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Design & Fabrication of Vertical Surface Cleaner

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Abstract: The Wall Climbing Robot designed in this study to combines the innovative propulsion system of propellers with the traditional locomotion method of wheels to achieve versatile and efficient mobility on both vertical and horizontal surfaces. By integrating propellers and wheels, the robot can seamlessly transition between climbing walls and moving along flat surfaces. The hybrid design not only enhances the robot's mobility but also optimizes its energy efficiency, making it suitable for prolonged missions in various environments. This research explores the synergistic integration of propellers and wheels, showcasing the robot's adaptability in real- world applications such as surveillance, inspection, and maintenance tasks in both indoor and outdoor scenarios. The developed Wall Climbing Robot presents a significant advancement in robotic mobility, offering a promising solution for complex tasks in diverse settings

I. INTRODUCTION

The field of robotics continues to push boundaries, embracing new challenges and technologies to develop versatile and adaptable machines capable of overcoming various obstacles. Wall climbing robots, in particular, have garnered significant attention due to their potential applications in inspection, maintenance, and surveillance tasks within complex environments. This study introduces a novel approach to designing a wall climbing robot, leveraging a simplistic wheeled chassis and an innovative propeller-based thrust mechanism to enable the robot to ascend vertical surfaces.

Traditional wall-climbing robots have often relied on complex mechanisms and intricate designs, which can impede their mobility and increase their energy consumption. In contrast, the proposed approach aims to simplify the robot's structure while maintaining its effectiveness in climbing walls. The integration of a wheeled chassis provides stability and enhances maneuverability, allowing the robot to traverse diverse terrains effectively. The introduction of a propeller-based thrust mechanism offers an efficient solution for generating the necessary force to facilitate climbing.

In the realm of advanced cleaning solutions, the Vertical Surface Cleaner stands as a cutting-edge innovation, designed to address the challenges of maintaining vertical surfaces such as walls, windows, and facades. This project aims to revolutionize the cleaning process by integrating a high-resolution camera, enhancing both functionality and efficiency.

II. LITERATURE SURVEY

The paper discusses the design and fabrication of a quadruped climbing robot capable of ascending vertical surfaces. The robot utilizes a suction mechanism for wall adhesion and is controlled using Basic Stamp[1]. Climbing robots are being developed to address a wide spectrum of applications, spanning from cleaning to inspecting challenging structures[2]. The paper outlines the steps for an optimization experiment using the Taguchi methodology to enhance vacuum pressure, a pivotal factor in augmenting suction force[3].

In this paper introduces an innovative quadruped mechanism, seamlessly integrating a four-bar and slider-crank mechanism with a vacuum adhesion module[4]. This paper introduces a wall-climbing robot that employs a semi-static movement approach[5]. Following study is dedicated to the development of a wall climbing robot with a focus on non-destructive inspections of various building structures[6]. The given project primarily addresses performance evaluation challenges in industrial applications, particularly within the piping sector. The core focus is the integration of robotics and magnetic technologies, utilizing permanent magnetic tracks[7] Climbing robots have found extensive utility in inspecting smooth walls; however, devising an effective adhesion method for inspecting cliff surfaces and dusty, high-altitude terrains with minimal vibration[8]

In this paper uses sensing approach relies on tactile and ultrasonic sensing, enabling it to adapt to uncertain environments. The robot's intelligence is further enhanced through a set of reflexive rules [12]. Conventional wall-climbing robots predominantly rely on rigid actuators, such as electric motors, leaving a gap for the realization of soft wall-climbing robots driven by muscle-like actuators [13] Concrete structures, such as bridges or viaducts, hold significant importance in global road infrastructure, though they are susceptible to external factors that lead to structural deterioration over time [14].

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The goal of the robot is to do inspections in industrial environments where climbing walls is essential for efficient examination The report will most likely include details about the robot's design, capabilities, wall climbing methods, visual inspection, GPR technology integration[15] It discusses their design, mechanisms, applications, and difficulties. Based on design variants, movement strategies, sensors, and application domains, the article categorizes and assesses existing robots [16]. The study is on a small flying robot designed to climb walls. The paper discusses the mechanism's design and operation, emphasizing its aerial capabilities and climbing functionality [17]

