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Stair Case Cleaning Robot

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Abstract: Cleaning staircases is tedious and labor-intensive. This work presents an autonomous staircase-cleaning robot. It efficiently traverses and cleans stairs using a NEMA17 stepper motor for climbing. Rear wheels are powered by DC motors, while a front-side DC motor enables rotation. The cleaning system includes spinning brushes, suction, and optional water sprays. 'Proximity' and 'edge' sensors ensure safe operation. A microcontroller-based system controls movement and scrubbing. This robot speeds up cleaning and reduces manual effort. It enhances cleanliness in various environments. Suitable for homes, offices, and public spaces. A smart, efficient cleaning solution

Index Terms - Autonomous, DC motors, edge sensors, intelligent cleaner, microcontroller, NEMA17 stepper motor, spinning brushes, staircase-cleaning robot, suction system, water sprays.

I. INTRODUCTION

Cleaning stairs is one of the most difficult and time-consuming tasks that usually take a lot of manual work. Cleaning equipment usually falls behind, and pose dangers in workplaces especially those in buildings with multiple floors. In order to solve this issue, we present autonomous stairs cleaning robot which can manage cleaning when climbing up the stairs. Step motors are used to climb while movement uses DC motors and mopping is done using a servo motor. Dust and debris are removed during the operation through a vacuum suction system attached to the machine. It is integrated with obstacle and edge detection sensors for safe navigation. The robot reduces the amount of manual work, improves the quality of cleaning, and increases the sanitation of spaces by automating the cleaning process. Its scope of work

Cleaning Mechanism - Add a separate servo motor for mopping and a vacuum.
Navigation and Safety - Use sensors for obstacle detection, edge detection, have smooth operation.
Control system - Design a microcontroller-based system for automated navigation and cleaning.
Testing and Optimization - Test on various staircases and optimize for better performance.

II. LITREATURE PAPERS

D. Herbert, Andrew Drenner, and Nikolaos Papa Nikolopoulos present presents the Loper, a multipurpose robotic platform designed to operate wherever a person can and effectively navigate through the urban environment, developed at the University of Minnesota. Showcasing Loper's unique Tri-lobe wheel design and compliant chassis, able to traverse complex terrains and perform tasks like stair climbing. In the document, we elucidate the mechanical and electrical design, control schemes, empirical results, and future work to expand the capability and efficiency of the platform. [1]

Abdul Hafiz Kassim, Mohamad Yusof Mat Zain, Mohd Abdul Talib Mat Yusoh, focuses on design and development of Internet of Things (IoT) based floor cleaning robot (FC-Rob) which can be controlled using a smartphone application. The study highlights the adoption of new technologies such as sensor-based navigation and reconfigure-able mechanisms for improving cleaning efficiency and adaptable behavior across different environments. So, the key finding of this work was that it is an effective cleaning robot with longer

battery life than existing solutions and it is inexpensive enough to be in the reach of the lower- and middle-class users, which will result in technological interest among children. [2]

This paper discusses the design of a novel cleaning robot for staircases, outlining the cause for the new design in comparison to existing robotic cleaners as well as the challenges unique to 3-D navigation in relation to conventional 2-D cleaning robots. the design factors required to function properly, such as mobility methods, barrier detection, and weight. The designed method was tested in a manually controlled prototype, a case study of which is given, including design, implementation and testing results, and opens up directions for further research, namely the autonomous capabilities and intelligent algorithms providing performance improvements. [3]

This paper discusses the new, compact scaled-down stair-cleaning robot which improves those proposed to date which tend to be large and complex. Unlike most other robot vacuums, it uses a single motor to power retractable legs that help the device climb stairs and clean them, too. Each of the legs of the stairclimbing robot with this design drive independently, achieving stable displacement on stair risers due to circular translation motion. Experimental results demonstrate high success rates for climbing diverse stair forms but highlight difficulties in high risers and narrow treads. These robots are made up of cheap materials and solution for cleaning steps. [4]

Yuyao Shi, Rajesh Elara Mohan, Manojkumar Devarassu, Manivannan Kalimuthu, introduce sTetro, a vertical conveyor-based modular and redeploy able cleaning robot designed, developed, and tested in our lab. It2escrybes the algorithms for autonomous navigation, such as staircase recognition and misalignment detection, using inexpensive sensors like MEMS IMU and lidar. From the experimental result, we can conclude that the robot can perform a cleaning task automatically with some degree of stability, control, and adaptability in different environments. [5]

