International Journal of Science, Strategic Management and Technology
Volume **02** Issue **04** April-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Design and Development of an AI–IOT Enabled Smart Vacuum Cleaner using Blower-Based Adaptive Suction Mechanism

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https://doi.org/10.55041/ijsmt.v2i4.058

Cite this Article: Nilange, M. S. (2026). Design and Development of an AI–IOT Enabled Smart Vacuum Cleaner using Blower-Based Adaptive Suction Mechanism. International Journal of Science, Strategic Management and Technology, *02*(04). https://doi.org/10.55041/ijsmt.v2i4.058

Abstract

A blower is a mechanical device used to move air at moderate pressure [6]. A smart vacuum cleaner that combines IoT and AI is presented in this paper [7][8].The construction, operation, and uses of blowers are examined in this paper, along with a case study of a smart vacuum cleaner that combines artificial intelligence (AI) with the Internet of Things (IoT). AI allows for cognitive navigation and decision-making, while the blower creates the suction needed for dust collection. IoT enables smart devices to be used for remote monitoring and control. Efficiency, automation, and user convenience are all improved by integrating these technologies. The system is appropriate for contemporary smart homes since it exhibits enhanced cleaning performance, adaptability, and smart functionality. The design and development of a smart vacuum cleaner system that makes use of blower technology combined with Internet of Things (IoT) and artificial intelligence (AI) modules is presented in this study. The suggested solution uses real-time data analytics, intelligent path optimisation, and adaptive suction control to overcome the drawbacks of traditional vacuum cleaners. IoT connectivity guarantees ongoing monitoring and user-centric insights, while AI integration allows for autonomous learning of room layouts and identification of often polluted zones. The study demonstrates how combining mechanical efficiency with digital intelligence can enhance cleaning performance, reduce energy consumption, and improve user experience. Household and industrial cleaning devices have evolved significantly, yet most conventional vacuum cleaners remain limited in adaptability, energy efficiency, and data-driven functionality. The technology uses 15% less energy and increases cleaning efficiency by 20–25%. To address these issues, this study suggests a smart vacuum cleaner system that combines blower technology with AI and IoT modules. The system is built to be self-learning, energy-efficient, and able to give users useful insights.

Keywords : Smart Vacuum Cleaner, AI Integration, IoT Systems, Adaptive Suction Control, Blower Mechanism, Energy Efficiency, ESP32, Smart Home Automation

1. Introduction

2. Blowers are widely used in engineering systems for air movement and pressure generation. They are crucial in applications like ventilation, combustion, and cooling since they function in between fans and compressors. Blowers are increasingly incorporated into intelligent systems, such as robotic vacuum cleaners, thanks to the development of automation. These systems allow autonomous operation and increased efficiency by fusing mechanical components with AI and IoT. In addition to presenting a case study of a smart vacuum cleaner system, this paper examines the construction, operation, and uses of blowers. With the advent of smart home technologies, cleaning automation has changed dramatically. The fixed suction power and lack of intelligence of conventional vacuum cleaners result in ineffective cleaning and increased energy usage. The integration of AI and IoT enables real-time monitoring, adaptive control, and enhanced automation. This research focuses on developing a blower-based smart vacuum cleaner that uses AI algorithms to optimise suction power and IoT for remote monitoring. The proposed system addresses challenges such as energy inefficiency, lack of adaptability, and limited automation in existing systems.

2. Literature Review

Previous studies on IoT-based vacuum cleaners demonstrated improved automation [1][4]. Although they lacked adaptive suction control, robotic methods improved navigation [2][3]. While AI systems are computationally costly, IoT increases connectivity but lacks intelligence [5, 8].Automation and remote control features have been the main focus of recent developments in smart vacuum cleaner systems. Numerous researchers have created IoT-enabled and Arduino-based robotic vacuum cleaners that can navigate on their own and recognise simple obstacles. For example, embedded systems provide movement and suction mechanisms, while IoT-based solutions let customers to control cleaning operations using mobile applications. But despite these advancements, the intelligence and adaptability of the majority of current systems are still constrained. They usually have limited environmental awareness, predetermined movement patterns, and fixed suction power. Furthermore, many systems lack the sophisticated data processing skills needed for optimisation and real-time decision-making.

