An Arduino-Based Robot for Wall Painting Tasks

Vijaya Kumar S, Sharath Kumar K, Chirag M, Chandan Gowda VM, Kiran T

Mechanical Department, M.S. Ramaiah University Of Applied Sciences, Bengaluru, India

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ABSTRACT

This project presents a robot designed to automate painting tasks in construction and maintenance industries. The robot utilizes BLDC fans for wall-climbing suction, enabling movement across vertical surfaces without scaffolding or ladders. Built with a lightweight 3D Printed Plastic chassis, the system integrates Arduino UNO microcontroller, IR sensors for obstacle detection, and Bluetooth connectivity for mobile app control. The paint delivery system features a spray mechanism with external tank for uniform coverage. This solution addresses safety hazards, labour costs, and time inefficiencies associated with traditional painting methods. The robot demonstrates practical robotics applications, offering enhanced safety, reduced operational costs, and improved efficiency in wall painting operations.

Keywords—wall painting, robot, wall climbing, paint robot

Aim - To develop Robot capable of climbing and painting walls.

PROBLEM STATEMENT

Need of the Project

The construction industry faces critical challenges in wall painting operations, particularly in high-rise buildings where traditional methods pose significant safety risks and operational inefficiencies. Manual painting requires high risk, multiple workers, and prolonged project timelines, resulting in high labor costs and increased accident potential. Current methods are inadequate for large-scale applications, in construction schedules and compromising worker safety. The growing emphasis on automation and workplace safety standards demands innovative solutions. An autonomous wall painting system is essential to eliminate human exposure to high heights, reduce labor dependency, accelerate project completion, and ensure consistent paint quality while meeting modern construction industry requirements for efficiency and safety.

Motivation

Wall painting in tall buildings is dangerous and takes too much time. Workers need scaffolding and ladders, which can cause accidents. It also costs a lot of money and requires many people to complete the job.

We wanted to create a robot that can paint walls safely without putting workers at risk. The robot can climb walls by itself and paint them automatically. This saves time, reduces costs, and keeps workers safe from falling.

The construction industry needs better tools to make work easier and safer. Our robot can help solve the problem of painting tall buildings while making the job faster and more efficient. This project shows how simple technology can help solve everyday problems in construction work.

Applications

Some of the applications where the Autonomous Wall painting robot can be used are Skyscrapers, Hospitals, Schools, Warehouses, Factories, Hotels, Apartments, Offices, Stadiums, Bridges

INTRODUCTION

Traditional wall painting in large buildings is labor-intensive, time-consuming, and hazardous, requiring scaffolding, ladders, and extensive manpower. This creates significant costs and safety risks. Our Autonomous Wall Painting Robot addresses these challenges by automating the painting process with minimal human intervention.

The system features a lightweight 3D Printed Plastic chassis that uses powerful BLDC fans to generate suction for climbing and moving across vertical surfaces. An Arduino UNO microcontroller manages operations, while IR sensors provide obstacle detection. Users control the robot via a Bluetooth-enabled mobile application that monitors battery status, connectivity, and paint spraying functions.

The integrated paint system includes a spray mechanism and external tank for even distribution. This innovation enhances safety, reduces costs, and significantly improves efficiency compared to traditional methods. Our robot demonstrates practical robotics applications in construction, showcasing how interdisciplinary engineering can modernize everyday industrial tasks while addressing real-world challenges.

In addition, components like the spray nozzle, suction system, and IR sensors are mounted for quick replacement, enabling adaptability for different wall textures and architectural layouts. The microcontroller is programmed with optimized motion algorithms to ensure uniform paint coverage, contributing to a professional finish. The Bluetooth control system includes a user-friendly interface that allows operators to switch between manual and autonomous modes seamlessly. This flexibility ensures control in dynamic environments while maintaining autonomy in repetitive tasks. Furthermore, the compact size of the robot makes it suitable for indoor and outdoor painting jobs, even in narrow or elevated space.

PRINCIPLES AND ASSUMPTIONS

Principles

- Simple Autonomous Functionality - The robot should perform basic autonomous wall movement and painting.
- Safe Wall Climbing Mechanism - BLDC fan-based suction should be safe for residential walls (like plaster or painted drywall).
- Lightweight and Portable Design - The robot must be compact, lightweight, and easy to carry and set up in small home or office settings.
- Affordable Materials - Use low-cost materials like acrylic or lightweight Plastic for the chassis to maintain affordability without compromising structural integrity.
- Moderate Paint Efficiency - Ensure coverage with minimal control—Uniform or fancy pattern optimization isn’t necessary at this scale.