III. OBJECTIVE

1) Design and fabricate a robot that can climb and clean the vertical surface
2) Build the robot in lowest cost
3) Lighter robot than robot available in the market
4) It also used as an inspection purpose
5) Construct a multifunctional robot clean glass and solar panel also
6) Build a specialized Cleaning mechanism that uses less force to oppose thrust force, since thrust force is mostly what keeps the robot attached to the wall

IV. METHODOLOGY

A. Methodology and Planning

Following are schematics showing the methodology and planning used to approach the design and manufacture of the final product

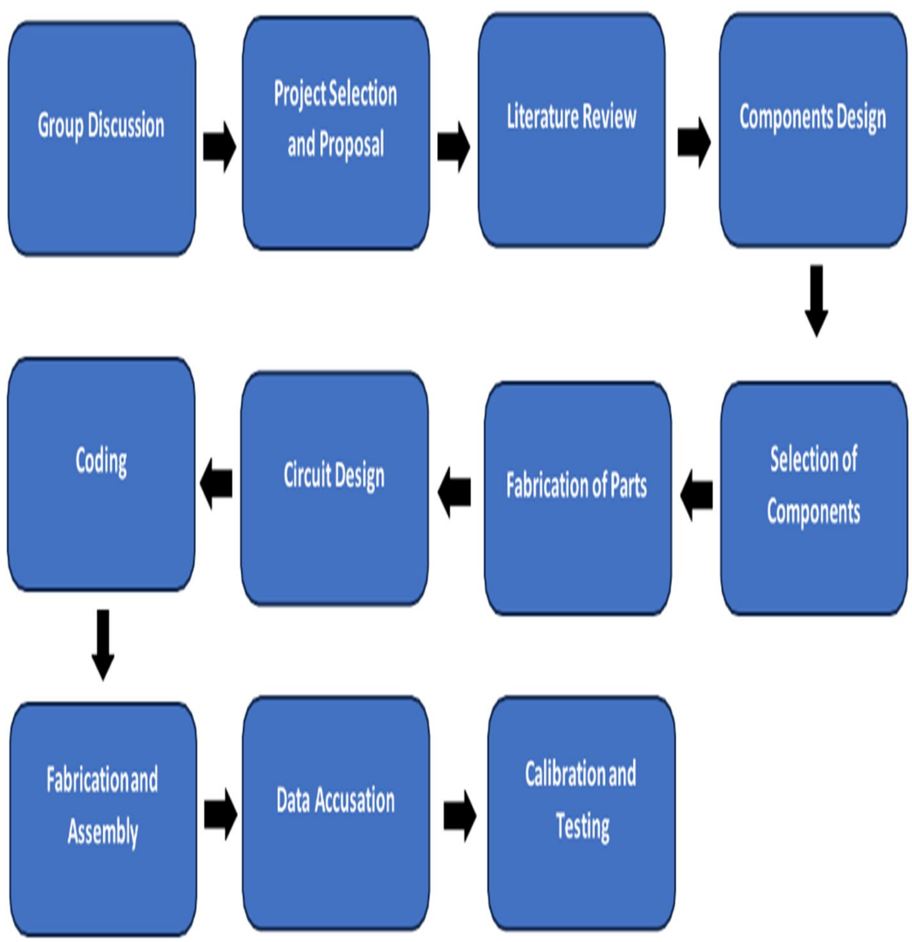

Fig.1. Flowchart of Methodology and Planning

V. DETAILS OF COMPONENT

list of components and respective mass

Tabel 1. Overall Mass of the robot

No	Component	Quantity	Total Mass(gm)
1	Chassis	1	138.0
2	Wheel	4	76.6
3	N20 Gear motor	4	38.8
4	Breadboard	1	66.6
5	BLDC motor	1	50.0
6	Propeller	1	12.0
7	Motor driver	1	26.0
8	ESP32	1	6.0
9	Battery	1	177.5
10	ESC	1	28.0
11	WIRES	1	23.0
12	ESP32 CAM	1	10.0
Overall Approximate Mass			**652.5 gm**

A. Chassis

As aluminum sheet is lightweight and has a good bending resistance, it has been employed as chassis material. A panel 4 mm thick is selected. It is composed of two thinly coated aluminum sheets and aluminum substance. Aluminum is strong and long-lasting due to its inherent resistance to corrosion. Aluminum has a high heat conductivity, which facilitates effective heat dissipation. An aluminum chassis can support overall durability, structural integrity, and heat dissipation. Aluminum chassis is a common choice for many industries looking for high-performance materials for their products since it offers a blend of strength, durability, and lightweight qualities. Aluminum chassis can provide a substantial contribution to overall weight reduction, which will enhance performance and fuel efficiency. The weight of the chassis is roughly 134 grams. It measures 249 mm in length, 190 mm in breadth, and 4 mm in height.