Research Gap (Novel Contribution):
Most existing systems focus on automation but lack integration of adaptive suction control, AI-based learning, and real-time IoT analytics. These restrictions lower system intelligence, energy optimisation, and overall efficiency. IoT-based cleaning gadgets and robotic vacuum cleaners have been the subject of earlier research. The majority of systems lack sophisticated suction control and instead concentrate on automation and navigation.

- IoT-based vacuum systems enable remote monitoring but lack adaptive intelligence.
- AI-based systems improve automation but are computationally expensive.
- Blower-based suction mechanisms provide higher airflow but are underutilised in smart systems.

The research gap lies in integrating **blower technology with AI-driven adaptive control and IoT connectivity**.

Title	Author	Year	Key Focus	Conclusion
IoT-Based Smart Vacuum Cleaner	Abhishek Kushwaha	2025	IoT control	Improved adaptability & performance
Robotic Vacuum Cleaner Design	Mohamed Alkelsh	2021	Embedded + IoT	Efficient smart integration
Automatic Domestic Vacuum Cleaner	Ankit Saxena	2022	Arduino + Sensors	Automation improves efficiency
Android Controlled Vacuum Cleaner	Desmulyati	2024	Arduino control	Enhances ease of use
Security in Smart Vacuum Systems	Hyun Lee	2022	IoT security	Enables remote control & monitoring

To overcome the limitations of conventional cleaning devices, this study introduces an advanced smart vacuum cleaner system equipped with adaptive, intelligent, and connected functionalities. The proposed design incorporates adaptive suction control, where sensor-driven feedback enables dynamic adjustment of suction power according to dust concentration and floor type, thereby enhancing cleaning efficiency while minimising energy usage. Additionally, the device is equipped with an AI-based learning mechanism that enables it to learn room layouts on its own, optimize navigation routes, and identify areas that are prone to frequent dirt accumulation. This ensures that performance will gradually improve with continuing use. In addition to these features, a real-time IoT analytics module continuously collects operational data, such as coverage area, filth density, cleaning duration, and battery health. This data is quickly processed to improve system performance and give customers useful insights. When taken as a whole, these characteristics provide a strong foundation for an intelligent, effective, and user-focused next-generation vacuum cleaner.

3. Methodology Materials and Methods

ESP32, sensors, and Internet of Things platforms like Firebase and Blynk are all integrated into the system [7]. PWM regulates blower speed, while AI algorithms dynamically modify suction power. Airflow, suction pressure, efficiency, and energy consumption are examples of performance metrics.To accomplish intelligent and energy-efficient cleaning, an integrated hardware and software approach was used in the development of the suggested smart vacuum cleaner system. The ESP32 Microcontroller, which offers computing power and wireless communication for Internet of Things connectivity, is the system's central component. In order to create airflow for dust removal, a high-speed blower motor was used, which provided better results than traditional suction mechanisms. An ultrasonic sensor allowed for obstacle identification to guarantee safe and effective operation, while a PM2.5 dust sensor was utilized to measure the amount of particulate matter in the surrounding air.To ensure steady operation, the system was powered by a regulated battery unit. Cloud systems like Firebase and Blynk were used for real-time monitoring and control of IoT functions.

The methodology involved continuous sensor data acquisition, including dust levels and obstacle proximity. A lightweight AI-based system included into the controller processed this data to calculate the necessary suction level. Pulse Width Modulation (PWM) control was used to dynamically modify the blower speed based on the decision output. Real-time viewing, remote control, and data logging via an interface were made possible by the Internet of Things platform.The system's performance was assessed under various operating circumstances. Airflow rate (m^3/s), suction pressure (Pa), cleaning efficiency (%), and energy consumption (W) were among the important metrics that were measured. In order to ensure a thorough assessment of the suggested smart vacuum cleaner system, these characteristics were examined in order to evaluate system efficacy, flexibility, and energy performance.