Assumptions

- Robot is assumed to work on limited workspace of $50cm^2$ area and project is shown on flat vertical surface (e.g. Wood, hard board, flat boards).
- Walls are assumed to be smooth and flat, with no heavy texture (like brick or stone) to allow suction to hold properly.
- Operation is assumed to be indoors or in protected areas—no exposure to rain, dust, or wind.

- Access to a 1 Power connection (from laptop/power bank) for Arduino, sensors and N20 motors,1 Cell of 9v for pump and one 48v Battery for BLDC motor is available for operation.
- Robot is assumed to work in short sessions (up to 1hour with* full battery).
- Paint used will be standard water-based or acrylic paint suitable for spraying without clogging.

OBJECTIVES

- To analyse existing research and market trends in wall painting automation, identifying functional gaps and opportunities for innovation.
- To define precise technical and functional requirements, including parameters such as payload and suction pressure, and to select the most suitable components for the application.
- To create a conceptual diagram illustrating the operational workflow of the robot.
- To develop an optimized design that balances functionality, payload capacity, and structural durability for practical usability.
- To test the prototype under various conditions and validate its functionality and reliability through live demonstrations.

Literature Review - Summary

Wall-climbing robots have emerged as a significant advancement in painting automation, offering notable advantages over conventional robotic systems. Traditional methods, such as rail-based mechanisms and cable-suspended robots, often require extensive pre-installed infrastructure or anchoring systems, limiting their adaptability and increasing setup complexity. In contrast, climbing robots adhere directly to vertical surfaces using advanced adhesion mechanisms, providing greater operational flexibility and mobility.

Previous research by Selvamarilakshmi et al. (2015) and Zaid and Selvakumar (2016) has outlined the inherent limitations of these traditional approaches, particularly their dependency on external support structures and their restricted movement across variable surfaces. Similarly, Kolekar et al. (2015) explored Cartesian robots for wall painting, noting their effectiveness in workspace coverage but highlighting their inability to adapt to irregular or non-linear surfaces.

In contrast, our robot is designed to overcome these limitations by incorporating a ducted-fan-based suction system, enabling stable adhesion on smooth vertical surfaces without the need for external support. Unlike earlier models, our design emphasizes portability, affordability, and indoor usability with a lightweight 3D-printed chassis, which makes it practical for small-scale and medium-scale projects, especially in domestic or commercial settings.

Moreover, while most previous studies focus on the mechanical or adhesion aspects alone, our work integrates a full system—combining wall climbing, obstacle detection via IR sensors, mobile-app-based wireless control, and an automated paint spraying mechanism. This holistic integration improves functionality and usability in real-world scenarios.

Our approach also improves safety by reducing reliance on ladders and scaffolding and lowers operational costs through semi-autonomous operation. Though challenges such as adhesion reliability, power efficiency, and full autonomy remain, the presented prototype lays a strong foundation for scalable solutions and further enhancements using AI-based path planning and surface adaptability.

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By focusing on practical deployment in typical indoor environments and incorporating interdisciplinary design principles, our work offers a more user-friendly and implementable solution compared to earlier studies, marking a step forward in making automated wall painting both accessible and effective.

Specifications

Table 1 outlines the comprehensive technical specifications of the Autonomous Wall Painting Robot, detailing its mechanical structure, electronic components, sensors, and functional parameters. Each element listed has been specifically selected and implemented to suit the operational requirements of this project, ensuring optimal performance across all automated painting tasks.

