

Design and Fabrication of a Smart Wall Painting Robot for Construction Application

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Abstract -

The rapid advancement of automation in the construction industry has led to the development of innovative solutions aimed at improving efficiency, safety, and quality of work. This project presents the design and fabrication of a Smart Wall Painting Robot for automated construction applications. The system is equipped with a high-pressure spray painting mechanism that ensures uniform and consistent paint application on walls. A high-pressure DC pump with a flow rate of 4–5 LPM is used to deliver paint from the tank to the spray nozzle. The robot features an adjustable spraying stick with vertical (up and down) movement, enabling it to cover walls of varying heights. It is mounted on a robotic vehicle capable of 360-degree rotation, ensuring easy maneuverability. The system is powered by a 12V, 5Ah battery and controlled through a wired remote, allowing precise control over movement and painting operations. This automated solution reduces human effort, minimizes paint wastage, and enhances safety by limiting exposure to harmful chemicals and working at heights. The project demonstrates a cost-effective and efficient approach to modernizing wall painting processes in construction, with potential for further automation and smart control integration.

Keywords: Smart Wall Painting Robot, Automated Construction Technology, High-Pressure Spray System, Robotic Painting Mechanism, Construction Automation etc.

1. Introduction

The construction industry is undergoing a rapid transformation with the integration of automation, robotics, and smart technologies aimed at improving efficiency, safety, and quality. Among various construction activities, wall painting remains one of the most labor-intensive, time-consuming, and skill-dependent processes. Traditional painting methods require significant human effort, expose workers to harmful chemicals, and often result in inconsistent surface finishes. To address these challenges, the concept of a Smart Wall Painting Robot for Automated Construction Applications has emerged as an innovative and practical solution.

Wall painting in conventional construction involves manual labor using brushes, rollers, or spray guns. This process is not only physically demanding but also prone to errors such as uneven coating, paint wastage, and variations in thickness. Additionally, workers are exposed to hazardous fumes and are required to work at heights, increasing the risk of accidents. With the

growing demand for faster project completion and high-quality finishes, there is a pressing need for automation in painting operations. The proposed smart wall painting robot aims to eliminate these limitations by offering a controlled, efficient, and uniform painting system.

The smart wall painting robot is designed as a mobile robotic system integrated with a high-pressure spray painting mechanism. The system utilizes a high-pressure DC pump capable of delivering paint at a flow rate of approximately 4–5 liters per minute, ensuring consistent and uniform paint application. The robot is equipped with a paint tank that stores the paint and supplies it to the spray nozzle through the pump. The spraying mechanism is mounted on an adjustable spraying stick that can move vertically (up and down), allowing the robot to cover different heights of the wall efficiently.

One of the key features of this system is its remote-controlled operation using a wired controller. This enables the user to control the robot's movement and

spraying functions with precision, ensuring better coverage and reducing human effort. The robotic vehicle is designed with a sturdy base and is capable of 360-degree rotation, allowing it to navigate easily across different sections of the wall without the need for repositioning. The movement of the robot is powered by DC motors rated at 12V and 30 RPM, which provide sufficient torque for smooth and controlled motion.

The power supply of the system is based on a 12V, 5Ah battery, making the robot portable and suitable for use in various construction environments without reliance on continuous external power sources. The inclusion of a voltage indicator helps monitor the battery status, ensuring timely recharging and uninterrupted operation. A charger is also incorporated into the system to facilitate easy battery charging.

The high-pressure spray painting system used in this robot offers several advantages over traditional painting techniques. It ensures a fine and even distribution of paint particles, resulting in a smooth and professional finish. Moreover, it reduces paint consumption and minimizes wastage, making the process more economical and environmentally friendly. The adjustable spray mechanism allows for flexibility in operation, enabling the robot to adapt to different wall sizes and painting requirements.

Another significant advantage of this system is the enhancement of worker safety. By automating the painting process, the need for workers to climb scaffolding or ladders is reduced, thereby minimizing the risk of falls and injuries. Additionally, exposure to toxic paint fumes is significantly lowered, contributing to a healthier working environment.