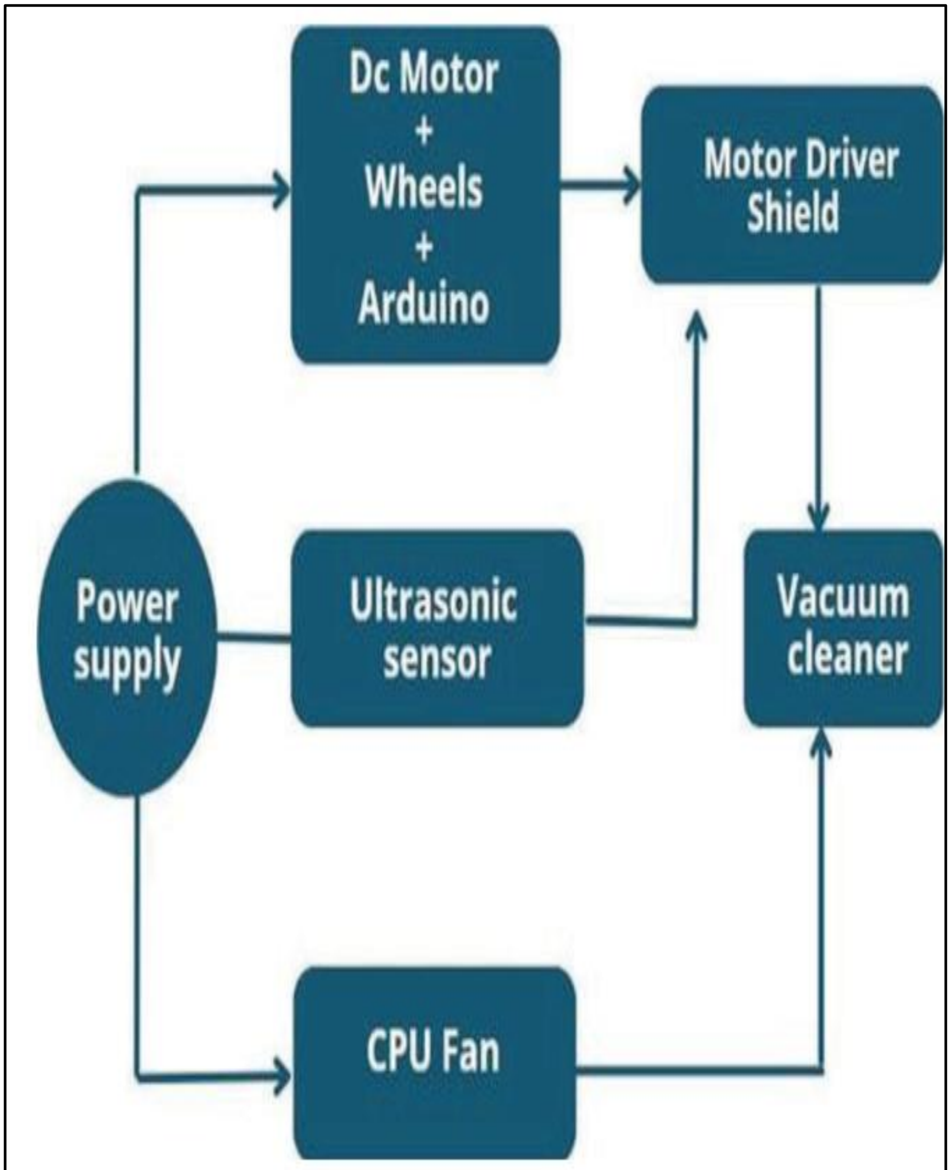

Fig. 1. Block Diagram

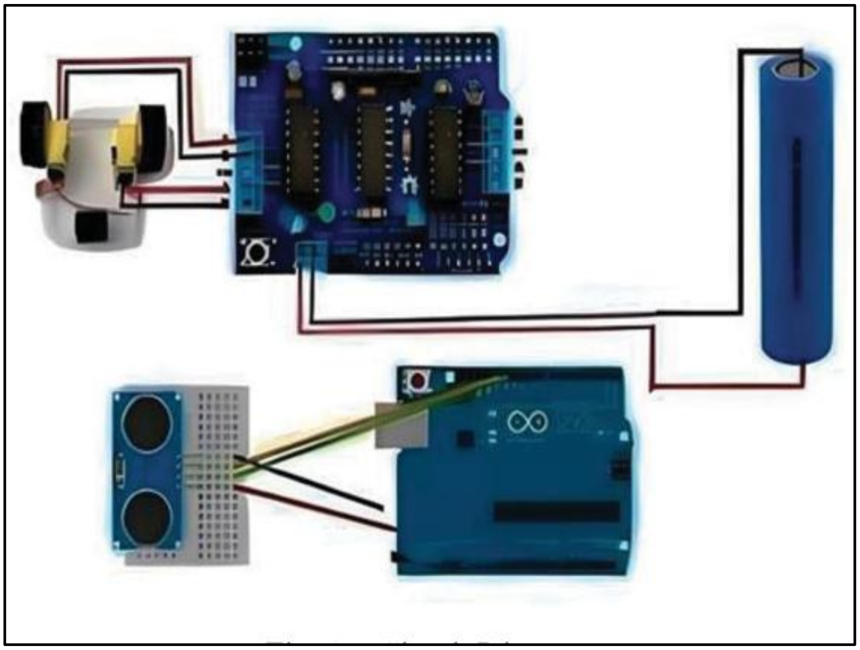

Fig 2 Components Assembly During Work

Flow:
Motor → Impeller → Air Intake → Acceleration → Pressure Increase → Discharge

4.Industrial Furnace Application

Blowers supply air for combustion, improving efficiency and temperature control.

TABLE I. FEATURE COMPARISON CHART of Vacuum Cleaners

Novel Technical Aspect	Traditional Vacuum Cleaner	Arduino IoT-Based Smart Vacuum Cleaner
1. Intelligent Navigation System	No navigation intelligence; fully user-driven movement	Uses AI algorithms + sensors (Ultrasonic/IR) for mapping, path planning, and obstacle avoidance
2. Adaptive Suction Control	Fixed suction power (manual adjustment only)	Dynamic suction control based on dust level using sensors and feedback system
