizes errors, reduces resource consumption, and accelerates deployment while ensuring safety and reliability.

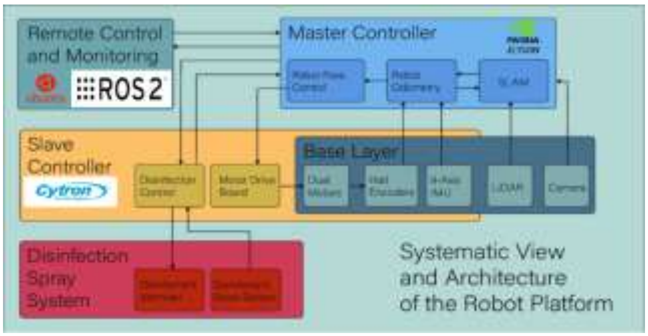

Fig -1: Architecture of the System

2. OBJECTIVES AND METHODOLOGY

2.1 PROBLEM IDENTIFICATION

In public spaces, hospitals, and industrial facilities, maintaining high levels of hygiene and sanitization has become increasingly critical, especially in the wake of global health challenges. Manual disinfection methods are labor-intensive, time-consuming, and often inconsistent, leaving room for human error and incomplete coverage. These traditional practices expose workers to hazardous environments and infectious agents, increasing the risk of disease transmission. Moreover, large and complex areas require systematic, repeated sanitization that human teams struggle to deliver efficiently.

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Although autonomous robots are being developed to address these challenges, significant barriers remain in ensuring these robots can navigate dynamically changing environments while performing precise disinfection tasks. Current systems often lack adaptability and intelligent path planning, resulting in inefficient coverage or excessive disinfectant usage. Additionally, the integration of real-time sensor data for obstacle detection and environmental awareness is either limited or highly complex, requiring advanced programming and continuous monitoring.

The absence of a flexible and robust software framework further hampers progress in this domain. Traditional robotic software platforms fall short when it comes to modular development, real-time control, and multi-sensor integration. ROS2 (Robot Operating System 2), with its distributed communication model and enhanced real-time capabilities, offers a solution—but effective implementation demands expertise in robotics middleware, sensor fusion, and control algorithms. Furthermore, ensuring smooth communication between autonomous navigation systems, disinfection mechanisms, and monitoring interfaces requires meticulous system architecture design and testing.

Additionally, the lack of standardized performance validation frameworks for autonomous disinfection robots makes it challenging to ensure reliability and compliance with health and safety standards before deployment. Addressing these challenges calls for an integrated development and testing environment that combines autonomous navigation, intelligent disinfection routines, and real-time monitoring using ROS2. This will not only enhance operational efficiency but also contribute significantly to public health and safety by providing consistent, effective, and risk-free disinfection in critical spaces.

2.2 PROPOSED METHODOLOGY

To address the challenges identified in autonomous disinfection, the proposed methodology employs a structured approach based on the ROS2 framework for the development and deployment of an autonomous mobile robot. The initial phase involves designing a modular robot architecture that integrates autonomous navigation, disinfection mechanisms, and real-time sensor processing. ROS2 will serve as the middleware to facilitate seamless communication between various hardware components such as LiDAR, cameras, ultrasonic sensors, and the disinfection unit.

The next step includes the development of robust SLAM (Simultaneous Localization and Mapping) and autonomous path-planning algorithms to enable the robot to efficiently map its environment and navigate dynamic spaces while avoiding obstacles. The robot will be equipped with environmental sensors that continuously provide data, enabling intelligent decision-making for coverage optimization and effective disinfection routines.

Simulation environments, such as Gazebo integrated with ROS2, will be employed to create realistic test scenarios. These simulations will allow for validation of navigation algorithms, disinfection coverage strategies, and sensor responses under varied conditions, minimizing errors before real-world deployment. Following successful simulation testing, the system will be deployed on a mobile robot platform, where real-time testing will be carried out in controlled environments to fine-tune system performance.

Finally, feedback mechanisms will be integrated into the system using ROS2 topics and services, allowing the robot to dynamically adapt its navigation and disinfection actions based on real-time sensor data. This adaptive control will enhance the robot’s ability to operate efficiently in unpredictable environments. The overall methodology aims to deliver a scalable and autonomous solution for disinfection applications, ensuring safety, reliability, and effectiveness in public and industrial spaces.

2.3 OBJECTIVES

The primary objective of this project is to design and develop an autonomous mobile robot using the ROS2 framework, capable of performing efficient and reliable disinfection in indoor environments such as hospitals, offices, and public spaces. The project aims to integrate autonomous navigation, environment mapping, obstacle avoidance, and disinfection mechanisms into a cohesive robotic system that can operate with minimal human intervention.

One of the key objectives is to develop robust and adaptive path-planning algorithms, enabling the robot to navigate dynamically changing environments while ensuring maximum coverage for disinfection. The project will focus on real-time sensor integration, allowing the robot to detect obstacles, people, and environmental conditions, and adjust its movement and disinfection routines accordingly.