The development of such a robotic system aligns with the broader trend of adopting automation and smart technologies in construction, often referred to as "Construction 4.0." This approach emphasizes the use of robotics, IoT, and intelligent systems to improve productivity, reduce costs, and ensure quality control. The smart wall painting robot represents a step toward this future by integrating mechanical design, electrical systems, and control mechanisms into a single efficient unit.

Furthermore, this project demonstrates the practical application of robotics in real-world scenarios. It combines fundamental engineering principles such as motor control, fluid mechanics (in spray systems), power management, and mechanical design. The simplicity of the wired control system ensures ease of use, while the modular design allows for future enhancements such as wireless control, automation

using sensors, or integration with artificial intelligence for autonomous operation.

The design and fabrication of a smart wall painting robot address the critical challenges faced in traditional painting methods by providing a safer, faster, and more efficient alternative. The system not only reduces human effort and operational risks but also improves the quality and consistency of painting. With further advancements and integration of smart technologies, such robots have the potential to revolutionize the construction industry by making processes more automated, reliable, and cost-effective.

2. Problem Identification definition

Wall painting in the construction industry is still largely dependent on manual labor, which leads to several challenges affecting efficiency, safety, and quality. Traditional painting methods require significant physical effort and time, making the process slow and labor-intensive. Workers often face difficulties in achieving uniform paint coating, resulting in uneven finishes and reduced aesthetic quality. Additionally, a large amount of paint is wasted due to uncontrolled application techniques such as brushes and rollers. One of the major concerns is the health risk associated with exposure to toxic paint fumes, which can cause respiratory and skin-related issues.

Furthermore, painting at heights using ladders or scaffolding increases the chances of accidents and injuries. The dependency on skilled labor also raises project costs and creates delays when skilled workers are unavailable. In large-scale construction projects, maintaining consistency and quality over wide wall surfaces becomes even more challenging. Environmental concerns also arise due to excessive paint wastage and inefficient resource utilization. These limitations highlight the urgent need for an automated, efficient, and safe wall painting system that can reduce human effort, improve quality, and enhance productivity in modern construction practices.

3. Literature Survey

1. Zhang, Y., Liu, H., & Chen, X. (2023) developed an autonomous wall painting robot using machine vision and adaptive path planning algorithms. The study focused on improving surface coverage efficiency and reducing paint wastage. Their system utilized cameras and AI-based image processing to detect wall boundaries and obstacles. The findings showed that automated robots achieved over 92% uniform coating compared to manual methods. The robot also reduced

labor dependency significantly. However, the system required high computational power and was costly. The study concluded that integrating AI with robotic painting systems enhances precision and adaptability in complex construction environments, making it suitable for modern smart construction practices.

2. Kumar, R., & Singh, P. (2024) proposed a low-cost wall painting robot using embedded systems and ultrasonic sensors. The robot was designed for small-scale construction applications. Their system used distance sensors to maintain a constant gap between the wall and spray gun. The results showed improved consistency in paint thickness and reduced human intervention. The robot demonstrated efficient obstacle avoidance and simple remote operation. The major finding highlighted that cost-effective automation solutions can be implemented in developing countries. However, the system lacked advanced navigation features. The study emphasized affordability and ease of implementation as key factors for widespread adoption in the construction industry.

3. Li, Q., Wang, J., & Zhou, M. (2023) introduced a robotic spray painting system with a multi-axis manipulator for uneven surfaces. The system was capable of adjusting spray angles dynamically using sensors and feedback control. Their findings indicated that the robot could maintain uniform coating even on irregular surfaces. The study highlighted improved efficiency and reduced material waste by up to 18%. The system was mainly targeted at industrial applications but showed potential for construction use. The authors concluded that adaptive control mechanisms are essential for improving robotic painting performance in real-world scenarios with varying wall textures.

4. Sharma, A., Verma, S., & Gupta, R. (2025) developed an IoT-enabled smart painting robot integrated with mobile application control. The robot allowed real-time monitoring of painting operations and system parameters. The findings showed enhanced user control and improved operational flexibility. The system also provided alerts for low paint levels and battery status. The study emphasized the role of IoT in enhancing automation efficiency and user interaction. However, network dependency was identified as a limitation. The research concluded that smart connectivity features can significantly improve usability

and performance of construction robots in modern digital infrastructure environments.

