SSN COLLEGE OF ENGINEERING

KALAVAKKAM-603110

INTERNALLY FUNDED STUDENT PROJECT - 2024

CleanCling

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Budget (in thousands)

23,900

Project Duration (in months)

18 MONTHS

Signature of the Project Students

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Signature of the HOD

1. Project Title: CleanCling

2. Broad Subject: Image processing , Robotics and Automation , Data processing

3. Project Duration *(in months)*: 18 months

4. Budget *(in thousands)*: 23,900

5. Project Summary :

This project, CleanCling, aims to develop an autonomous wall-climbing robot capable of detecting and removing dust from vertical surfaces using image processing. With the growing need for automated cleaning solutions in residential, commercial, and industrial spaces, this project addresses the challenge of cleaning hard-to-reach areas, such as walls and ceilings, where dust accumulation often goes unnoticed.

Related work in robotics has seen advancements in floor-cleaning robots, but few solutions focus on vertical cleaning. Globally, research in countries such as Japan and the United States has led to prototypes of wall-climbing robots for industrial applications, like inspections and maintenance. In India, robotic cleaning solutions are emerging, primarily focused on floor and window cleaning. However, CleanCling uniquely integrates wall-climbing technology with dust detection using a lightweight design optimised for dust collection on a variety of surfaces.

The project execution involves a Raspberry Pi for image processing, motors for wall movement, a camera for dust detection, and a dust collection system. The expected outcomes include the development of a new cleaning technology, combining real-time dust detection with wall-climbing mobility. This prototype will provide a basis for future developments in autonomous vertical cleaning systems, with potential applications in both consumer and industrial sectors.

6. Keywords :

- Wall-climbing robot
- Autonomous cleaning
- Dust detection
- Image processing

- Vertical surface cleaning
- Robotics
- Real-time processing
- Dust collection mechanism

7. Objectives

- **Develop an Autonomous Dust-Cleaning System**: Create a robot capable of autonomously navigating and cleaning vertical surfaces, effectively picking up dust and debris without manual intervention.
- **Integrate Image Processing for Dust Detection**: Utilise image processing techniques to identify areas with dust accumulation and focus cleaning efforts precisely, ensuring efficient dust removal.
- **Create a Safe and Stable Wall-Climbing Mechanism**: Ensure the robot adheres securely to walls and maintains stability across various surface textures, avoiding slips or falls.

8. Introduction

This project aims to develop an autonomous **wall-climbing dust-picking robot** capable of cleaning vertical surfaces such as walls and windows. Using **image processing** to detect dust and **LiDAR/IR sensors** for navigation and obstacle detection, the robot will move autonomously to identify and clean dirty areas. The goal is to create a lightweight, power-efficient system that operates effectively in various environments, offering an innovative solution for automated cleaning tasks. This robot has the potential for both residential and industrial applications, contributing to the advancement of robotics in automation and sustainability.

9. Definition of the Problem

Traditional cleaning methods for vertical surfaces, such as walls and windows, are often labour-intensive and time-consuming. In addition, cleaning in hard-to-reach or elevated areas can pose safety risks and require specialised equipment. There is a need for an **autonomous, efficient cleaning solution** that can operate on vertical surfaces, detect and remove dust and debris, and navigate obstacles without human intervention.

The challenge is to design a **wall-climbing robot** that is both lightweight and powerful enough to perform cleaning tasks autonomously, while also being energy-efficient and capable of working in various environmental conditions. Key issues include creating a reliable navigation system, integrating effective dust detection and collection mechanisms, and ensuring the robot can safely adhere to and move across walls without falling or losing stability.

10. Review of status of Research and Development in the subject

Provide an overview of existing cleaning robots and image processing techniques. Include a review of existing wall-climbing robots and discuss their applications, advantages, and limitations.Highlight the gap that your project aims to address—automated wall-cleaning with real-time dust detection.

