IES International Journal of Multidisciplinary Engineering Research

# Windomax: Advanced Wall Climbing and Window Glass Cleaning Robot

Denson P D[1], Amy Antony[2], Mohammed Razal K[3], Krishnadarshan M S[4], Nivya K Venu[5]

[1,2,3,4] *Student, Department of Electrical and Electronics Engineering, IES College of Engineering, Chittilappilly, Kerala, India*

[5] *Assistant Professor, Department of Electrical and Electronics Engineering, IES College of Engineering, Chittilappilly, Kerala, India*

*Email_id: densondaveed2005@gmail.com , amyantony961@gmail.com, mohammedrazalkechery@gmail.com, darshankrishna027@gmail.com, nivyakvenu@iesce.info*

**Abstract**

This project presents the design and development of a lightweight wall-climbing cleaning robot that uses a propeller-based adhesion system to adhere to vertical surfaces and perform cleaning tasks autonomously. By generating thrust perpendicular to the wall through a high-speed BLDC motor and propeller, the robot produces sufficient normal force to create frictional adhesion capable of counteracting gravity. The system integrates locomotion, cleaning, and control mechanisms to maintain balance, adhesion, and cleaning efficiency throughout operation. The developed prototype demonstrates the feasibility of employing aerodynamic adhesion for wall-cleaning applications, achieving stable control and efficient power utilization. Overall, this work contributes to the advancement of service robotics, particularly in automated cleaning and inspection systems for vertical structures.

*Keywords*: Wall-climbing, Cleaning, Robot, Propeller, Adhesion, Aerodynamic, Autonomy, Locomotion, Control, Robotics, Wallclimbing, Efficiency, Stability, ESP32, BLDC Motor, Easy control

**DOI: https://doi.org/10.5281/zenodo.18884160**

## 1. Introduction

The growing demand for automated cleaning in hazardous and hard-to-reach areas has led to the development of wall-climbing robots for cleaning vertical surfaces such as glass façades, high-rise windows, industrial tanks, and solar panels, where manual cleaning is risky and inefficient. Creating a reliable wall-climbing robot involves major challenges, especially generating enough adhesion to counter gravity. While methods like vacuum suction, magnetic adhesion, and electrostatic attraction exist, propeller-based aerodynamic adhesion is preferred for its lightweight design, versatility, and ability to work on both magnetic and non-magnetic surfaces by producing thrust perpendicular to the wall to increase normal force. The robot must also maintain stable mobility despite surface irregularities or changes in orientation, requiring precise control of propeller speed, motor torque, and wheel traction with support from sensors such as gyroscopes, accelerometers, and proximity detectors. Its cleaning mechanism must be effective yet lightweight, using tools like microfiber rollers or bristle brushes while keeping power consumption low. To ensure energy efficiency, the system uses lightweight BLDC motors, Li-Po batteries, and optimized propellers, while microcontrollers such as ESP32 or STM32 manage propulsion, locomotion, and sensor feedback. With potential for future AI-based path planning and computer vision, the project ultimately aims to develop a propeller- assisted wall-climbing cleaning robot that uses aerodynamic thrust to adhere to vertical surfaces and deliver stable, efficient cleaning for domestic, commercial, and industrial applications.

## 2. Objectives

The goal of this project is to design and develop a lightweight wall-climbing cleaning robot capable of adhering to and moving on vertical surfaces using propeller-generated aerodynamic thrust while performing effective cleaning tasks. The system is intended to provide a safe, efficient, and cost-effective alternative to manual cleaning of tall buildings, glass façades, industrial tanks, and other hard-to-reach surfaces. To ensure practicality, energy efficiency, and suitability for real-world applications, the objectives are structured into primary objectives that define the core design requirements and secondary objectives that further enhance the system's performance, reliability, and usability.