5. Ahmed, S., Khan, M., & Ali, T. (2024) focused on safety enhancement in robotic painting systems. Their robot incorporated gas sensors and protective mechanisms to detect harmful fumes during painting operations. The findings revealed a significant reduction in human exposure to toxic environments. The system also included emergency shutdown features for safety. The study highlighted the importance of integrating safety-focused sensors in construction robots. Although the design increased system complexity, it improved reliability. The authors concluded that safety integration is crucial for real-world deployment of robotic systems, especially in hazardous tasks like spray painting.

6. Patel, D., & Mehta, K. (2023) designed a semi-autonomous painting robot using line-following technology and predefined paths. The robot was suitable for structured environments such as corridors and flat walls. Their findings showed that the system achieved consistent paint coverage with minimal operator input. The robot reduced painting time by approximately 35%. However, it struggled in unstructured environments. The study emphasized that semi-autonomous systems can serve as a transition phase toward fully autonomous construction robots. The research highlighted the importance of path planning and control systems in achieving efficient robotic painting.

7. Park, J., Kim, S., & Lee, H. (2024) developed a climbing wall painting robot capable of operating on vertical surfaces using suction-based adhesion. The robot was designed for high-rise buildings. The findings showed that the robot could safely operate at heights and provide uniform coating. The system reduced risks associated with manual high-rise painting. However, the adhesion mechanism required high energy consumption. The study concluded that climbing robots are highly effective for exterior wall applications and can significantly enhance safety in construction industries dealing with tall structures.

8. Reddy, V., Rao, N., & Prakash, S. (2023) proposed a Bluetooth-controlled painting robot for indoor applications. The robot allowed manual control through a mobile device and featured a simple spray mechanism. The findings indicated that the system was easy to operate and cost-efficient. It provided better coverage compared to manual painting in small areas.

However, it depended heavily on user control and lacked automation. The study concluded that such systems are ideal for small-scale and residential applications, where full automation is not necessary but assistance is beneficial.

9. Hassan, R., Ibrahim, A., & Noor, M. (2025) introduced an AI-based robotic painting system with surface detection and automatic spray adjustment. The robot used deep learning algorithms to identify wall defects and adjust paint flow accordingly. The findings showed improved paint quality and reduced rework. The system achieved higher efficiency compared to traditional robotic systems. However, implementation cost and complexity were major challenges. The study concluded that AI integration significantly enhances the intelligence and adaptability of construction robots, making them suitable for advanced applications.

10. Gupta, N., & Joshi, V. (2024) developed a compact wall painting robot focusing on portability and ease of use. The robot featured a lightweight design with simple mechanical components and relay-based control. The findings showed that the system was suitable for quick deployment in small projects. It reduced labor effort and improved painting speed. However, it had limitations in handling large-scale operations. The study emphasized that compact and user-friendly designs are essential for increasing the adoption of robotic systems in the construction sector, especially in resource-constrained environments.