Another critical goal is to establish seamless interaction between simulated testing environments and real-world deployment. The project will use simulation tools like Gazebo, interfaced with ROS2, to validate navigation strategies, coverage patterns, and sensor responses before transferring the system to a physical mobile platform. This transition ensures that the robot's real-world performance aligns with its simulated behavior, minimizing errors and improving reliability.

The project also aims to demonstrate the use of environment mapping (SLAM) and autonomous decision-making based on sensor feedback, allowing the robot to adapt to new environments without manual

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reprogramming. Through continuous data exchange between sensors, control algorithms, and disinfection modules, the robot will be capable of identifying high-risk zones and focusing disinfection efforts where needed most.

Moreover, this development will provide a foundation for scalable deployment in larger spaces or multiple units working collaboratively. The project's outcomes are expected to contribute to safer public and healthcare environments by automating disinfection tasks that are otherwise labor-intensive, time-consuming, and prone to human error.

Ultimately, the objective is to deliver a robust, intelligent, and adaptive mobile robot platform built on ROS2 that can autonomously perform disinfection tasks with high efficiency, reliability, and precision, setting the groundwork for future advancements in autonomous service robotics in public health and safety applications.

3. PROPOSED WORK MODULE

3.1 PROPOSED WORK

The proposed work for this project focuses on the development and deployment of an Autonomous Mobile Robot (AMR) using ROS2 for disinfection applications. This project is structured around three core modules: mechanical design and fabrication, software integration and navigation setup, and testing and validation. The first phase involves designing the AMR in SolidWorks, focusing on stability, load capacity, and ease of movement, followed by the fabrication of the robot with precision and safety in mind. The next stage is software integration, where ROS2 is configured with key packages such as Nav2, sensor integration, and motion planning algorithms, enabling autonomous navigation and obstacle avoidance. Finally, extensive simulation and real-world testing will be conducted to evaluate the AMR's disinfection capabilities, ensuring accurate path following, effective coverage, and adaptability to dynamic environments. Each of these modules is essential to achieving a robust and efficient AMR system capable of autonomous disinfection in various operational settings.

3.1.1 3D MODELLING

The initial phase of this project involves the 3D design and modelling of the Autonomous Mobile Robot (AMR) using SolidWorks. This process begins with creating detailed CAD models of all key components, including the robot chassis, mounting structures, wheel assemblies, sensor housings, and motor placements.

Special attention is given to dimensions and material selections to ensure structural integrity, stability, and optimal load distribution. The design process also incorporates appropriate slots and mounting points for essential electronics such as the Jetson Orin Nano, Cytron motor drivers, RPLIDAR sensors, and power modules. Once individual components are designed, they are assembled virtually in SolidWorks to verify mechanical clearances, alignment, and functional movement of wheels and sensors.

Stress analysis and motion simulations are conducted to ensure durability and mobility under different operating conditions. The finalized 3D model serves as the blueprint for the fabrication stage, ensuring that every part of the AMR is precisely designed for smooth integration, efficient operation, and ease of maintenance in real-world disinfection tasks.

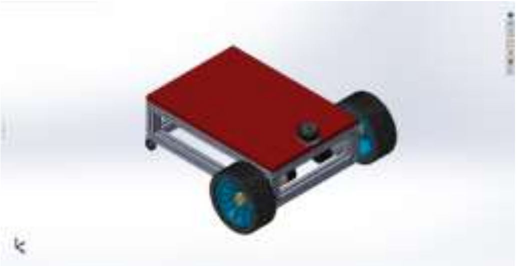

Fig -2: 3D Model Of AMR

3.1.2 FABRICATION

The second phase focuses on the fabrication of the Autonomous Mobile Robot (AMR) based on the 3D models designed in SolidWorks. The fabrication process begins with precision cutting and assembly of the chassis and structural components using lightweight yet durable materials such as aluminium and high-grade plastic composites. The wheel assemblies and mounting brackets are manufactured and fitted to ensure proper alignment and smooth mobility. Following the mechanical assembly, key electronic components, including the Jetson Orin Nano, Cytron Smart Drive MDDS30 motor driver, RPLIDAR A2M12 sensor, and planetary gear DC motors with encoders, are carefully installed and wired. Attention is given to secure placement, efficient cable management, and reliable power distribution. Functional checks are performed throughout the fabrication process to verify motor rotation, encoder feedback, and sensor accuracy. The integration of all mechanical and electrical systems ensures that the AMR is structurally stable, operationally reliable, and fully prepared for deployment in real-world disinfection applications.