## 3. Problem Statement

The problem addressed in this project is the challenge of safely and efficiently cleaning vertical structures such as tall buildings, glass façades, and industrial surfaces that are difficult, dangerous, and costly to clean manually. Traditional cleaning methods rely heavily on human labor, which poses significant safety risks and often leads to inconsistent results. There is a need for an autonomous system capable of adhering to and maneuvering on vertical surfaces while performing effective cleaning operations. The project aims to solve this problem by developing a lightweight wall-climbing robot that uses propeller generated aerodynamic thrust to achieve stable adhesion, maintain balance, and deliver efficient cleaning performance, demonstrating a viable alternative for automated vertical-surface maintenance.

## 4. Methodology

### 4.1 Problem Analysis and Data Collection

The main problem in this project is designing a lightweight robot that can stick to vertical surfaces and clean without slipping. Since traditional adhesion methods are heavy or limited, a propeller-based system is used to create enough thrust for wall attachment. Data was collected on motor thrust, friction needed for adhesion, robot weight, balance, power use, and cleaning performance. Surface friction and sensor feedback were also measured to ensure stable movement and efficient cleaning. This information helped develop a stable, lightweight, and energy-efficient wall-climbing cleaning robot.

### 4.2 Design of the system

The system is designed as a lightweight wall-climbing robot that uses a propeller-based adhesion method to stick to vertical surfaces. A high-speed BLDC motor and propeller create thrust toward the wall, giving the robot enough normal force to stay attached through friction. The robot includes a locomotion system for movement, a cleaning mechanism for surface wiping, and a control system to manage balance, adhesion, and power use. All components work together to allow the robot to climb walls smoothly, stay stable, and clean efficiently while using energy effectively.

**4.3 Block diagram**

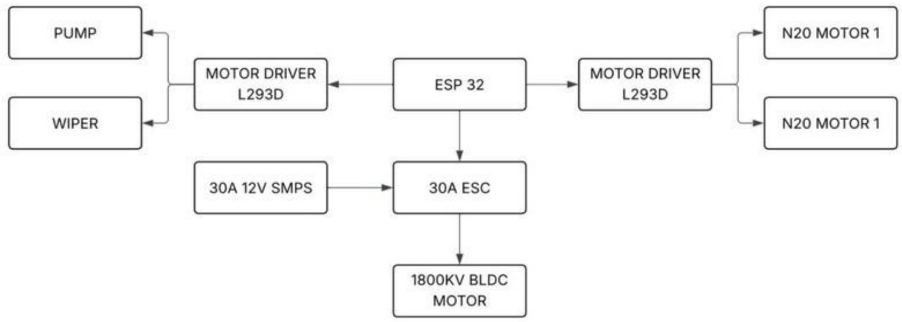


Figure 1: Block diagram of WINDOMAX: Advanced wall climbing & window glass cleaning robot