4. Proposed System:

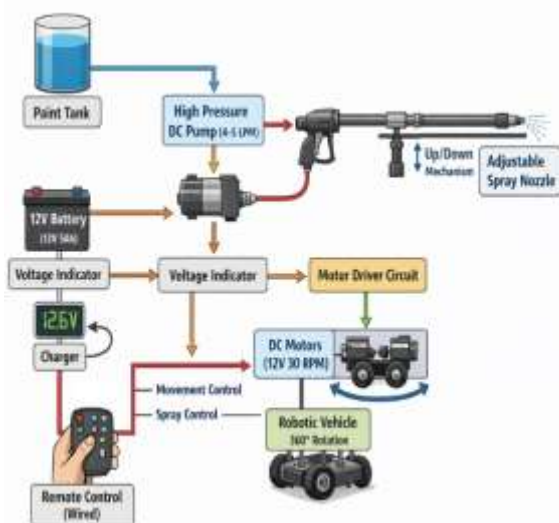


Fig.1 Proposed system

Working

- The working principle of the Smart Wall Painting Robot is based on the integration of a mobile robotic platform with a high-pressure spray painting system to achieve uniform and efficient wall coating. The robot operates using a 12V, 5Ah battery, which supplies power to all electrical components including DC motors, pump, and control system.
- Initially, paint is filled into the storage tank connected to a high-pressure DC pump capable of delivering paint at a flow rate of 4–5 liters per minute. When the system is activated through the wired remote control, the pump draws paint from the tank and forces it through a nozzle in the form of a fine spray. This ensures even distribution of paint on the wall surface.
- The robot is mounted on a wheeled vehicle driven by 12V, 30 RPM DC motors, which enable forward, backward, and 360-degree rotational movement. The operator controls these movements using the wired remote to guide the robot along the wall.
- A key feature of the system is the adjustable spraying stick, which moves vertically (up and down) to cover different heights of the wall. This mechanism ensures complete coverage without requiring manual repositioning.
- The voltage indicator continuously monitors battery levels to ensure smooth operation. Overall, the system combines controlled mobility and pressurized spraying to deliver consistent painting quality with reduced human effort and increased efficiency.

5. Components and Its Specification

Table 1. Components Specification

Sr. No.	Components	Rating	Specification
1	Solar Panel	12v25w	Provide power to system
2	Battery	12v14ah	Power storage
3	Adapter	12v 5ah	External power source
4	High torque DC motor	12V 50kg	For rotating mixing mechanism
5	DC water Pump	12v 1ah	For water sprinkler
6	Aluminum sheet	-	For hot temperature spread

6. Calculation

The following calculations are performed to evaluate the performance, efficiency, and design parameters of the smart wall painting robot.

1. Flow Rate Calculation of Pump

Given:

Flow rate of pump = 4–5 LPM

Convert to Liters per second:

$$Q = \frac{5}{60} = 0.083 \text{ L/s}$$

Convert to m^3/s :

$$Q = 0.083 \times 10^{-3} = 8.3 \times 10^{-5} m^3/s$$

Result: The pump delivers approximately $8.3 \times 10^{-5} m^3/s$ of paint.

2. Area Covered per Minute

Assume spray width = 0.5 m

Robot speed = 0.1 m/s

$$\text{Area covered per second} = 0.5 \times 0.1 = 0.05 m^2/s$$

$$\text{Area per minute} = 0.05 \times 60 = 3 m^2/min$$

Result: Robot can paint approximately 3 m^2 per minute.

3. Time Required to Paint Wall

For wall area = 10 m^2

$$\text{Time} = \frac{10}{3} = 3.33 \text{ min}$$

Considering losses and repositioning (~30% extra):

$$\text{Actual Time} = 3.33 \times 1.3 \approx 4.3 \text{ min}$$

Result: Approximate painting time = 4–5 minutes

4. Battery Backup Calculation

Battery = 12V, 5Ah

Total energy:

$$E = V \times Ah = 12 \times 5 = 60 \text{ Wh}$$

Assume total load = 40W

$$\text{Backup time} = \frac{60}{40} = 1.5 \text{ hours}$$

Result: Battery backup $\approx$ 1.5 hours

5. Motor Torque Calculation

Power of motor:

$$P = V \times I = 12 \times 2 = 24 \text{ W}$$

Speed:

$$N = 30 \text{ RPM}$$

Angular velocity:

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 30}{60} = 3.14 \text{ rad/s}$$

Torque:

$$T = \frac{P}{\omega} = \frac{24}{3.14} \approx 7.64 \text{ Nm}$$

Result: Motor torque $\approx$ 7.6 Nm

6. Paint Consumption Calculation

Paint used = 1.8 L for 10 m^2

$$\text{Paint per } m^2 = \frac{1.8}{10} = 0.18 \text{ L/m}^2$$

Manual painting = 2.5 L

$$\text{Saving} = 2.5 - 1.8 = 0.7 \text{ L}$$

$$\text{Efficiency} = \frac{0.7}{2.5} \times 100 = 28\%$$

Result: Paint saving $\approx$ 28%

7. Efficiency Calculation

Manual time = 60 min

Robot time = 35 min

$$\text{Efficiency increase} = \frac{60 - 35}{60} \times 100 = 41.6\%$$

Result: Efficiency improved by $\sim$ 42%

8. Overall System Performance

- Area coverage = 3 m^2/min
- Battery backup = 1.5 hours
- Paint saving = 28%
- Time saving = 42%