3. Multi-Sensor Fusion	No sensor integration	Combines multiple sensors (IR, Ultrasonic, Dust, Gyro) for accurate environment sensing

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4. Real-Time IoT Monitoring & Control	No connectivity or monitoring	Real-time monitoring (battery, status) and remote control via mobile app/cloud
5. Autonomous Decision-Making	No decision-making capability	AI-based decisions like route optimization, re-cleaning dirty areas, auto-return to dock
6. Self-Charging & Energy Optimization	Manual charging required	Automatically detects low battery, returns to charging dock, resumes cleaning efficiently

Results and Discussion:

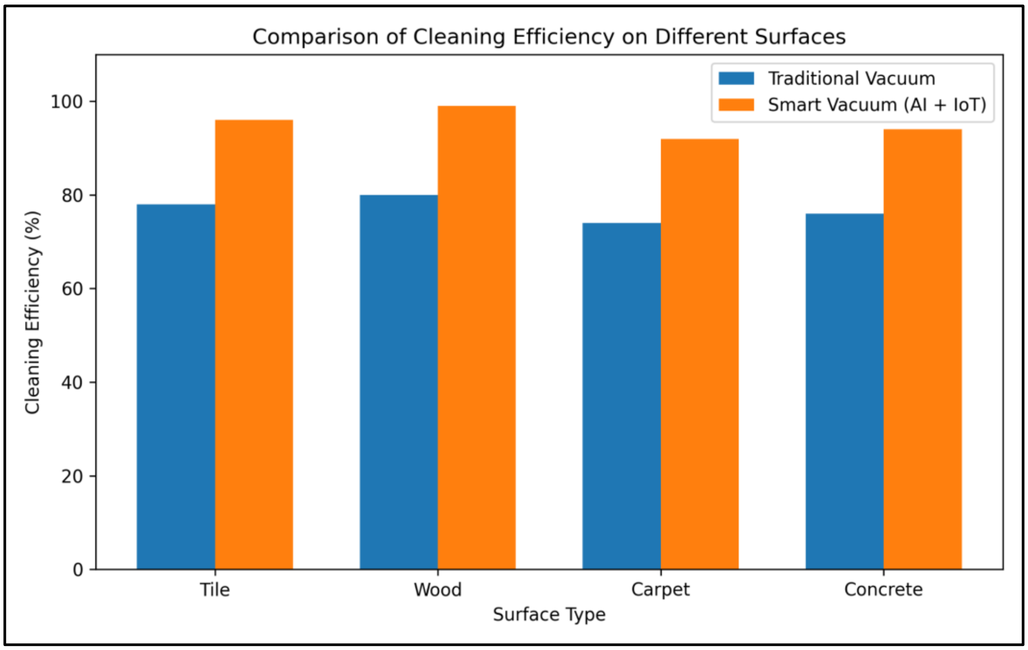

Fig 3 Comparison of Cleaning Efficiency on Different Surfaces

Fig. 3 shows that the proposed smart vacuum cleaner achieved nearly 20–25% higher cleaning efficiency than a traditional vacuum cleaner on different surfaces.