10.1 National Status

- Indian institutes like the Indian Institute of Technology (IIT), SSN College of Engineering, and VIT University are actively involved in robotics and automation research. Various projects focus on developing robots for specialised tasks such as vertical cleaning, industrial inspection, and even agriculture. Reference link : (2)
- Indian researchers are exploring different types of wall-climbing mechanisms, such as adhesive grippers, magnetic wheels, and vacuum suction systems. These projects often aim to address the challenges specific to Indian environments, such as the need for low-cost solutions and adaptation to diverse building types.
- Companies like Genrobotics and RoboShuttles have developed robots for cleaning and maintenance tasks in urban environments. For example, Genrobotics has introduced the Manhole Cleaning Robot, which, while not focused on vertical surfaces, showcases the interest in developing autonomous solutions for labour-intensive tasks.

10.2 International Status

- **United States**: Research institutions like **MIT**, **Stanford University**, and **UC Berkeley** have conducted extensive work in robotics, including wall-climbing robots. For example, MIT's **Biohybrid Robots** and **Climbing Robots** focus on mimicking biological climbing techniques using soft materials for better adaptability to surfaces. Reference link : (3).
- **Japan**: Known for its robotics advancements, Japan has produced robots like **The Window Cleaning Robot** developed by **Panasonic**, and **Suction-based Robots** by various academic institutions. Japan's focus is often on industrial and commercial cleaning robots that can function in both indoor and outdoor environments. Reference link : (1)

11. Novelty / Importance of the proposed project in the context of current status

The proposed wall-climbing dust-picking robot aims to address several key challenges in the current landscape of autonomous cleaning and navigation robots, offering unique advantages that distinguish it from existing technologies.

1. Multi-functional Design for Vertical Cleaning:
    - While many current robots focus on cleaning horizontal surfaces or large windows using suction or magnetic systems, this project proposes a robot specifically designed for vertical surface cleaning, offering a solution that can handle diverse environments, from residential walls to industrial structures. The combination of image processing for dust detection and a wall-climbing mechanism sets this robot apart from most existing commercial cleaning robots.
2. Integration of Advanced Image Processing for Dust Detection:
    - Most existing wall-climbing robots rely on simple proximity sensors or basic visual input for navigation. In contrast, the proposed project integrates advanced image processing to identify and clean areas with dust and debris, ensuring that cleaning efforts are focused on precisely the areas that need attention. This precision enhances efficiency and reduces unnecessary energy consumption.
3. Combination of LiDAR/IR Sensors for Accurate Navigation:
    - While some existing robots use LiDAR or IR sensors for navigation, this project intends to integrate these sensors into a cohesive system that enables the robot to navigate dynamically in real-time, adapt to different surface textures, and avoid obstacles with minimal human intervention. The use of both sensors in combination with image processing will allow the robot to map and move autonomously in complex environments, a significant step forward in wall-climbing robotics.
4. Lightweight and Energy-Efficient Design:
    - One of the significant challenges in vertical climbing robots is the trade-off between weight, power, and functionality. This project focuses on creating a lightweight and power-efficient robot without sacrificing performance. By integrating energy-efficient systems and optimizing the weight-to-power ratio, the robot will be able to operate for extended periods, providing real-time cleaning without frequent recharging.

12. Patent details *(domestic and international),* if applicable

13. Work plan and Detailed technical information

Phase 1: Research & Concept Design (Months 1–3)

- **Objective:** Define goals and create the initial design.
- **Tasks:**
    - Study wall-cleaning robots, patents, and market needs.
        - Define robot functions (climbing, cleaning, sensors, power).
        - Create design sketches and 3D models.
    - Deliverables: Research report, requirements document, and design sketches.

Phase 2: Component Selection & System Design (Months 4–5)

- **Objective:** Finalise parts and overall architecture.
- **Tasks:**
    - Choose sensors, motors, power supply, and cleaning mechanism.
    - Draft system architecture and component layout.
- **Deliverables:** Detailed component list and system design.

Phase 3: Mechanical Design & Assembly (Months 6–8)

- **Objective:** Build the physical structure.
- **Tasks:**
    - Create detailed CAD models and select materials.
    - Assemble robot chassis, climbing mechanism, and components.
- **Deliverables:** Robot body with wall-climbing capability.

Phase 4: Sensor Integration & Calibration (Months 9–10)

- **Objective:** Install and fine-tune sensors.
- **Tasks:**
    - Integrate navigation (LiDAR, IR) and dust detection (RGB camera) sensors.
    - Calibrate for distance, proximity, and image clarity.
- **Deliverables:** Calibrated sensors and power system.

