"WINDOW CLEANING ROBOT"

This project report is submitted to

Yeshwantrao Chavan College of Engineering

(An Autonomous Institution Affiliated to Rashtrasant Tukdoji Maharaj Nagpur University)

In partial fulfilment of the requirement for the award of the degree

of

Bachelor of Technology in Electronics & Telecommunication Engineering

by

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CERTIFICATE OF APPROVAL

This is to Certify that the project report entitled "**Window Cleaning Robot**" has been successfully completed by **Anushka Gupta, Chirag Deshbhratar, Jay Charde, Lalit Deshbhratar & Yash Pimparade** under the guidance of **Dr. Sachin S. Khade** in recognition to the partial fulfilment for the award of the degree of Bachelor of Engineering in Electronics & Telecommunication Engineering**, Yeshwantrao Chavan College of Engineering** ***(An Autonomous Institution Affiliated to Rashtrasant Tukdoji Maharaj Nagpur University)***.

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Signature of External Examiner

Name:

Date of Examination:

DECLARATION

We hereby declare that

a. The work contained in this project has been done by us under the guidance of my supervisor.
b. The work has not been submitted to any other Institute for any degree or diploma.
c. We have followed the guidelines provided by the Institute in preparing the project report.
d. We have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
e. Whenever we have used materials (data, theoretical analysis, figures, and text) from other sources, we have given due credit to them by citing them in the text of the report and giving their details in the references. Further, we have taken permission from the copyright owners of the sources, whenever necessary.

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Abstract:

Windows in both residential and commercial buildings play a crucial role in maintaining aesthetics and visibility. However, traditional window cleaning methods often involve manual labour, proving time-consuming, especially for tall or hard-to-reach windows. Elevated cleaning poses inherent risks such as falls and injuries. Additionally, common issues like dust accumulation in sliding window channels and the challenge of cleaning outer surfaces further complicate the process. To address these challenges, our project aims to develop an innovative Smart Window Cleaner. A robot equipped with wet and dry functionalities, efficient power management, and the ability to clean the windows, including sliding channels. This Smart Window Cleaner addresses the inefficiencies of manual cleaning by autonomously navigating vertical surfaces, employing advanced algorithms to adapt its cleaning strategy based on surface conditions. It enhances efficiency and significantly reduces the time required for cleaning.

The incorporation of smart power management ensures optimal energy usage, contributing to long-lasting cleaning. Eliminating the need for human intervention in precarious situations. The robot's design encompasses the ability to clean window channels, addressing the common issue of dust accumulation in hard-to-reach areas. Environmentally friendly cleaning solutions and resource-efficient operations contribute to the project's commitment to environmental benefits. The SWC's design includes a user-friendly interface, allowing for easy programming of cleaning schedules and remote monitoring via mobile devices, ensuring convenience for users. In conclusion, the development of the Smart Window Cleaner integrates advanced robotics to address longstanding challenges in window cleaning. With a focus on efficiency, cost savings, safety, environmental benefits, convenience, increased productivity, technological advancement, and customer satisfaction, this project introduces a transformative solution to elevate the standards of window maintenance in residential and commercial spaces.

Keywords– Smart Window Cleaner, Window cleaning methods, Manual labour, Tall or hard-to-reach windows, Elevated cleaning, Falls and injuries, Dust accumulation, Sliding window channels, Efficiency, Time reduction, Energy usage, Environmental benefits, User-friendly interface, Remote monitoring, Convenience, Increased productivity, Residential and commercial spaces, Residential and commercial spaces