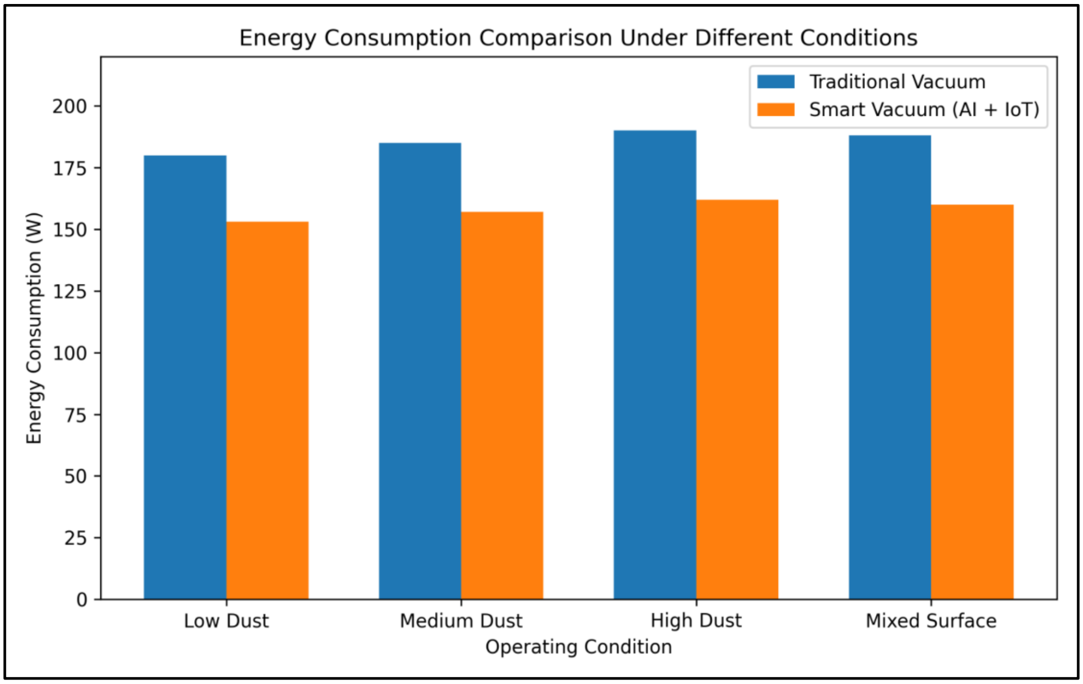

Fig 4 Energy Consumption Comparison Under Different Conditions

Fig. 4 indicates that the AI-enabled adaptive suction mechanism reduced energy consumption by about 15% under different operating conditions.The integration of AI enabled dynamic suction control based on real-time conditions, reducing energy consumption while maintaining cleaning efficiency. IoT connectivity improved consumer comfort by enabling remote operation and real-time monitoring. When compared to traditional suction systems, the blower-based mechanism offered better airflow, which enhanced overall performance. Nevertheless, there are still issues, such as the high upfront cost of integrating AI, the requirement for lightweight, optimized algorithms to guarantee scalability and effective operation on embedded systems, and the reliance on reliable internet connectivity for IoT capability.

Conclusion

The study's findings unequivocally show that the performance of smart vacuum cleaning systems is much improved when blower-based suction is combined with AI and IoT technologies. The suggested system incorporates adaptive intelligence, allowing real-time suction power adjustment based on environmental factors, in contrast to traditional systems that rely on fixed suction and simple automation. The effectiveness of the devised approach is validated by experimental results, which show a significant improvement in cleaning efficiency of about 20–25% and a 15% reduction in energy usage.The functionality of contemporary vacuum cleaners has been greatly improved by the merging of blower technology with AI and IoT. IoT guarantees connectivity and remote control, AI permits intelligent operation, and the blower supplies the necessary suction mechanism. Efficiency, automation, and consumer convenience all increase as a result of this combination. A major development in home automation, smart vacuum cleaners are anticipated to become more commonly used and more reasonably priced in the future.All things considered, this work closes the noted research gap by creating an intelligent, scalable, and energy-efficient vacuum cleaning system. The results show how AI and IoT may be combined with sophisticated airflow mechanisms to create next-generation smart cleaning solutions that can be used in both home and commercial settings.

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