Phase 5: Software Development (Months 11–13)

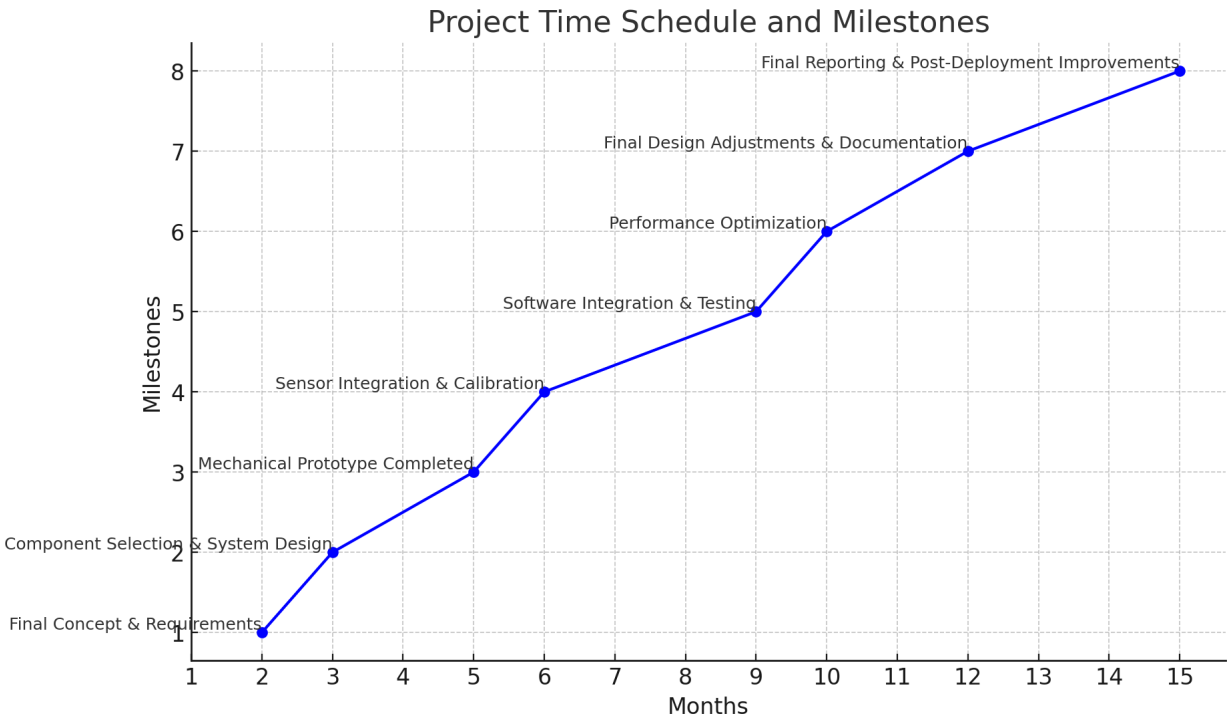
- **Objective:** Develop navigation, control, and dust detection software.
- **Tasks:**
    - Write algorithms for path planning, obstacle avoidance, and dust detection.
    - Integrate software with hardware for autonomous operation.
- **Deliverables:** Navigation, cleaning, and control software.

Phase 6: Testing & Optimization (Months 14–15)

- **Objective:** Test and refine the robot.
- **Tasks:**
    - Evaluate in various wall types and lighting conditions.
    - Optimise algorithms, battery life, and cleaning performance.
- **Deliverables:** Test report and final optimised robot.