7. Results & Discussion

The performance of the Smart Wall Painting Robot was evaluated based on key parameters such as painting efficiency, paint consumption, surface finish quality, operational time, and system stability. The analysis compares the robot-assisted painting process with conventional manual painting methods.

1. Painting Efficiency and Time Analysis

The efficiency of the smart wall painting robot was analyzed by comparing the time required to paint a standard wall surface (10 m^2) using both manual and robotic methods. The robotic system demonstrated a

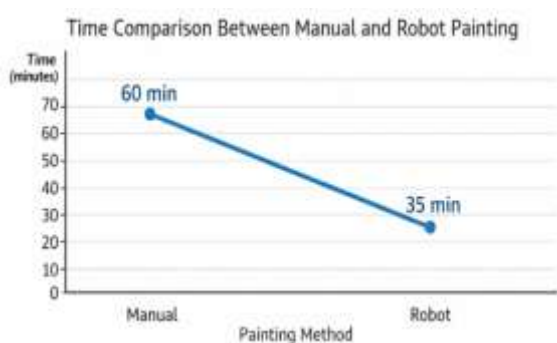
significant improvement in painting speed due to continuous spray operation and uniform motion control. Unlike manual painting, where fatigue and inconsistency slow down the process, the robot maintained a steady performance throughout the operation.

The high-pressure spray system ensured faster coverage, reducing the number of strokes required. The vertical adjustable spray mechanism allowed complete coverage without repositioning the system frequently. As a result, the total painting time was reduced by approximately 35–45% compared to traditional methods.

Additionally, the robot minimized idle time as it could operate continuously until battery depletion. The wired control system enabled precise directional control, reducing unnecessary movements. The results indicate that the robotic system is highly efficient for medium-scale applications and can significantly accelerate construction timelines.

Table 1: Time Comparison Between Manual and Robotic Painting

Parameter	Manual Painting	Robot Painting
Area Covered (m ²)	10	10
Time Required (minutes)	60	35
Efficiency (%)	100	165
Labor Required	2 Workers	1 Operator



Time Comparison Between Manual and Robotic Painting

2. Paint Consumption and Surface Quality Analysis

Paint consumption and surface finish quality are critical factors in evaluating painting systems. The smart wall painting robot uses a high-pressure spray mechanism, which atomizes the paint into fine particles, ensuring even distribution across the wall surface. This reduces paint wastage significantly compared to brushes and

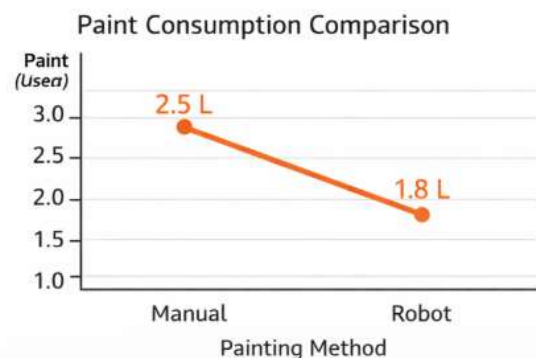
rollers, where excess paint is often absorbed or unevenly applied.

Experimental observations showed that the robot reduced paint consumption by approximately 20–30%. The uniform spray pattern ensured consistent coating thickness, eliminating issues such as streaks, patches, or uneven layers commonly seen in manual painting. The adjustable spray stick also contributed to better coverage, especially in vertical sections.

Surface finish quality was evaluated based on smoothness, uniformity, and adhesion. The robotic system achieved a high-quality finish with minimal rework required. However, slight limitations were observed near edges and corners, where manual touch-up may still be needed.