Chassis Design

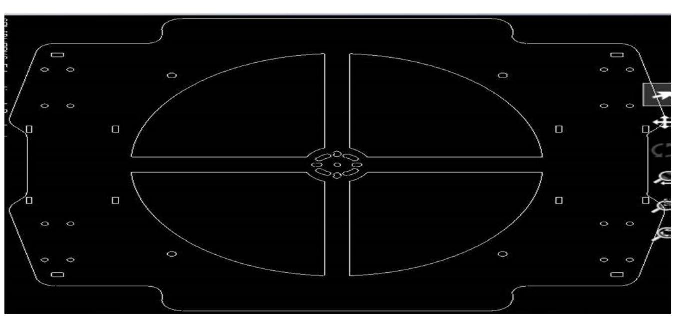

Fig.2. Design of Chassis

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B. BLDC Motor

A type of electric motor that runs on a direct current voltage source and is electronically commutated is known as a brushless DC electric motor (BLDC). It continuously modifies the DC current flowing through its windings, which modifies the magnetic field as well. In this manner, as long as the motor is powered, the rotor can continue to rotate. For this project, a 2200KV brushless motor, A2212/6T, was utilized. Here, the structural characteristics of the motor are indicated by A2212.It indicates a motor with a 22 mm diameter and a 12 mm shaft height. 6T stands for six pole turns.2200KV indicates that the motor will rotate 2200 times in a minute at a supply of 1V.

Fig.3. Brushless DC Motor

C. Ducted Fan

For instance, it can often be in the robot under the operating condition that makes progress, thrust direction can have some inclinations angle upwards. Ducted fan are bound up on the power, the thrust generating apparatus that forms is fixed in the travel mechanism. The control box, which can be wired or wireless, manages the travel mechanism and forms the integral body of the climbing robot. It can have one or more; in order to generate greater thrust and counteract response torque, select the ducted fan mode, which allows for the arrangement of greater thrust. The robot uses a motor to ascend and has a service cable that draws power from the ground supply electric electricity. This fan's design, with its particular number of blades and motor specifications, is probably intended to maximise airflow while consuming the least amount of power. Given its voltage input, the 2200kV motor rating implies that it can rotate at faster rates, which could lead to improved airflow performance

Fig.4.Ducted Fan

D. Electronic Speed Controller (ESC):

On turning on the proper MOSFETs to produce a revolving magnetic field, an ESC, or electronic speed controller, regulates the brushless motor's motion or speed. The motor will run faster the higher the frequency or the faster the ESC cycles through the six periods. Even if a 30A ESC is employed, given the specifications of the BLDC that has been used in the project, a 50A or 80A ESC would be more suitable.

Fig.5. Electronic Speed Controller

E. ESP32

Based on the low-cost ESP8266 System-on-a-Chip (SoC), the ESP32 (Node MicroController Unit) is an open-source software and hardware development environment. The Espressif Systems-designed and -produced ESP8266 has all of the essential components of a computer, including networking (Bluetooth), CPU, RAM, and even a contemporary operating system and SDK. This makes it a fantastic option for all types of Internet of Things (IoT) projects. GPIO (General Purpose Input Output) pins on the ESP32 board enable users to communicate with a variety of sensors, actuators, and other electronic components. Programming is made easier by its interoperability with the Arduino IDE, which makes it simple for users to write C/C++ code. The ESP32's integrated Bluetooth connectivity makes it possible to connect to the internet with ease, which makes it perfect for uses such as remote monitoring, home automation, and sensor networks.

Fig.6. ESP32

F. Motor Driver

An electrical system that consists of an electric motor that powers the machine is called a motor drive. It usually regulates the torque, speed, and directions. A motor driver is required when utilizing a controller to manage a motor. An L293D H- Bridge motor driver has been attached for this project. For driving DC and stepper motors, use this high power motor driver module, the L293D. An L298 motor driver integrated circuit and a 78M05 5V regulator make up this module. Up to four DC motors or two DC motors with directional and speed control can be operated by the L293D Module. An electrical device or module called a motor driver is in charge of regulating the direction and speed of an electric motor. By converting signals from the controller into power outputs to run the motor, it serves as a bridge between a microcontroller or control system and the motor.