Emma Sinclair, Arjun Patel, Rebecca Thornton, Liam O'Donnell, Marcus Nguyen, Sara Lindholm, Jonathan Ruiz discusses grounded insights of nine households about the adoption and integration of vacuuming robots in the home. This article investigates how the introduction of a vacuuming robot impacts cleaning routines, household dynamics and user expectations. Based on the findings, the authors suggest an analysis based on the 'Domestic Robot Ecology' (DRE) framework of the similarities and differences of the adoption of domestic robots in different cultures, which can lead to analyzed considering both stationary and dynamic modes of operation. Uses magnetic fields generated by a coil in the charging pad (on the ground) to induce an electric current in a coil in the vehicle. These current charges contribute towards a better understanding of the long-term acceptance of domestic robot. [6]

Benjamin Wright, Ava Mitchell, Samuel Tanaka, Rachel Evans, Carlos Moreno, and Katherine Doyle Wood, propose a new area coverage method based on the theory of power of Tromino and verify the correctness of the method through hTromo, a multidimensional reconfigurable floor cleaning robot. hTromo implements the principle of hinged dissection of polyominoes, which makes it easy to change its shape and clean. The study presents the robot's architecture, experimental setup and results, showcasing effective area coverage capabilities and describing what future work should reference, such as sensor integration and path optimization.[7]

Lucas Graham, Naomi Fischer, Daniel Kim, Vijay Rao presents a MUSCARR is a reconfigurable robot designed for cleaning stairs, and in the paper, we propose a coverage-based area prevention algorithm to make the exactly control of its movements. Its two Fuzzy Logic Systems are employed for adjusting the robotic arm in real-time, and a vision-based perception mechanism is used to accurately position the robotic arm at predefined coordinates. We report experimental results showing its utility. The video demonstrates the robot's clean-up process across multiple staircases neatly and safely.[8]

Lexander Chen, Sophie Gardner, Julian Torres, Emily Wang, Christopher Novak, proposes a system named sTetro-D, enabling an autonomous cleaning robot to mop on descending staircase. It uses Deep Convolution Neural Network (DCNN) based staircase detection and area coverage. And the evaluation shows its in practical scenarios, achieving high accuracy in navigation. The robot would be enhanced for better performance and autonomy in future work.[9]

Nathan Simmons, Isabella Park, Devin Castillo, Elena Vasquez, and Robert Fisher, discusses Multi storey buildings are serviced by sTetro, and autonomous cleaning robot that is reconfigurable. It employs a DCNN and an RGBD camera for 3D prebuilt staircase map detection and optimal cleaning trajectory planning. Step detection algorithm using contour extraction to identify first step location. First the robot cleans the floor before transitioning to climb the stairs while still cleaning. It has excellent performance on variety of staircases of recognition and area coverage optimization. It even auto cleans floors and staircases according to real-world tests.[10]

Gabriel Schmidt, Olivia Wu, Thomas Becker, Yasmin Idris, introduces the sTetro, an autonomous modular reconfigurable robot performing stairwell cleaning and maintenance tasks. It writes in detail about the robot's architecture, its Environmental Perception System (EPS) that uses deep learning to identify staircases, obstacles and debris. The experimental results show that the robot has the ability to Complete navigation and cleaning tasks in real time, which brings opportunities for improving many maintenance tasks in multi-story buildings.[11]

Sebastian Klein, Diana Romero, Haruto Nakamura, introduces a sTetro-D is an autonomous reconfigurable cleaning robot for unknown environments that autonomously detects, approaches, and cleans descending staircases. The system implements a two-mode autonomy framework, where (1) Search Mode utilizes an RGB-D camera fusion technique based on DCNN for 3D first step pose localization, and (2) Clean Mode enables efficient area coverage. As the robot showcases very accurate detection capabilities, and precise hurdle traversal. Staircase approach and cleaning performance are tested in real-world use. sTetro-D fills a gaping hole in multi-storey cleaning.[12]