**4.4 Circuit diagram**

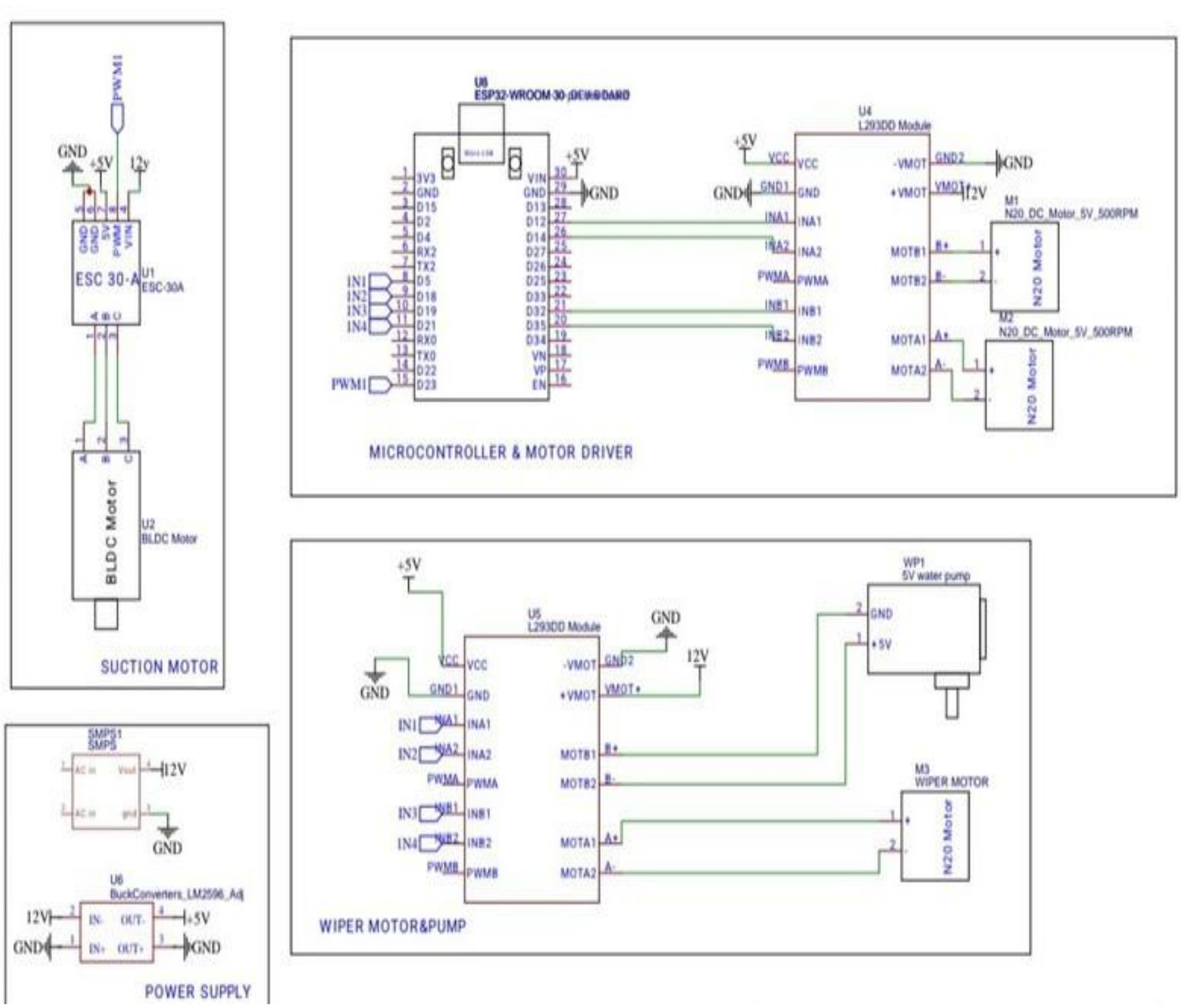


Figure 2: Circuit diagram of WINDOMAX : Advanced wall climbing & window glass cleaning robot