Component	Specifications	Function
BLDC Motor	• Voltage: 7.4-11.1V	Main propulsion / lift mechanism
	• Current: 10-12A	
	• Speed: 980KV	
	• Shaft:3.17mm	
	• Weight: 50g	
BLDC ESC	• Current: 30A continuous	Motor speed control
	• Voltage: 2-3SLiPo (7.4-11.1V)	
	• BEC: 5V/2A	
	• PWM frequency: 50Hz	
Propeller	• Diameter: 10cm (4 inch) • Material: Plastic	Thrust generation
	• Shaft hole: 3.17mm	
N20 Motors	• Voltage: 3-6V	Wheel drive motors
	• Speed: 100RPM • Torque: 0.8 kg·cm	
	• Current: 150mA	
	• Shaft: 3mm D-type	
IR Sensor	• Voltage: 3.3-5V	Obstacle detection
	• Range: 2-30cm	
	• Output: Digital/Analog	
	• Current: 7mA	
Servo Tester	• Voltage: 4.8-6V	Manual motor control
	• Output: PWM signal	
	• Frequency: 50Hz	
	• Channels:3	
Microcontroller	• Voltage: 7-12V input	Main control unit
	• Logic: 5V	
	• Digital I/O: 14 pins	
	• Analog: 6 pins	

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	• Flash: 32KB	
Bluetooth Module	• Voltage: 3.6-6V	Wireless communication
	• Range: 10m	
	• Baud rate: 9600-115200 • Protocol: SPP	
Paint Pump	• Voltage: 12V DC	Paint delivery
	• Flow rate:1.2L/min	
	• Pressure: 0.4MPa • Current: 1A	
Spray Nozzle	• Material: Plastic	Paint spraying
	• Orifice: 1-2mm	
	• Thread: Standard	
	• Pattern: Adjustable	

Table 1. Specifications of the Model

Concept and Model Development

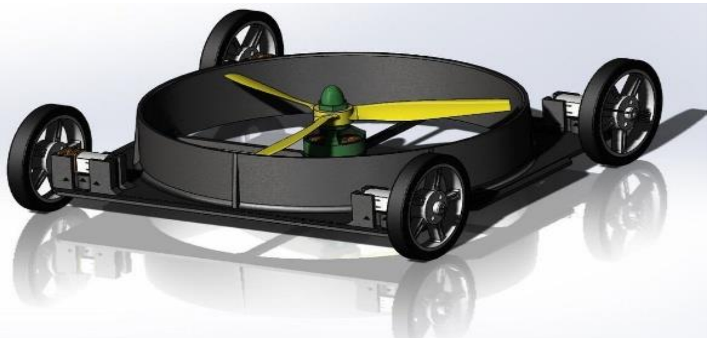

Fig. 1. CAD Model

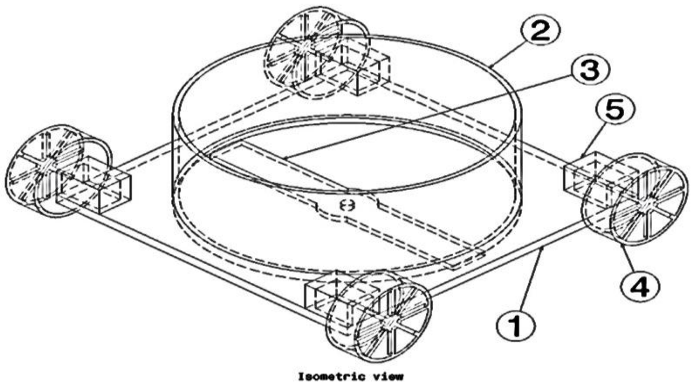

Fig. 2. CAD Model Assembly Draft

Bill of Material: Robot Model

Number	Name	Type	Quantity
1	Base	Part	1
2	Fan Cover	Part	1
3	Fan Holder	Part	1
4	N20 motor Holder	Part	4
5	Wheel	Part	4