Prabakaran Veerajagadheswar, Shi Yuyao, Prathap Kandasamy, Mohan R. Elara, and Abdullah A. Hayat, introduces a novel robotic platform designed for cleaning staircases and slopes. Unlike existing robots that operate on either stairs or slopes, s-Scarr can traverse both by reconfiguring its morphology. The robot consists of three interconnected modules with a vertical linear actuator, enhancing stability and preventing toppling. Experiments demonstrated its ability to perform smooth transitions and effective area coverage on inclined surfaces. The study highlights the importance of reconfigurable mechanisms in robotic cleaning applications and suggests future improvements for autonomy and efficiency.[13]

Kartik Mudaliyar, Nimbaji Tayde, Amol Zalke, Nikhil Morankar, Rahul Narde, and Nilesh Empreddiwar presents the development of a stairclimbing robot designed to navigate both structured and unstructured environments. The robot employs a specialized wheel and linkage mechanism, enabling it to overcome obstacles and ascend stairs with high energy efficiency. It features remote controlled operation, rubber-coated wheels for improved traction, and a lightweight yet durable aluminum structure. The study explores the mechanical components, construction methodology, and advantages of the design, highlighting its potential applications in surveillance, hazardous environment navigation, and autonomous cleaning. The robot's adaptability to curved and inclined surfaces further demonstrates its effectiveness in real-world scenarios. [14]

Thejus Pathmakumar, Vengadesh Ayyalusami, presents an innovative cleaning robot, hTetro, which is inspired by Tetris tiling theory to achieve efficient area coverage. Traditional robotic floor cleaners often face challenges in covering irregular spaces, but hTetro overcomes these limitations by reconfiguring its shape dynamically. The robot leverages polyomino tiling theory, a mathematical concept used in gaming and graphics, to autonomously generate optimal tile sets for full area coverage.[15]

III. METHODOLOGY

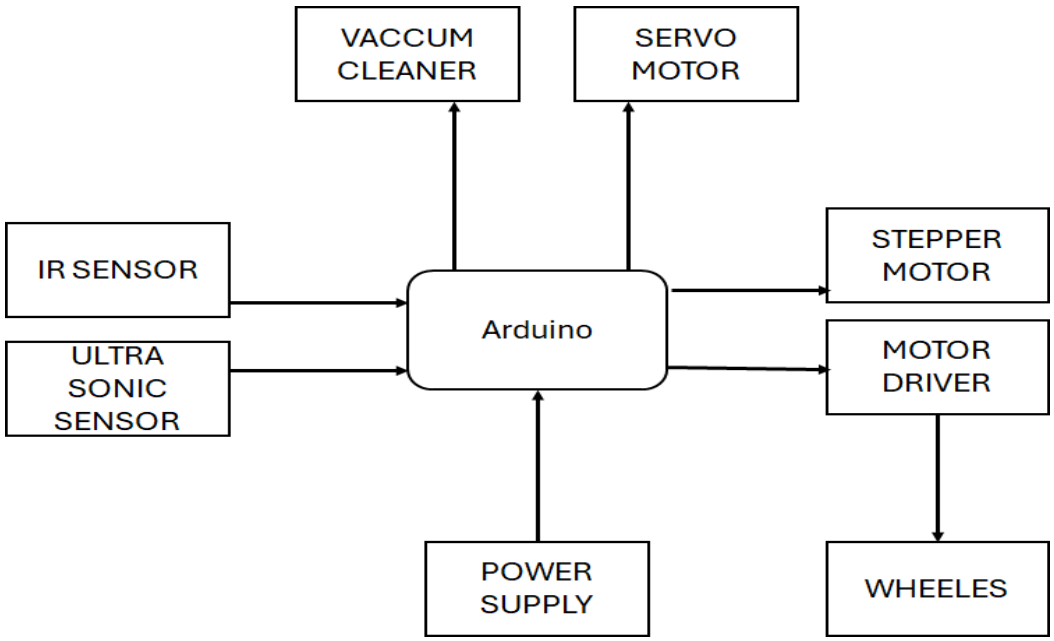

Fig.1 Block diagram related to staircase cleaning robot

Block diagram: Figure 1 The diagram represents an Arduino-based staircase-cleaning robot with sensors, motors, a vacuum cleaner, and a power supply for autonomous operation.

Objectives:

* To Ensure thorough cleaning of stair edges, corners, and risers for improved cleanliness. To Develop a reliable climbing mechanism for smooth and stable movement on staircases.
* To Improve battery efficiency to extend operational time while maintaining performance.
* To Create a lightweight and space-efficient robot suitable for both residential and commercial use.
* To Design a durable and affordable system with minimal maintenance requirements.