### 4.5 Simulation diagram

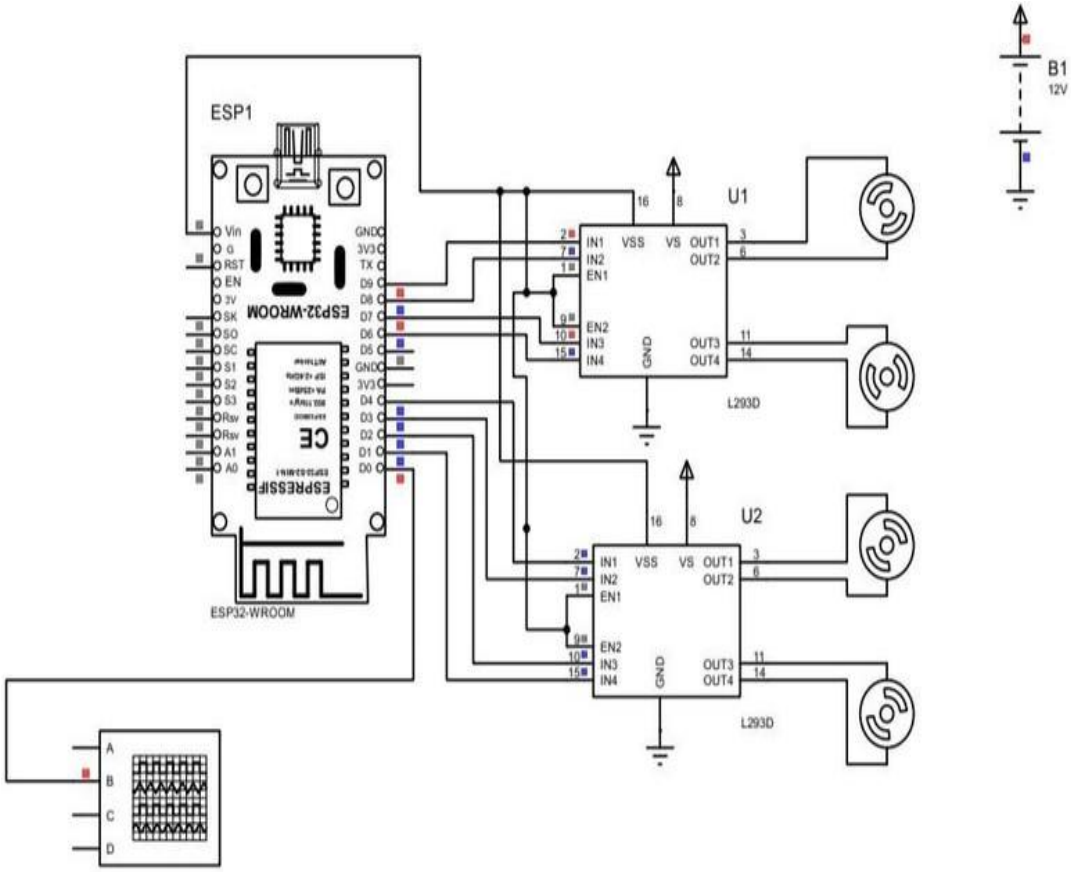


Figure 3: Simulation diagram of WINDOMAX: Advanced wall climbing & window glass cleaning robot

### 4.6 Hardware Implementation

The hardware implementation of the lightweight wall-climbing cleaning robot integrates propulsion, adhesion, locomotion, and cleaning components into a compact system. A high-speed BLDC motor with a specially designed propeller generates the thrust needed for stable adhesion on vertical surfaces. The lightweight, rigid chassis supports motor-driven wheels that provide traction under the propeller-produced normal force. The cleaning unit, equipped with a rotating brush or wiper, is powered by a separate motor for consistent performance. An onboard microcontroller manages sensor inputs, motor drivers, and power distribution to maintain balance, regulate adhesion, and control movement. This integrated hardware design enables stable climbing and efficient cleaning.

### 4.7 Experimental Setup and Testing

The testing of the wall-climbing cleaning robot validates the performance of all subsystems individually and together. It includes thrust verification of the adhesion module, locomotion and stability checks under movement and disturbances, cleaning performance evaluation for brush coverage and efficiency, and control system testing for sensor accuracy and motion routines. Subsystem designs or programming are iterated based on results to optimize performance. Final deliverables include the assembled robot, CAD drawings with BOM, control software

(ESP32/Arduino code), and documented test results.

**4.8 Performance Evaluation**

The performance evaluation of the wall-climbing cleaning robot tests each subsystem and the complete system. The adhesion module is checked by measuring thrust to ensure surface contact, while locomotion and stability are assessed by moving the robot and observing traction, balance, and response to disturbances. Cleaning performance is evaluated through brush coverage and efficiency, with speed or position adjusted if needed. The control system is tested for sensor accuracy and proper execution of motion and cleaning routines. Based on results, hardware or programming is modified to optimize performance. Final deliverables include the assembled robot, CAD drawings with BOM, control software (ESP32/Arduino code), and documented test results.