Chapter: 1

Introduction

1.1 Overview:

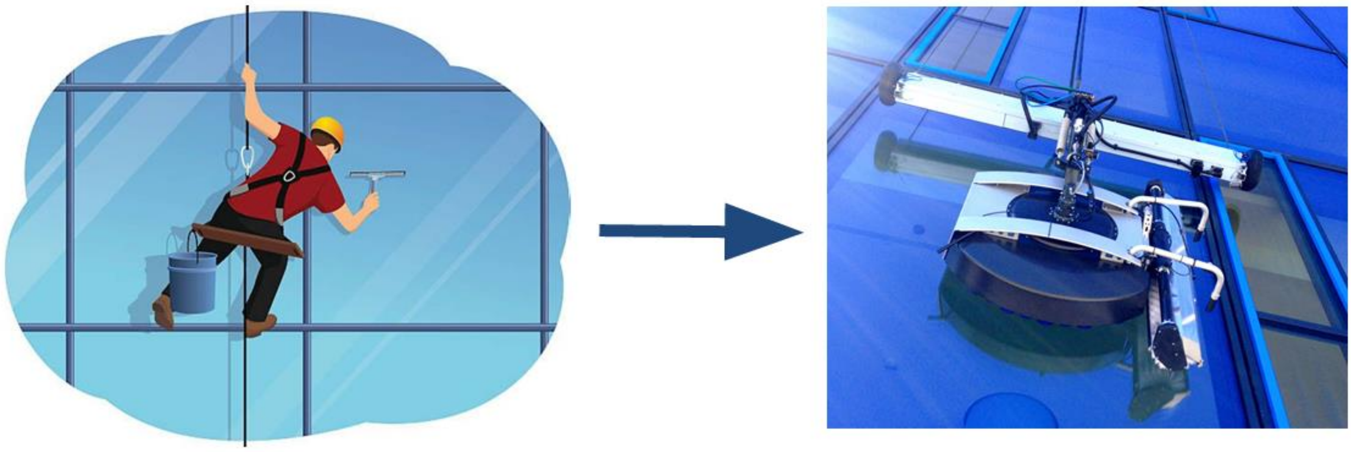

Fig: 2.1

In the realm of modern living, the integration of automation and robotics has steadily transformed mundane household tasks into seamless, efficient processes. Among these tasks, window cleaning, a perennial chore for both residential and commercial spaces, stands as a candidate ripe for innovation. Traditional methods, often labour-intensive and time-consuming, have inspired a shift toward intelligent solutions that not only enhance efficiency but also address safety concerns and environmental considerations.

The introduction of the Smart Window Cleaning Robot marks a significant leap forward in the quest for practical and intelligent automation. Windows, integral components of architectural design, play a crucial role in shaping the aesthetics and functionality of buildings. However, maintaining their clarity and cleanliness poses challenges, particularly for tall or hard-to-reach windows. The Smart Window Cleaning Robot emerges as a solution poised to revolutionize the conventional approaches to window cleaning.

This project recognizes the limitations of traditional methods, where manual labour may be hazardous, time-consuming, and often neglects areas like sliding window channels. By conceptualizing and implementing a robotic solution, our endeavour is to streamline and enhance the window cleaning process comprehensively.

The Smart Window Cleaning Robot is envisioned to climb windows with ease, utilizing both wet and dry functionalities for effective cleaning. Beyond its primary function, the robot incorporates features for efficient power management and addresses the often-overlooked cleaning needs of sliding window channels. With user-friendly controls accessible through a mobile application, this innovation aims to make window cleaning a convenient, safe, and efficient experience.

This introduction sets the stage for a comprehensive exploration of the Smart Window Cleaning Robot project. As we delve into its design, functionality, and the myriad benefits it brings to both residential and commercial settings, it becomes clear that this endeavour aligns with the broader narrative of leveraging technology to enhance daily living experiences. The Smart Window Cleaning Robot is not just a technological advancement; it represents a paradigm shift in reimagining and simplifying the maintenance of a fundamental aspect of our living spaces.

1.2 Problem Statement:

Windows in residential and commercial buildings require regular cleaning to maintain aesthetics and visibility. Traditional window cleaning methods often involve manual labour and can be time-consuming, especially for tall or hard-to-reach windows. Window cleaning at elevated heights involves inherent risks, such as falls, and injuries.

Chapter: 2

Construction & Working of Model

2.1 Introduction:

In this chapter, we delve into the groundbreaking realm of the smart window cleaning robot, poised to redefine traditional approaches to window cleaning. This technological marvel embodies advanced features designed to not only enhance the efficiency of window cleaning tasks but also to elevate safety standards and contribute to environmental sustainability.

2.2 Design and Construction:

A meticulous construction process lies at the heart of the smart window cleaning robot. Its design intricacies incorporate key components to ensure optimal functionality. The climbing mechanism, driven by a high-power BLDC motor suction system, endows the robot with the ability to securely adhere to vertical surfaces. Complemented by wheeled locomotion, stability is ensured, and the inclusion of a microfiber cloth guarantees a thorough and gentle cleaning process without compromising the integrity of the glass surface.

2.3 Working Mechanism:

At the core of the robot's operation is a sophisticated working algorithm. The process unfolds with the establishment of a Wi-Fi/Blink connection, activating the suction motor and initiating wheel rotation for movement. Scaling vertical surfaces is achieved through the high rpm BLDC motor by creating thrust against the glass, accompanied by the rotational movement of the wiper arm, ensuring a meticulous cleaning of the glass surface. An intelligent obstacle detection system dynamically alters the robot's direction, enabling seamless navigation around obstacles.