Working

The robot operates when all components receive power, supplying the correct voltage and current to the Arduino, sensors, motors, vacuum cleaner, and servo motor. The IR sensor detects edges to prevent falls, while the ultrasonic sensor measures distance and detects obstacles for safe navigation. The Arduino processes sensor data in realtime, making decisions to control movement and cleaning mechanisms. A stepper motor enables precise, stable staircase climbing, while the motor driver ensures smooth wheel motion, controlling acceleration and braking. When positioned on a step, the vacuum cleaner efficiently collects dust and debris through suction. A servo motor operates the mopping mechanism, wiping away any remaining dirt or stains in a controlled manner. Sensors continuously monitor obstacles and determine the next step, allowing the robot to repeat the cleaning cycle until it successfully climbs the entire staircase.

Flowchart:

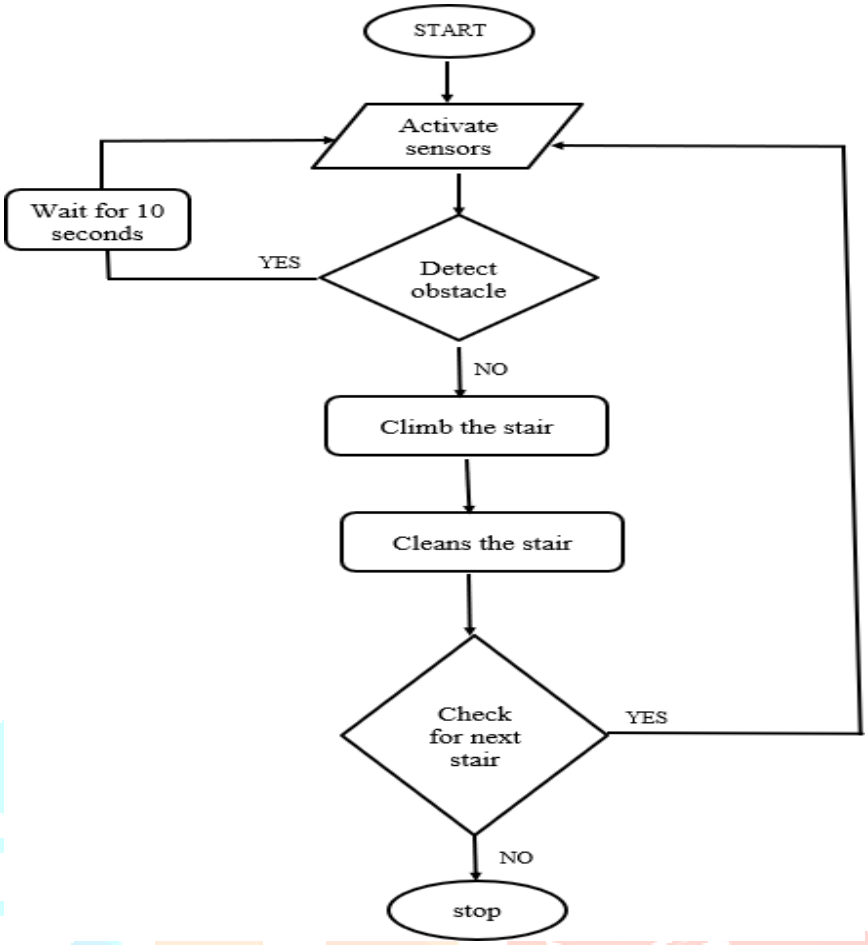

Fig 3. Flow chart staircase cleaning robot.

IV. RESULTS

The robot starts in its initial position, with all components at rest. The NEMA17 stepper motor is stationary, the nut and bolt mechanism is at its lowest position, and the green wheels are aligned with the ground while the yellow wheels provide support. The servo motor holding the cleaning brush is set at 180°, and all electronic components, including the motor driver, Arduino, and power supply, are initialized and ready for operation. The system ensures that sensors, if present, are active to detect obstacles and stair dimensions

Fig 4(a). The robot's frame moves upward in a locomotion.