## 5. Conclusion

The design and development of the lightweight wall-climbing cleaning robot with a propeller-based adhesion system successfully demonstrate a novel approach to autonomous vertical-surface cleaning. By employing a high-speed BLDC motor and propeller to generate thrust perpendicular to the wall, the robot achieves sufficient normal force for frictional adhesion, effectively counteracting gravitational forces. The integration of locomotion, cleaning, and control systems enables the robot to maintain stability, consistent adhesion, and efficient cleaning performance during operation. The developed prototype confirms the practicality and effectiveness of aerodynamic adhesion for wall-climbing applications, showing stable control and optimized power usage. Further more, the project highlights the potential of such systems for service robotics, particularly in scenarios requiring automated cleaning or inspection of vertical and hard-to-reach structures. This work not only validates the feasibility of propeller-based adhesion mechanisms but also lays the groundwork for future advancements in autonomous maintenance robots, offering a safe, efficient, and scalable solution for a variety of industrial and commercial applications

## 6. References

[1]. Q. Zhang, R. Gao, M. Li, Y. Xu, W. Zhu, “Design and Stability Analysis of a Wall-Climbing Robot Using Propulsive Force of Propeller,” Symmetry, vol. 13(1), 2021. https://doi.org/10.3390/sym13010037

[2]. K. Mahmood, S. H. Bakhy, M. A. Tawfik, “Propeller-type Wall-Climbing Robots: A Review,” IOP Conference Series: Materials Science and Engineering, vol. 1094,2021.https://doi.org/10.1088/1757-899X/1094/1/012106

[3]. H. B. Santos, M. A. S. Teixeira, N. Dalmedico, A. S. de Oliveira,F. Neves-Jr., J. E. Ramos, and L. V. R. de Arruda, ‘Model predictive torque control for velocity tracking of a four-wheeled climbing robot,’’ Sensors,vol. 20, no. 24, p. 7059, Dec. 2020,https://doi.org/10.3390/S20247059

[4]. R. G. Yue, S. P. Wang, “A Survey of Technologies for Climbing Robots,” Applied Mechanics and Materials, vols.236-237, pp.556-562, 2012. https://doi.org/10.4028/www.scientific.net/AMM.236-237.556

[5]. A. Papadimitriou, G. Andrikopoulos, and G. Nikolakopoulos, ‘‘On the optimal adhesion control of a vortex climbing robot,’’ J. Intell. Robotic Syst., vol. 102, no. 3, p. 57, Jul. 2021, https://doi.org/10.1007/S10846-021-01420-3

[6]. A. Srisuchinnawong, B. Wang, D. Shao, P. Ngamkajornwiwat, Z. Dai, A. Ji, and P. Manoonpong, ‘‘Modular neural control for gait adaptation and obstacle avoidance of a tailless gecko robot,’’ J. Intell. Robotic Syst.,vol.101,no.2,p.27,Feb2021,https://doi.org/10.1007/S10846-020-01285-y

[7]. Q. Hu, E. Dong, and D. Sun, ‘‘Soft gripper design based on the integration of flat dry adhesive, soft actuator, and microspine,’’ IEEE Trans. Robot., vol. 37, no.4,pp.1065–1080,Aug.2021,https://doi.org/10.1109/TRO.2020.3043981

[8]. R. E. Abdulkader, P. Veerajagadheswar, N. H. Lin, S. Kumaran, S. R. Vishaal, and R. E. Mohan, ‘‘Sparrow: A magnetic climbing robot for autonomous thickness measurement in ship hull maintenance,’’ J. Mar. Sci. Eng.,vol.8,no.6,p.469,Jun.2020,https://doi.org/10.3390/JMSE8060469