2.4 Testing and Validation:

The efficiency and safety of the smart window cleaning robot undergo rigorous validation through a comprehensive testing process. This entails a meticulous evaluation of its climbing capabilities, the effectiveness of the cleaning mechanism, and the responsiveness of obstacle avoidance algorithms. Rigorous testing ensures compliance with stringent safety standards and guarantees consistent, reliable performance.

2.5 Benefits and Utilities:

a. **Enhanced Efficiency:** The smart window cleaning robot stands as a testament to heightened efficiency in window cleaning. By significantly reducing the time and labour traditionally associated with this task, it emerges as a beacon of efficiency in the realm of automated cleaning technologies.

b. **Cost Savings:** Automation heralds a new era of cost savings for residential and commercial users alike. By obviating the need for professional window cleaning services, substantial economic benefits are realized, marking a paradigm shift in cost-effective maintenance.

c. **Improved Safety:** The robot's ascent on the walls translates to improved safety, eliminating the perilous need for human scaling during window cleaning. This attribute becomes particularly invaluable in commercial settings with towering buildings, ensuring the well-being of maintenance personnel.

d. **Environmental Benefits:** Beyond its immediate applications, the smart window cleaning robot contributes to a cleaner and more sustainable environment. By reducing dependence on chemical cleaning agents, it aligns with the broader ethos of environmental stewardship.

e. **Convenience:** User convenience takes centre stage as the robot allows for scheduled cleaning sessions and remote control through smartphone apps or other devices. This seamless integration of technology into daily life underscores the user-friendly nature of this innovative solution.

2.6 Technological Features:

a. **Climbing Mechanism:** A sophisticated climbing mechanism is the backbone of the robot's vertical mobility. By employing a high-power BLDC motor to create thrust against the glass, it achieves a secure grip on vertical surfaces, ensuring stability during the cleaning process.

b. **Locomotion:** Wheeled locomotion further enhances the robot's movement capabilities, providing stability and effective navigation. This technological feature is fundamental to achieving seamless and efficient cleaning operations.

c. **Cleaning Functions:** The robot is equipped with dual cleaning capabilities—wet and dry. This versatility ensures adaptability to various cleaning scenarios, adding a layer of sophistication to its operational repertoire.

d. **Cleaning Material:** At the forefront of the cleaning process is the utilization of a microfiber cloth. This choice of material not only ensures effective cleaning but also upholds a gentle approach to preserving the integrity of glass surfaces.

e. **Costing:** In line with accessibility, the project adopts a low-cost approach. This deliberate choice makes the smart window cleaning robot economically viable, ensuring its reach to a diverse spectrum of users.

This chapter provides an immersive exploration into the intricate design, construction, and operational facets of the smart window cleaning robot. Each feature and utility are scrutinized, providing a comprehensive understanding of the technological prowess that underpins this innovative solution.

Chapter: 3

Work Done

This chapter provides the experimental work carried out. The entire operation of each equipment and components are discussed in detail.