Fig.7. Motor Driver

G. Gear Motor

The robot has four N20 12V 60RPM gear motors attached. A DC Mini Metal Gear Motor like this one is perfect for building robots .Low RPM, great torque, and light weight. exquisitely crafted, robust, difficult to wear. With outstanding stall qualities and effortless hill climbing ability. These motors are the key elements in this project since they have a high torque that allows them to climb a vertical surface.

Fig.8. Gear Motor

H. Battery

A synthetic electrolyte, as opposed to a liquid one, is used in the rechargeable lithium-ion battery technology, which is also known as a lithium-ion battery. For this project, a 2200mAh 11V 3S 20C Lippo battery is utilized as the power source. Three cells are present. The continuous discharge rate is 20C, the rated voltage is 11.1, and the full charge voltage is 12.7.

Fig.9. LiPPO Battery

I. ESP32 cam

The ESP32-CAM is a tiny ESP32-based development board with a camera onboard. It allows for Wi-Fi connectivity and features a 2MP camera module. It's widely used for IoT projects, DIY surveillance systems, and various image processing applications. The board supports programming via the Arduino IDE and can be easily integrated into existing projects.

Fig.10. ESP 32 CAM

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VI. CIRCUIT DIAGRAME

The schematic circuit diagram of this Wall Climbing Cleaning Robot is as follow

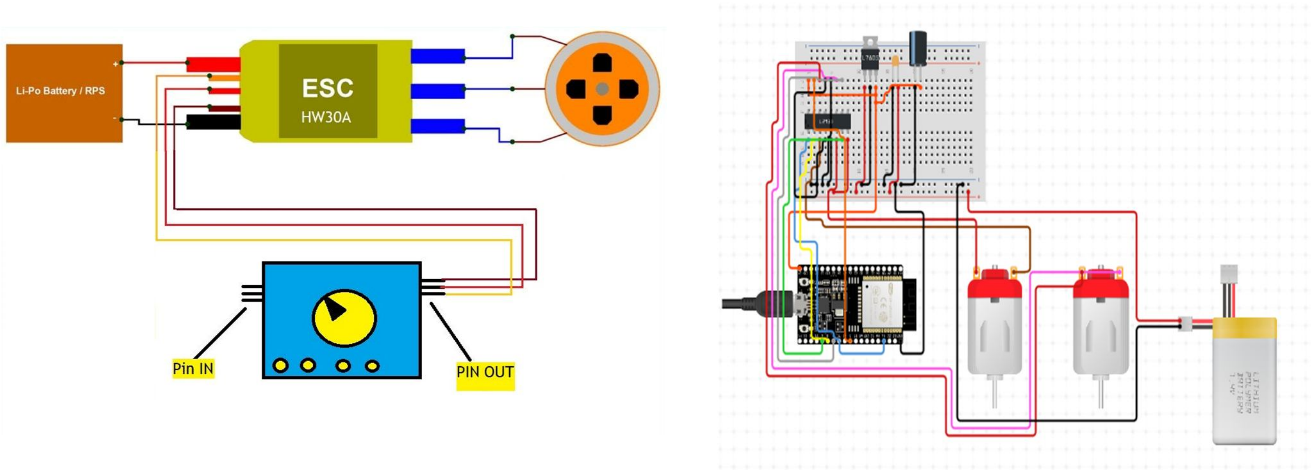

Fig.11. Circuit diagram of this Wall Climbing Cleaning Robot

Developing a wall-climbing robot integrating four N20 12V 110RPM gear motors, a motor driver, a ESP32, and a BLDC motor entails a sophisticated circuit arrangement. The ESP32, acting as the central control unit, interfaces with the motor driver, which manages the power and direction of each N20 gear motor used for movement and stabilization. These gear motors are strategically placed to facilitate the robot's navigation and adherence to vertical surfaces. Simultaneously, the ESP32 coordinates the operation of the BLDC motor, which drives the specialized mechanism enabling the robot's climbing capability.

The connections between the ESP32, motor driver, and individual motors, including the BLDC motor, involve intricate wiring configurations. Each motor driver channel is assigned to control a specific N20 gear motor, regulating its speed and direction based on commands received from the ESP32.