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Fig -3: Fabricated AMR

3.1.3 PROGRAMMING AND SIMULATION

The third phase involves programming the Autonomous Mobile Robot (AMR) using ROS2 and conducting simulations to validate its performance in disinfection applications. ROS2 packages are developed to handle critical functions such as sensor data processing, path planning, navigation, and obstacle avoidance. The Nav2 stack is configured to enable the AMR to autonomously map its environment, generate paths, and follow them with precision. RPLIDAR data is integrated into the system to provide real-time environmental awareness, allowing the robot to detect obstacles and adjust its trajectory accordingly. Simulation tests are performed in RViz, where the AMR's movements, localization accuracy, and navigation efficiency are monitored under various virtual scenarios. These simulations replicate real-world conditions, verifying the programming logic and adaptability of the robot to dynamic environments. This phase ensures that the ROS2-based control and simulation environment is reliable, enabling a smooth transition from simulation to real-world deployment for effective and autonomous disinfection tasks.

Fig -4: URDF Setup

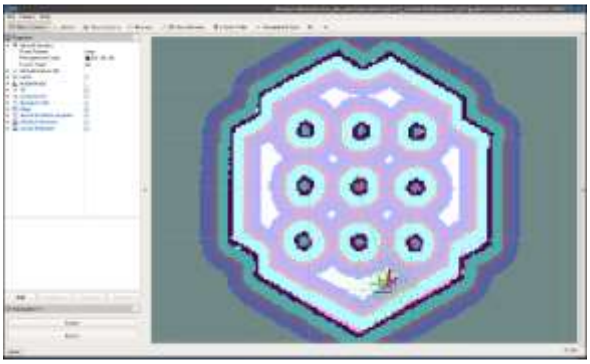

Fig -5: Nav2 Environment

3.1.4 TESTING AND DEPLOYMENT

The final phase focuses on testing and real-world deployment of the Autonomous Mobile Robot (AMR) to ensure that it performs effectively in practical disinfection applications. After completing simulation validation in ROS2, the AMR is subjected to extensive hardware testing, where all components, including the Jetson Orin Nano, RPLIDAR A2M12, planetary gear DC motors with encoders, and Cytron Smart Drive MDDS30, are integrated and calibrated. The robot's navigation and obstacle avoidance capabilities are tested in controlled environments to assess accuracy and responsiveness. Real-world testing involves placing the AMR in actual indoor spaces where it autonomously maps the area, plans paths, and executes disinfection tasks with precision. The ROS2-based system is monitored for consistency in task execution, reliability in different environmental conditions, and the ability to adapt to dynamic changes in surroundings. These tests confirm the functionality of the AMR beyond simulations, ensuring that the design, programming, and integration efforts result in a fully operational and autonomous system ready for deployment in real-world disinfection scenarios.

4. RESULTS AND DISCUSSION

The results of the project demonstrate the successful development and deployment of an autonomous mobile robot built on ROS2 for disinfection applications. Using real-time communication between sensors and control systems, the robot was able to perform autonomous navigation and disinfection tasks efficiently. The integration of the Nav2 stack allowed smooth path planning and execution with accurate obstacle avoidance capabilities. The testing process showed that the robot could map the environment and follow predefined disinfection paths with high precision and stability. The RPLIDAR sensor provided accurate environmental data, while odometry feedback from the planetary gear motors ensured controlled and stable movement. The processing power of the Jetson Orin Nano enabled seamless execution of these tasks without delays. Simulations and real-world tests were conducted to verify navigation reliability and coverage consistency across different scenarios. Key metrics such as trajectory accuracy and disinfection path completion time were analysed, confirming that the system performed as expected under varying conditions. Additionally, the robot showed flexibility in adapting to dynamic environments, responding to sudden obstacles and re-planning routes effectively. Real-time visualization through RViz helped verify the correctness of navigation, localization, and mapping during the process. The integration of all components and systems proved highly effective in validating the robot's functionality without requiring continuous manual control. These results confirm that the autonomous mobile robot developed on ROS2 is capable of handling mapping, navigation, and disinfection tasks in indoor environments. The system's reliability and scalability make it suitable for future deployment in healthcare facilities, public spaces, and industrial settings, where autonomous disinfection is essential.

5. CONCLUSION

In this project, an autonomous mobile robot for disinfection applications was successfully developed using ROS2. The system showcased substantial benefits in terms of affordability, flexibility, and real-time autonomous navigation in both simulated and real-world environments. By utilising open-source ROS2 packages and harnessing the computational capabilities of the Jetson Orin Nano, the need for costly proprietary control and navigation systems was eliminated, allowing for a highly adaptable and customisable robotic platform.

The implementation of simulation tools such as RViz and the Nav2 stack reduced dependency on physical trials, saving valuable development time and resources while enabling thorough validation in diverse scenarios. Additionally, reliable real-time communication between sensors, motor controllers, and the onboard computing system was established, allowing for efficient disinfection operations with precise control and obstacle avoidance. This completed system not only streamlined development but also provides a strong foundation for future research and industrial deployment, with the potential to expand into other autonomous service robot applications.

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