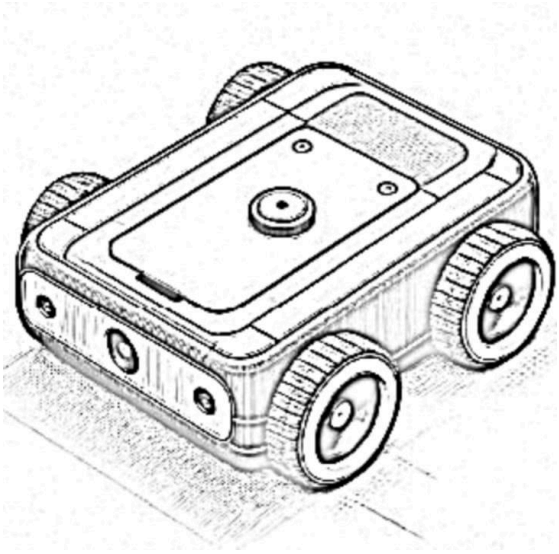
14. Time schedule of activities giving milestones:

1. **Month 2:** Final concept and requirements document
2. **Month 3:** Component selection and system design finalisation
3. **Month 5:** Mechanical prototype completed
4. **Month 6:** Sensor integration and calibration complete
5. **Month 9:** Software integration and testing complete
6. **Month 10:** Performance optimization completed
7. **Month 12:** Final design adjustments and project documentation submitted
8. **Month 15:** Final reporting and post-deployment improvements



15. Deliverables

- **Prototype** – A complete dust detection system built with sensors and Raspberry Pi to measure and analyse dust levels.
- **Software** – Custom code for gathering sensor data, processing images, and detecting dust in real time.
- **User Guide** – Simple instructions on how to assemble, operate, and maintain the system.
- **Data Report** – Results showing the system's dust detection accuracy and performance under different conditions.



16. Target beneficiaries of the proposed work

- **Cleaning Industry**: Safer, automated high-rise and indoor cleaning.
- **Facility Management**: Efficient dust removal in hard-to-reach spaces.
- **Healthcare**: Enhanced sanitation for hospitals and clinics.
- **Robotics Researchers**: Advancements in autonomous wall-climbing robotics.
- **Construction/Maintenance**: Dust removal for inaccessible areas.
- **Public Health**: Cleaner environments, improved air quality.

17. Suggested plan of action for utilisation of research outcome expected from the project

- Prototype Development: Finalise the CleanCling robot prototype for demonstration and testing in real-world environments.
- Industry Applications: Deploy CleanCling in industrial settings (e.g., warehouses, factories) for cleaning hard-to-reach areas like walls and ceilings
- Further Research: Conduct additional studies on improving the robot's energy efficiency, dust detection algorithms, and adaptability to different wall surfaces.

18. References

1) Afzalaghaeinaeini, A.; Seo, J.; Lee, D.; Lee, H. Design of Dust-Filtering Algorithms for LiDAR Sensors Using Intensity and Range Information in Off-Road Vehicles.Published:

27 May 2002
https://pdfs.semanticscholar.org/5734/6d79cb31de294316230e9fc6b3adbe9fb06d.pdf

2) Xie, D.; Xu, Y.; Wang, R. Obstacle detection and tracking method for autonomous vehicle based on three-dimensional LiDAR. *Int. J. Adv. Robot. Syst 2019.*
https://www.mdpi.com/1424-8220/22/11/4051

3) https://ieeexplore.ieee.org/abstract/document/1598051

19. List of facilities and Equipments available with Department for the project

20. Budget Estimates

BUDGET ESTIMATION : 23900

21. Budget Justification

Component	Model	Quantity	Price (INR)
Wall-Climbing Car Base	Generic Model with Suction Mechanism	1	₹3,000
LiDAR Sensor	YDLIDAR X4	1	₹6,000
IR Sensor	IR Proximity Sensor Module (Generic)	2	₹200 each (₹400)
Mini Camera Module	Raspberry Pi Camera Module V2	1	₹2,800
Raspberry Pi	Raspberry Pi 4 Model B (4GB RAM)	1	₹8,000
Arduino Board	Arduino Uno R3 (Clone)	1	₹800
Motor Drivers	L298N Dual H-Bridge	2	₹400 each (₹800)

DC Motors	High Torque DC Motor (12V, 100 RPM)	4	₹600 each (₹2,400)
Dust Collection Unit	Mini Vacuum Cleaner Module	1	₹1,200
Battery Pack (Li-ion)	12V 3500mAh Rechargeable Battery Pack	1	₹2,500
Miscellaneous Components	Wires, connectors, adhesives, etc.	-	₹1,000