3.1 Work Done:

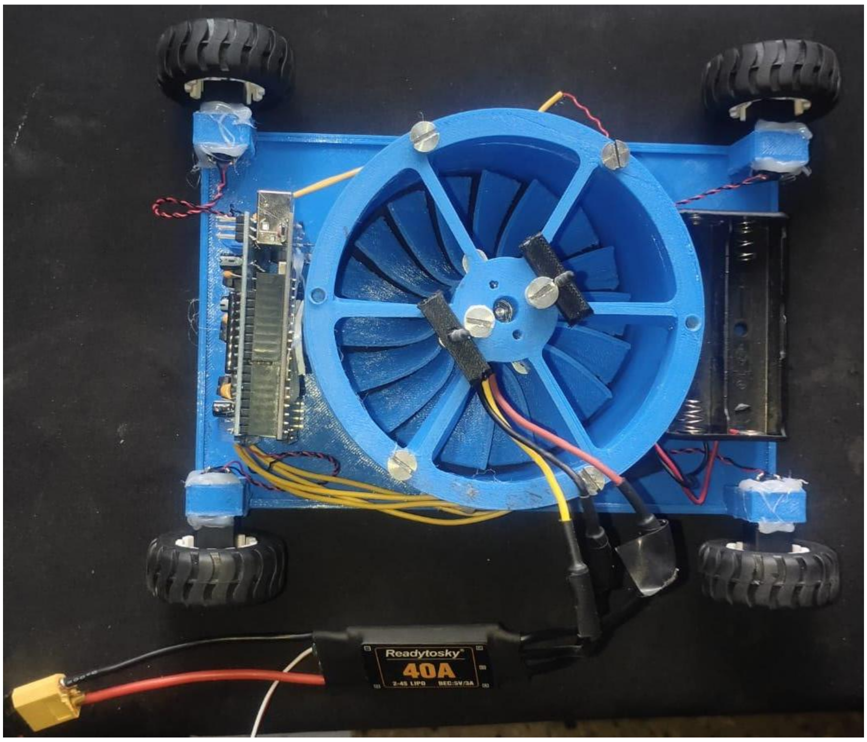

Fig: 3.1.1 Previous Model 1

During the completion of phase 1 of this project, we designed and implemented two different models for working first one is shown in fig.3.1

In this model we have used BLDC motor of 2200Kv which rotate with the speed of 24000 RPM for creating a suction force, which helps the bot to climb and keep adhesion over the glass surface. This was achieved by using a EDF (Electric Duct Fan) unit which is very popular in aerodynamics for the suction purpose. The EDC unit is designed and 3D printed using PLA filament material.

The EDF was designed with a duct, motor mount and a propeller. Propeller was of 22 blades allowing the fast air to flow through minimum space thus creating a sufficient thrust for keeping adhesion over the glass surface. BLDC motor was mounted over a motor mount. Motor was powered with 11.1V Li-Po battery with a 40A rated ESC. For the movement of bot, we used N20 motor of 250rpm and an Arduino UNO controller with motor driver shield for programming the movement of bot. However, this model was not feasible over a smooth surface so we designed another model with new mechanism for adhesion. The new model looks like fig. 3.2

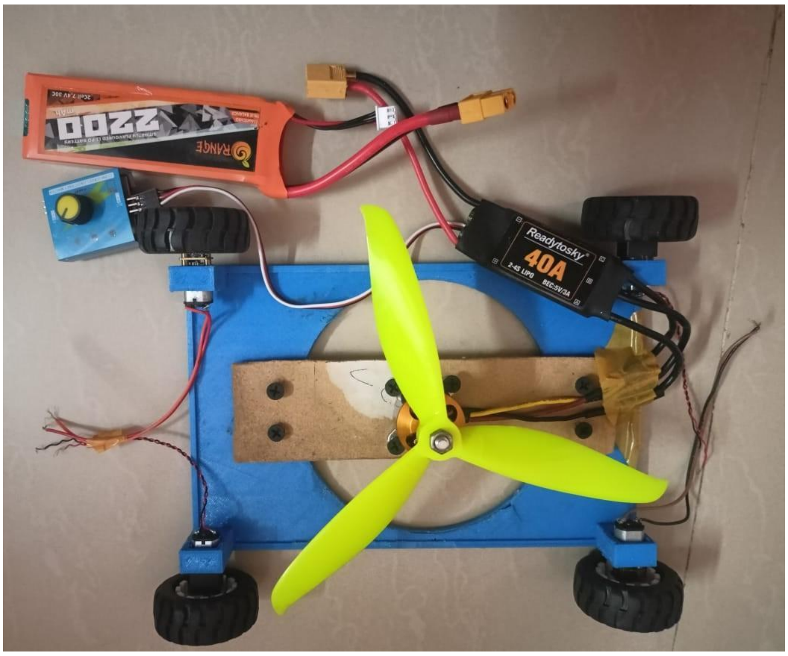

Fig: 3.1.2 Previoust Model 2

In this model we use BLDC motor with 3 blade propeller to create a thrust against the glass due to which the thrust created by the motor pushes the window cleaning bot towards the glass surface. In this model the motor is powered with 7.4-volt LiPo battery with a 40 Amp ready to sky the ESC. The ESC helps the motor to consume high current for creating a sufficient amount of thrust. BLDC motor is fitted over a bot chassis. The chassis is design in such a way that it keeps the gap of 4 mm between the surface and the bot. In previous bot we used N20 micro gear motor of 250 RPM that is replaced by 20 RPM high torque and N20 motor, which creates height torque and give sufficient force for movement of bot over the vertical glass surface. This N20 motor are also powered with 7.4V LiPo battery. Testing and validation over the different glass surfaces are still under process. This model is very efficient to climb over glass, It is even light weighted boat.