To ascend the stairs, the NEMA17 stepper motor rotates in the forward direction, driving the nut and bolt mechanism, which lifts the robot's main body along the guide rods. This movement causes the green wheels

to move upward, facilitating stair climbing, while the yellow wheels rotate forward to provide balance. The Arduino microcontroller regulates the movement speed, ensuring stability, and the motor driver module efficiently distributes power. The robot continues to ascend until it reaches the top of the stair, at which point the motor stops, stabilizing the robot

Once the robot reaches the desired height, it begins to return to its initial position. The NEMA17 stepper motor reverses direction, causing the nut and bolt mechanism to lower the robot's body. The green wheels descend, making contact with the stair, and the yellow wheels adjust for support. The Arduino controller monitors the descent speed, ensuring a smooth return to prevent jerky movements. The frame structure provides additional support, maintaining balance, while the power supply ensures consistent voltage output to avoid power fluctuations. When the robot reaches the initial position, all movement components reset, preparing for the cleaning phase.

Fig 4(b) The robot's frame ascends to the next step.

Fig 4(c) The robot moves towards the left Side till the wall is detected.

The dust sweeping mechanism is then activated. The servo motor rotates from 180° to 0°, positioning the cleaning brush against the stair surface. The sweeping brush moves systematically, collecting dust and debris, which is either pushed forward or suctioned using a vacuum system if available. The Arduino ensures precise movement timing, and if extra debris is detected, the sweeping motion may repeat for thorough cleaning. The collected dust is either stored in a compartment or disposed of externally. After completing the cleaning operation, the servo motor resets the brush to its original 180° position

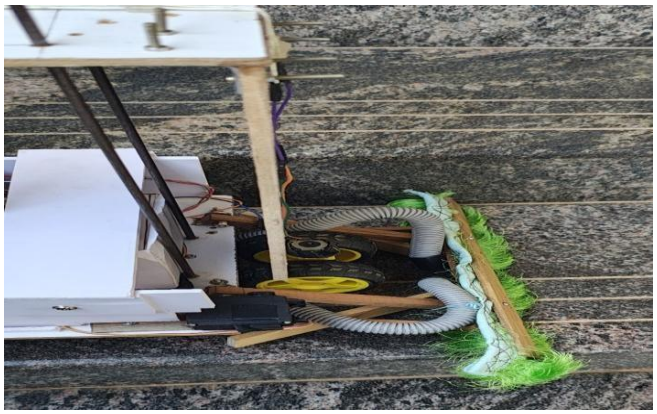

Fig 4(d) The mop touches the ground by Using servo motor to clean.

Finally, the robot performs a reset operation to prepare for the next cycle. The servo motor moves the brush to the right and then back to the left for final dust collection. The system ensures that all debris is cleared before proceeding. The Arduino resets the stepper motor position, and the NEMA17 motor is ready for the next stair-climbing cycle. The robot remains stable, ensuring efficiency and accuracy in every movement.

V. APPLICATION

A staircase cleaning robot offers versatile applications across various environments, significantly reducing manual effort and enhancing hygiene. In household settings, it automates staircase cleaning, ensuring regular maintenance and keeping stairs dust-free and hygienic. In commercial buildings such as offices, malls, and hotels, it maintains cleanliness despite high foot traffic. Hospitals benefit from its ability to provide a dust-free and germ-free environment, preventing allergen accumulation and supporting stringent hygiene standards. Educational institutions like schools and universities can use it to keep staircases clean in high-movement areas, reducing health risks. In industrial settings such as factories and warehouses, the robot effectively removes dust and debris, improving workplace safety by keeping staircases clean and slip-free. For smart homes, it can be integrated into home automation systems to perform scheduled cleaning autonomously, making home maintenance more convenient and efficient. Public spaces such as railway stations, airports, and government buildings also benefit, as the robot reduces the need for manual cleaning in busy environments. Additionally, it provides a helpful solution for the elderly and individuals with mobility challenges, easing the physical burden of cleaning staircases and promoting independent living.

VI. CONCLUSION

This is a staircase cleaning robot performs automated cleaning by climbing the stairs. It combines a vacuum suction system with a mopping mechanism driven by a servo motor to facilitate the removal of dust and debris. The ultrasonic sensor helps to detect the obstacles, and the IR sensor helps to detect the edge. Smooth Mobility with Stepper and DC Motors Processing of the data is done in Arduino Nano which ensures quick and easy compatibility with hardware components. the robot can be on its own for a long time. Energy efficient system & compact design of the robot makes it easy to use for household & commercial purposes.

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