Moreover, the ESP32 communicates with the motor driver through dedicated control pins to manage these motors effectively. Additionally, the BLDC motor, synchronized with the ESP32, requires precise wiring and control signals to engage the climbing mechanism securely and safely. The ESP32 sends commands and coordinates the rotation and operation of the BLDC motor, allowing the robot to scale vertical surfaces.

This comprehensive integration demands meticulous attention to wiring, pin configurations, and power requirements to ensure seamless coordination among the ESP32, motor driver, and motors. Detailed specifications and guidelines from component datasheets are vital to guarantee proper connections, voltage compatibility, and optimal functionality.

VII. ILLUSTRATION OF WORKING METHODOLOGY

The Block Diagram of working methodology of Wall Climbing paint Robot fabricated for this project are given below

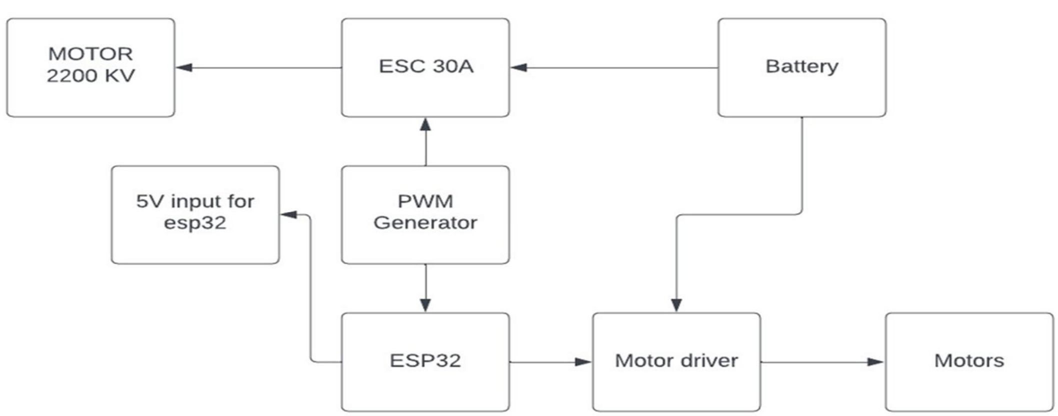

Fig.12. Illustration of Working Methodology of the Robot

VIII. LAYOUT OF ROBOT CONTROLLING REMOTE

Our robot controlling remote has been designed with the following layout on the internet. With this open-source web platform, developers can create and modify their own customized graphical user interfaces (GUIs) for controlling ESP32 with a tablet or smartphone. By application, the GUI operates on the phone or tablet. Our graphical user interface is made to

1) Control the direction of the Robot.
2) Easy to connect with ESP32 Bluetooth.
3) Turn off and Turn on the whole controlling system.

Fig.13. Layout of Robot Controlling Remote

IX. EXPERIMENTATION & CALCULATION

1) Electronic Speed Controller (ESC) Selection

Calculating load current of the BLDC A2212/6T 2200KV 3 phase induction motor From the specification of this BLDC Power,
P = 239W
Assuming Power Factor, Cosφ = 0.8
Measured line to line voltage of 3 phase connection, Vline= 7.95 V
Load current draw by BLDC motor, Irms.load = P/√ (3 *Vline*Cosφ)
= 239 /√ (3 *7.95 *0.8)
= 54.72 A

Hence, we need at least 50A ESC to run our robot properly. But due to the unavailability, we used a 30A ESC instead. For this, while running the BLDC, the ESC generating excessive heat that why we get a short running time

2) Thrust of a duct fan with a BLDC motor:

Thrust = ((3.14/30)*(K.V)*Current*Diameter*Number of Blades)^2
KV is the motor's velocity constant (2200 KV).
Current is the current supplied to the motor in amperes (2 A).
Diameter is the diameter of the fan blades in millimeters (72 mm).
Number of Blades is the total number of blades on the fan (12).

3) Condition For Clinging On Vertical Surface:

Measuring the thrust force generating by the propeller:
Firstly, the BLDC motor attached with a six inches propeller was placed on the weight machine and rotated it near to full angular speed. The BLDC is connected through a30A ESC with 12V 2200mAh Li-Po battery. The reading measured from the weight machine was 917 gm.
Therefore the thrust force generated by the propeller, F_{Thrus} = (917/1000) Kg * 9.81m/s2
= 8.99577 N
In sense, if thrust force is greater than mg/μs then the body should be more static.