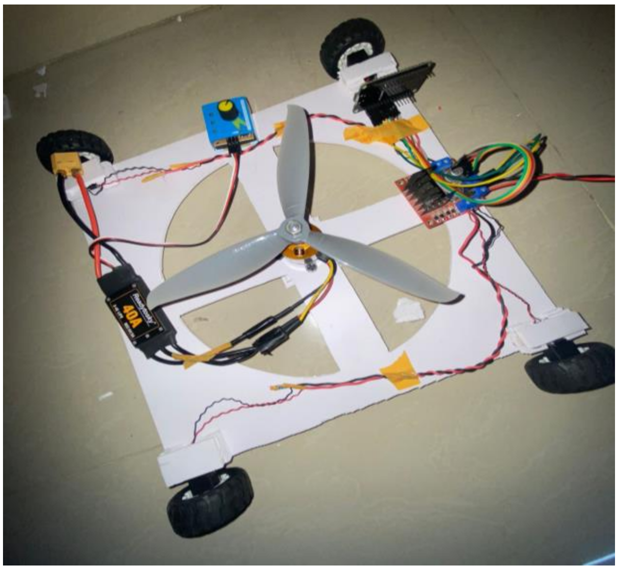

Fig:3.1.3 Present Model

3.2 Software or Component:

1. **2200kv BLDC Motor**

Fig: 3.2.1 BLDC Motor

Sr. No.	Features	Parameters
1)	Model	A2212
2)	KV	2200
3)	MAX Efficiency Current	4-10A >75% v
4)	Current Capacity	12A / 60s
5)	No Load Current	10 V: 0.5A
6)	Apply to the LiPo	2 - 3S
7)	Shaft Diameter	3.17mm
8)	Weight	60gm

Table: 3.2.1

2. **ESC 40A (Electronic Speed Controller)**

Fig: 3.2.2 ESC

Sr. No.	Features	Parameters
1)	Model	ReadytoSky 40A
2)	Burst Current (A)	60
3)	Constant Current (A)	40
4)	BEC	Yes (5v/3A)
5)	Suitable LiPo Batteries	2-4S
6)	Dimensions(mm)	7x3
7)	Weight	34gm

Table:3.2.2

3. Lithium Polymer Battery-2S

Fig: 3.2.3 LiPo Battery

Sr. No.	Features	Parameters
1)	Model	ORANGE 2200/2S-30C
2)	Voltage	7.4
3)	Max Continuous Discharge (A)	30C(66A)
4)	Dimensions(mm)	16x31x106
5)	Discharge Plug	XT-60
6)	Weight	115gm

Table: 3.2.3

4. N20 micro gear motor

Fig: 3.2.4 N20 micro gear motor

Sr. No.	Features	Parameters
1)	Model	N20
2)	Rated Operating Voltage	6
3)	No Load current	25-45
4)	Operating Voltage(V)	3-9
5)	Rated Speed (RPM)	25
6)	Rated Torque(kg-cm)	1.5
7)	Stall Current	1

Table: 3.2.4

5. Wheels

Fig: 3.2.5 Wheels

Sr. No.	Features	Parameters
1)	Body Material	Plastic
2)	Grip Material	Rubber
3)	Central Shift hole diameter (mm)	3
4)	Shipping weight (Kg)	0.02
5)	Dimensions (cm)	15x10x6

Table: 3.2.5

6. Servo tester

Fig: 3.2.6 Servo tester

Sr. No.	Features	Parameters
1)	Output	15mA
2)	Voltage	4.8-6
3)	Output signal	1.5ms±0.5ms
4)	Shipping Weight(gm)	8
5)	Dimensions(cm)	35x30x15

Table: 3.2.6

Chapter: 4

Results, Discussions & Conclusions

4.1 Results:

The window-cleaning robotic system outlined in this document has been effectively created. To substantiate the efficiency of the robot, comprehensive experiments have been carried out in both controlled laboratory settings and real-world field scenarios.

The results of the analysis of the needs of the window-cleaning robot system developed include:

a. Robots can work with manoeuvring in all directions with the conditions of various shapes of the windows.
b. The robot is currently capable of walking on a vertical smooth surface and an inclined surface that is angled up to 45 degrees.
c. Robots that are built have a cleaning mechanism in the form of a microfibre cleaning cloth.
d. The BLDC motor is used for creating adhesion over the surface using suction.
e. Wireless control is needed to reach in all directions.