Table 2. Bill of Materials

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Block Diagram

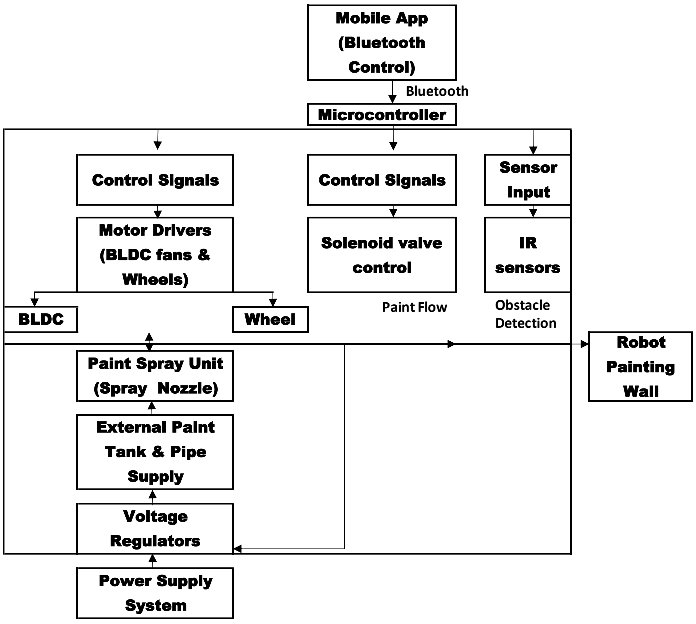

Fig. 1. Model Block Diagram

The above Fig. 3. Shows the system architecture with Arduino Uno as the main controller, Input sensors (IR sensor, Bluetooth module, manual switch), Output actuators (BLDC motor system, N20 wheel motors, paint pump, roller), Power control through relay modules.

Circuit Diagram

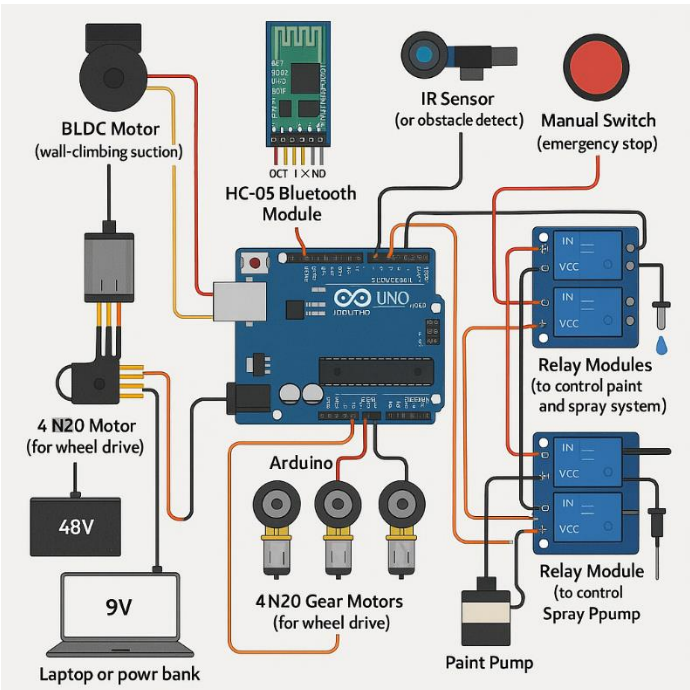

Fig. 2. Model Circuit Diagram

The circuit diagram illustrates the complete electrical connections and component integration. It shows the Arduino UNO microcontroller as the central processing unit, connected to BLDC for wall adhesion. Bluetooth module for wireless communication, motor drivers for movement control, and the paint spraying system.

Arduino Pin Connections

Arduino Pin	*Component*	*Function*
D0 (RX)	HC-05 TX	Bluetooth Receive
D1 (TX)	HC-05 RX	Bluetooth Transmit
D2	Relay 1	Paint Pump Control
D3	Relay 2	Spray System Control
D4	BLDC ESC	Motor Speed Control
D5	N20 FL	Front Left Motor
D6	N20 FR	Front Right Motor
D7	N20 RL	Rear Left Motor
D8	N20 RR	Rear Right Motor
D11	Buzzer	Audio Feedback
D12	Manual SW	Emergency Stop
A0	IR Sensor	Distance Measurement

Table 2. Pin connections

The following commands are assigned for the Bluetooth terminal application, as illustrated in Fig. 5:

F - Move Forward

B - Move Backward

L - Turn Left

R - Turn Right

S - Stop Movement

Fig. 3. App. Control Buttons

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Test and Demonstarion

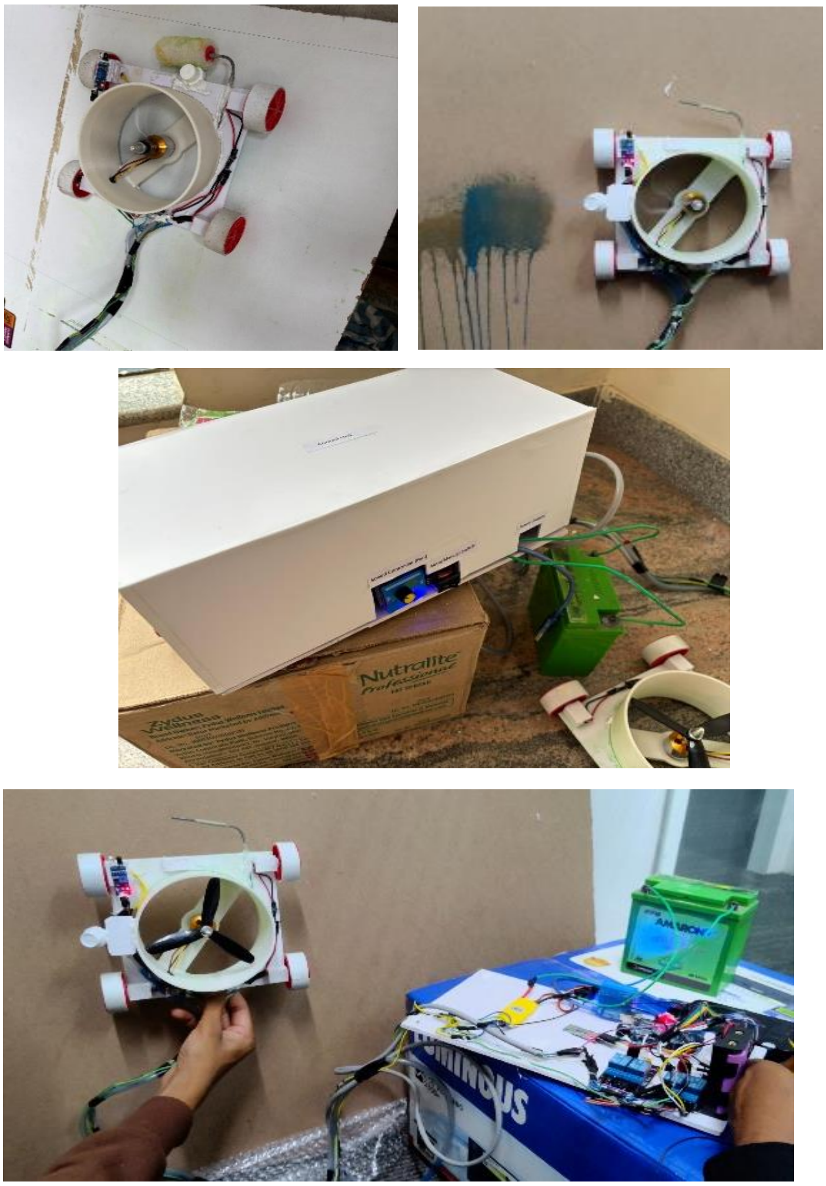

Fig. 4. Developed Model

Results and Calculations

Table 3. Model Parameters

Wheel Circumference (Distance per Rotation)

The circumference of the wheel determines how far the robot moves in one full rotation of the wheel.

Circumference = $\pi \times$ Diameter

Circumference = 3.1416×42mm = **131.94 mm ≈ 13.1cm**

So, the robot moves **13.1 cm** for each full wheel rotation.

Speed required to paint a wall of given length

Testing the wall length is 0.4 meters (40 cm), and the robot completed at 11.58 Seconds:

Speed = 400 / 11.58 = **0.03454 m/sec ≈ 3.454 cm/sec**

Force Required to Climb Vertically

$F = m \times g$

$F = 0.5 \times 9.81$

F= **4.905 N**

Total Torque Required

Total Torque = F × r

Total Torque = 4.905 × 0.021 = **0.103 N·m**

Torque per motor = 0.103 ÷ 4 = **0.026 N·m**

Since the robot moves at 0.03454 m/sec,

In 1 second, it paints a line that's 0.03454 m long.

Area painted per second

Area/sec = Speed × Spray Width

= 0.03454 m/sec × 0.1 m

= **0.003454 m²/sec**

Area per minute

Area/min = 0.003454 × 60

= **0.20724 m²/min**

With 1.2 L of paint per minute, this gives:

Paint coverage efficiency:

0.20724 m² / 1.2 L ≈ 0.1727 m²/L

Test Parameter	Result
Total paintable area	~0.20724 m²/min flow
Battery runtime (Arduino & N20)	~1 hour (powered by external USB or power bank)
Pump battery (9V)	~30–40 minutes of continuous spraying
BLDC fan battery (48V)	~15 minutes suction operation before recharge
Suction test (vertical surface)	Holds firmly for >10 minutes on smooth wood/ply
Obstacle avoidance	IR sensor detects obstacles within 25 cm reliably
Paint quality	Even spray pattern with minimal overspray