Hence
, F_{thrust}..$\geq mg/\mu s$
So, $m \leq (F_{thrus} .\mu 1 .) / g$
=> $m \leq (8.99577 * 0.8) / 9.81$
=> $m \leq 0.652$ kg
$\therefore m \leq 652$ gm
According to this calculating we have to pack up our Wall climbing Cleaning robot's overall mass within 652 gm

X. MODEL IMAGES

Fig.14. Base Plate

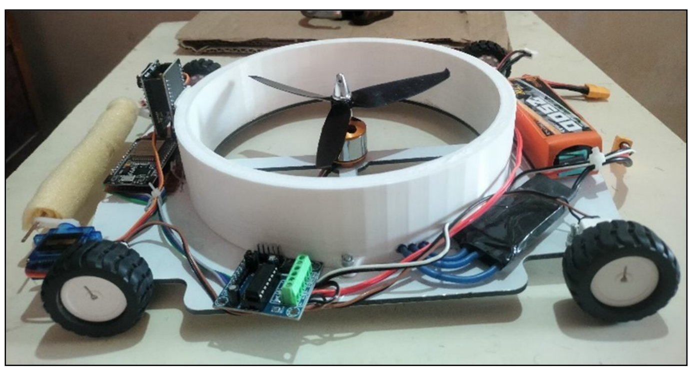

Fig.15. Side View

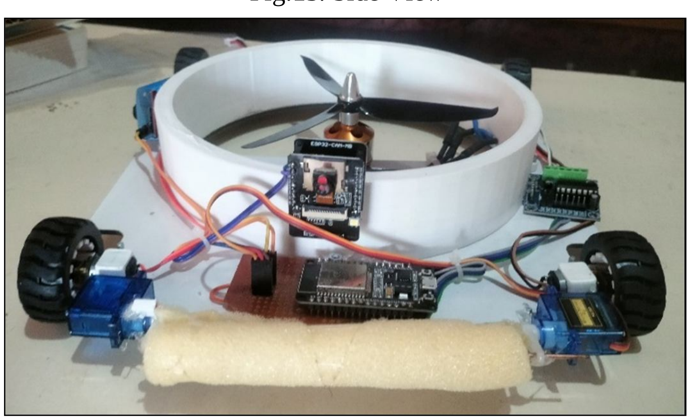

Fig.16. Front View

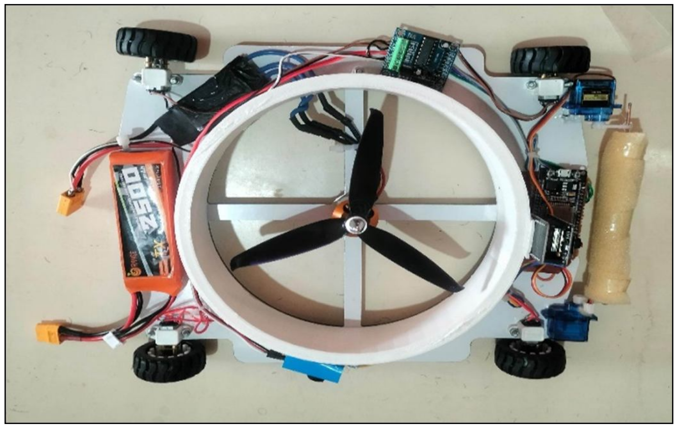

Fig.17. Top View

XI. CONCLUSION

Our goal with this project was to create a basic, inexpensive robot that could climb walls as well on horizontal surface. Compared to other wall climbing techniques, the propeller thrust method is relatively easy to develop and reasonably priced. A highly exact calculation is made throughout the climbing process to ensure that there is sufficient thrust to hold the robot's entire body to the vertical surface. Determining the friction coefficient (μs) in static condition of the robot's rubber wheels on the white board was a crucial computational step. It was determined using an experimental process. Another essential component is the robot's programming code. If this isn't done as accurately as feasible, the robot won't function as intended. The Cleaning mechanism is a specially built mechanism created just for this robot. The stress and deformation of the chassis are also calculated separately. This is a crucial step since the results of the computation directly affect the choice of chassis material. In order to keep this robot stable and operating smoothly, the overall weight distribution as well as the component setups and their placements are crucial. This project is still in its early phases, nevertheless. It is possible to increase the robot's capabilities and optimize its efficiency through more research and development. And the robot is also act as a surveilling purpose

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