A miniature window-cleaning robot equipped with four N20 gear motors having an RPM of 20 & wheels has been designed and tested. The Electronic Speed Controller (ESC) is used which regulates the speed and direction of the BLDC motor. One Brushless DC motor having an RPM of 24,000 is used to create thrust to drive the robot's motion, which is controlled by a ESP32 controller.

The robot structure which includes the chassis, motor mount & propeller or fan is made of Polylactic Acid (PLA) filament. An on-board LiPo 2S-battery and a BLDC motor and four N20 motors are used which makes it weigh about 1.5 kgs. The Arduino Uno serves as the main controller, coordinating the functions of various components. The servo tester is a highly useful tool to manually control and test servo motor, ESC and also to determine motor direction. The device also can be used as a signal generator for electric speed controller (ESC), for testing the motor system without using a transmitter and receiver.

Based on the results of tests that have been done, the window cleaning robot specifications developed have the following product specification values:

• Weight robot: 1.5 kgs approx.

• Size length, width, height robot: 20cm x 13cm

• Robot battery capacity: 2200mAh LiPo-2S battery

• The ability of the robot working life time: ± 45 minutes

• Total current consumption of the robot: Motor 33A max

• The current consumption control system: 2A

• Robot Working Voltage: Motor 7.4 Volt

4.2 Discussions:

Based on the results of the design and testing of the window cleaning robot system developed, it can be deduced as follows:

a. **Efficiency Boost:** The smart window-cleaning robot makes window cleaning faster and easier, saving time and effort.
b. **Cost-effective:** Automating window cleaning cuts costs for homes and businesses, eliminating the need for professional services.
c. **Safety First:** The robot improves safety by handling tall windows, eliminating the risk of humans working at heights.
d. **Green Cleaning:** Using the robot reduces the need for harmful cleaning chemicals, promoting a cleaner and eco-friendly environment.
e. **Convenient Control:** Users can conveniently schedule and control the robot from anywhere using smartphone apps or other devices.
f. **Increased Productivity:** For businesses, the robot ensures uninterrupted operations during window cleaning, enhancing overall productivity.
g. **Aesthetic Appeal:** Clean windows enhance the look of buildings and homes, potentially increasing property values.
h. **Technological Advancement:** The robot represents progress in robotics and automation technology.
i. **Customer Satisfaction:** Satisfied users enjoy cleaner spaces, leading to increased customer satisfaction and loyalty.

Work is still being done to improve the robot’s climbing capability on smooth surfaces of all orientations. Further areas of testing will determine performance qualities including maximum walking speed of the robot at various window angles, maximum load-carrying capacity, and total current consumption as a function of time. In the future, a touch, light, or other suitable sensor will be added to the front of the robot to detect the presence of a perpendicular window.

In future research, the adhesion mechanism will be optimized to reduce gripping time and to reduce noise, which makes the robot adaptive for cleaning tasks. The gripping mechanism will be developed which will enable it to climb the windows with multi levels. This will enable robots to overcome obstacles such as window grills. Furthermore, the sensor system will be upgraded to enhance the autonomous control ability of the robot.

4.3 Conclusions:

The design and fabrication of the window-cleaning robot has been successfully achieved as shown in figure [ ]. The components used are easily available and programming required is simple. This robot illustrates the feasibility of the robot solution from the aspects of safety, cleaning efficiency, and economic benefits.

a. First, the application environments of the window-cleaning robot are classified into domestic use and high-rise building use. According to different application environments, the performance characteristics of the robots are analysed.
b. Second, the locomotion and mechanism of the robot is discussed. Its advantages and disadvantages, as well as the applications, are discussed.
c. Next, the cleaning mechanism is dictated.
d. Finally, the sensor and controller units are discussed.

The designed robot has a stable structure and has shown a capability of climbing on vertical surfaces with a stable climbing gait. Light weight batteries and light weight fibre made structure is used to reduce the weight for better climbing performance. The cleaning mechanism should not only have sufficient degrees of freedom but also ensure large enough contact force. The cleaning speed is closely related to the surface complexity, size, and locomotion mode of the robot. Various feedback control schemes have been proposed to adjust the robot state by regulating the locomotion, adhesion, and cleaning mechanisms.

Different path planning algorithms can be implemented and tested. Finally, this robot should be further developed by incorporating environmental awareness using different sensors and autonomous climbing capability to perform tasks at difficult to reach places where human access is difficult. Both internal and external sensors can be employed to detect the working states of the robot and environment.

Chapter: 5

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