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Table 4. Experimental Results

Parameter	Value
Payload Mass - m	**0.5 kg**
Gravity - g	9.81 m/s²
Wheel Radius - r	21 mm = 0.021 m
Motors Used	4 × N20 motors (100 RPM)
Paint Pump Flow Rate	1.2 L/min
Spray Pattern Width (approx.)	10 cm (0.1 m)

Criteria	Manual Painting	Our robot
Labor Required	2–3 people	1 operator (semi-autonomous)
Safety Risk	High (working at height)	Low (no ladders/scaffolding needed)
Time Efficiency	~2–3 hours / 10 m²	~1.5 hours / 10 m²
Cost	Moderate (daily wages)	Low (one-time investment)
Coverage Quality	Variable	Uniform spray
Wall Access	Limited to reachable areas	Smooth vertical indoor walls

Table 5. Manual Painting vs Robot Comparison

FUTURE SUGGESTION

To enhance the capabilities of the Autonomous Wall Painting Robot and address its current limitations, several key improvements should be considered:

Power and Adhesion Systems: Develop hybrid power solutions that combine high-capacity batteries for extended operation. Integrate backup adhesion mechanisms, such as magnetic systems for metal surfaces or gecko-inspired adhesion, to improve reliability during power fluctuations.

Surface Adaptability: Design adjustable suction chambers and flexible chassis components to handle textured walls, corners, and irregular surfaces. Develop weather proof housing for outdoor applications with enhanced resistance to environmental conditions.

Advanced Paint Systems: Incorporate multi-colour paint reservoirs with automated mixing capabilities, pressure sensors for consistent spray patterns, and paint thickness monitoring for quality control.

Scalability: Design modular systems that allow multiple robots to work collaboratively on large-scale projects, with centralized coordination and synchronized operations to enhance productivity and coverage efficiency.

CONCLUSION

The project titled **"An Arduino-based Robot for Wall Painting Tasks"** was undertaken with the primary objective of designing a self-operating robot capable of climbing walls and performing painting tasks. Through this endeavour, a functional prototype was developed that successfully achieved autonomous wall climbing and efficient paint application. The completion of this project marks a significant step toward introducing automation into traditionally labour-intensive and hazardous tasks such as wall painting.

The robot is built around a lightweight and durable chassis made of 3D-printed plastic material, ensuring it can support various essential components without compromising mobility. The climbing mechanism, which uses Brushless DC fans, enables the robot to adhere to vertical surfaces by creating consistent suction force. This was one of the core technical challenges of the project and was successfully addressed through rigorous testing and optimization of airflow and fan configuration.

Mobility on the wall is achieved with movement in all directions - forward, backward, left, and right, enabling the robot to cover a defined work surface area. The painting system consists of a mounted spray nozzle. The robot's electronics, controlled by the Arduino UNO microcontroller, enable wireless communication with a mobile app, giving users real-time control over movement. Additional features such as IR obstacle detection and automated control logic further enhance the robot's ability to perform tasks reliably and safely.

The mobile application features a simple, user-friendly interface that allows even non-technical users to operate the robot with ease. The integration of hardware and software components was accomplished through progressive development and iterations made throughout the project.

The robot's performance demonstrated advantages in terms of time savings, safety, and consistency compared to traditional manual painting methods. By reducing the need for scaffolding or ladders, the risk associated with working at heights is significantly minimized. While the current prototype is primarily suitable for smooth indoor walls and small-scale projects, it lays the foundation for more advanced iterations that could handle varied textures, outdoor conditions, and autonomous navigation across complex wall geometries.

However, the project also revealed certain limitations. The reliance on a stable power supply for the suction mechanism means that even small fluctuations in power can cause the robot to lose adhesion and fall. Additionally, the limited battery runtime restricts its ability to operate over large areas or for extended periods. The system is also currently dependent on user input for navigation, lacking full autonomous path planning. These limitations point toward opportunities for future research and enhancement, such as integrating computer vision for wall mapping, improving suction efficiency, or exploring alternative adhesion methods like magnetic systems or gecko-inspired technologies.

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