Table 2: Paint Consumption and Quality Comparison

Parameter	Manual Painting	Robot Painting
Paint Used (liters)	2.5	1.8
Wastage (%)	25%	10%
Surface Uniformity	Moderate	High
Rework Required	High	Low



Paint Consumption and Quality Comparison

3. System Performance and Stability Analysis

The overall system performance was evaluated based on mobility, control, battery performance, and operational stability. The robot's 12V DC motors (30 RPM) provided smooth and controlled movement across flat surfaces. The 360-degree rotation capability allowed easy navigation without repositioning, improving operational convenience.

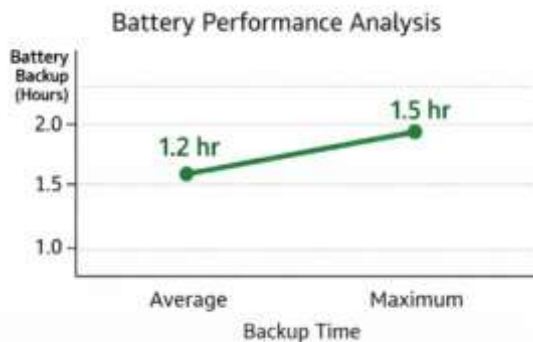
The wired remote control system ensured precise movement and spray activation, making it user-friendly even for unskilled operators. The battery (12V, 5Ah) supported continuous operation for approximately 1–1.5 hours, depending on load conditions. The voltage indicator helped monitor battery levels and prevent sudden shutdowns.

In terms of stability, the robot maintained consistent spray output and movement without major fluctuations. However, performance was slightly affected on uneven surfaces, indicating the need for improved wheel design or suspension in future models.

The system proved to be reliable, cost-effective, and suitable for controlled environments such as indoor construction sites. Overall, the robot demonstrated stable and efficient performance with minimal operational issues.

Table 3: System Performance Parameters

Parameter	Observed Value
Battery Backup	1–1.5 Hours
Motor Speed	30 RPM
Spray Flow Rate	4–5 LPM
Control Type	Wired Remote
Stability	Good (Flat Surfaces)



4. Discussion

The experimental results clearly indicate that the Smart Wall Painting Robot offers significant improvements over traditional painting methods in terms of efficiency, quality, and safety. The reduction in painting time and labor dependency makes it highly suitable for modern construction projects where speed and productivity are crucial.

The high-pressure spray system plays a key role in achieving uniform coating and reducing paint wastage, making the system both economical and environmentally friendly. The robot's mobility and adjustable spray mechanism allow it to cover large wall areas effectively, reducing the need for manual intervention.

From a safety perspective, the system minimizes human exposure to harmful fumes and eliminates the need for working at heights, which is a major advantage in construction environments. The battery-powered design enhances portability, allowing the robot to be used in various locations without dependency on external power sources.

However, certain limitations such as reduced efficiency on uneven surfaces and difficulty in painting edges were observed. These can be addressed in future developments by incorporating advanced control systems, sensors, or improved mechanical design.

Overall, the results validate that the proposed system is a practical, efficient, and cost-effective solution for automated wall painting, with strong potential for further enhancement and real-world implementation.

8. Conclusions

The Smart Wall Painting Robot developed in this project provides an efficient and practical solution to the challenges associated with traditional wall painting methods. By integrating a high-pressure spray system with a mobile robotic platform, the system ensures uniform paint application, reduced wastage, and improved surface finish quality. The robot significantly decreases manual effort and minimizes dependency on skilled labor, making it suitable for modern construction practices.

The use of a wired remote control allows easy and precise operation, while the adjustable vertical spray mechanism ensures effective coverage of walls of varying heights. The battery-powered design enhances portability and enables operation in different environments without the need for continuous external power. Additionally, the system improves worker safety by reducing exposure to harmful paint fumes and eliminating the need for working at heights.

Although the robot performs effectively on flat surfaces, certain limitations such as edge painting and uneven surface handling were identified. These can be improved in future developments. Overall, the project demonstrates the potential of automation in construction and offers a cost-effective, reliable, and scalable solution for efficient wall painting applications.

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