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SURVEY ON STAIR CASE CLEANING ROBOT

S. Shajith Ali[1], Yashwanth M[2], Vyshak G R[3], Adithya D[4],

Dr. Rekha N[5]

Department Of Electronics And Communication, K S Institute Of Technology, Bangalore, India[1]

Department Of Electronics And Communication, K S Institute Of Technology, Bangalore, India[2]

Department Of Electronics And Communication, K S Institute Of Technology, Bangalore, India[3]

Department Of Electronics And Communication, K S Institute Of Technology, Bangalore, India[4]

Professor, Department Of Electronics And Communication, K S Institute Of Technology, Bangalore, India[5]

ABSTRACT- The Staircase Cleaning Robot is an innovative solution designed to automate the cleaning of staircases in residential, commercial, and industrial settings. The robot is equipped with advanced sensors for obstacle detection, edge recognition, and precise navigation, ensuring effective cleaning without falling or collisions. It features modular cleaning tools, including brushes and vacuum mechanisms, tailored to remove dust and debris in horizontal surfaces. Powered by a rechargeable battery and the robot can operate autonomously. This device offers a time-saving, efficient, and user-friendly alternative to manual staircase cleaning.

Keywords – Autonomous cleaning, obstacle detection, edge recognition, modular cleaning tools, automation, robotics.

I. INTRODUCTION

In our daily life maintaining cleanliness in staircases poses unique challenges due to their structure and frequent usage in residential, commercial, and industrial spaces. Traditional
manual cleaning methods are often time-consuming, labor-intensive, and prone to inconsistencies. With advancements in robotics and automation, there is a growing need for innovative solutions that can address these challenges efficiently and effectively. The Staircase Cleaning Robot is a cutting-edge development aimed at automating the cleaning process of staircases. Equipped with advanced sensors for obstacle detection, edge recognition, and precise navigation, the robot ensures thorough cleaning while preventing falls or collisions. By leveraging modular cleaning tools, including brushes and vacuum mechanisms, this device is tailored to remove dust and debris from horizontal surfaces with precision. Designed for autonomous operation and powered by a rechargeable battery, the robot offers a user-friendly, efficient, and time-saving alternative to manual cleaning, making it a valuable addition to modern cleaning.

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II. LITERATURE PAPER

Rajesh Kannan Megalingam. has proposed **"Stair case cleaning robot: Design considerations and a case study".** In this paper the proposed idea is to design a 3-D staircase climbing robot capable of autonomously cleaning various facilities, including houses and public buildings, by navigating stairs and uneven surfaces. However, the drawbacks include the complexity of ensuring the robot's stability and weight distribution while climbing, the need for advanced sensors and algorithms for effective navigation, and the challenge of accommodating the diverse dimensions of staircase steps, which can vary widely without standardization. Additionally, existing cleaning robots are primarily 2-D and lack the capability to manage stairs, highlighting the need for further research and development in this area. [1]

Patil et al. has proposed **"A New Compact Stair-Cleaning Robot".** The proposed idea in this paper is a new compact stair-cleaning robot that utilizes a single motor to drive retractable legs for efficient stair climbing and cleaning, addressing the issues of size, complexity, and cost associated with traditional robots. However, the robot has drawbacks, including limited performance on stairs with high risers or narrow treads, potential stability issues during descent, and the need for further improvements in reliability and control algorithms for optimal cleaning efficiency. [2]

TaeWon Seo et al has proposed **"Stair-Climbing Robots: A Review on Mechanism, Sensing, and Performance Evaluation".** This paper reviews various stair-climbing robots, focusing on their mechanisms, sensing strategies, and performance evaluations. It categorizes robots into tracked, legged, wheel-legged, and wheel-linkage types, highlighting innovations that enhance stair navigation. The study also addresses challenges faced by these robots, particularly their reliance on stair risers. [3]

Areed and Marwa F. has proposed **"Humanoid Autonomous Self- Balancing Weight"**. The paper proposes an automated humanoid robot capable of lifting heavy

loads and climbing stairs using ultrasonic sensors for obstacle detection and navigation. It outlines a cost-effective design that replaces expensive 3D cameras with ultrasonic sensors, ensuring stability and self-balancing during operation. The robot is intended for practical applications, including contactless delivery, by efficiently navigating complex environments while carrying packages. [4]

Leppänen, S. Salmi, A. Halme has proposed **"Work Partner HUT Automation's new hybrid walking machine".** Stairs are common obstacles in indoor environments and are difficult to overcome for robots. The speed of robot stair-climbing should be similar to that of humans for commercial products, but their speed remains limited. Additionally, the variety of dimensions of stairs is also a significant problem for robust stair-climbing by robots. In this paper, a curved spoke based tri-wheel mechanism is proposed for fast and robust stair-climbing. The goal speed of stair-climbing is similar to the human speed for variously sized stairs. The proposed wheel system is composed of a tri-wheel mechanism with a curved spoke, wherein the dimensions of the mechanism are determined based on a kinematic analysis. [5]

Kanyasorn Phongphaitoonsin has proposed **"Development and Control of a Stair-Climbing Vacuum Cleaner Robot".** This thesis presents the design and implementation of a vacuum cleaner robot capable of autonomously navigating and cleaning staircases. The robot utilizes low-cost sensors and a scissor lift mechanism for effective stair climbing. It is driven by an Arduino microcontroller, interfacing with various components for seamless operation. The study highlights the challenges faced and the solutions developed to optimize functionality and efficiency. Overall, the research contributes to advancements in robotic cleaning technology. [6]

Ayman Assem has proposed **"Smart Staircase: Interactive Design for Social Distancing and Crowd Management".** This study explores a novel architectural framework that integrates design and technology to enhance crowd management and enforce social distancing in public spaces. By focusing on staircases as critical vertical circulation elements, the research introduces interactive designs leveraging Arduino microcontrollers, ultrasonic sensors, and LED lighting. A 1:5 scale prototype was developed to test user-responsive illumination systems that optimize crowd flow and encourage compliance with social distancing protocols. Combining architectural design principles with smart technologies, the proposed solution dynamically manages user behavior while promoting safety and functionality in high-traffic environments. [7]

Sheng Liu, Weiming Qing, Dong Zhang, Chongzao Gan, Jiacheng Zhang, Sihua Liao, Kexiang Wei, Hongxiang Zou has proposed **"Flexible Staircase Triboelectric Nanogenerator for Motion Monitoring and Gesture Recognition".** This paper presents a flexible triboelectric nanogenerator (TENG) with a staircase-style structure, utilizing tin antimony oxide

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(ATO)-modified polyvinylidene fluoride (PVDF) composite films for human motion monitoring and gesture recognition. The ATO/PVDF film significantly enhances the triboelectric charge density, achieving a peak voltage of 70 V and a power density of 0.58 W/m²—10 times higher than pure PVDF. The sensor can monitor wrist or finger movements, enabling real-time gesture recognition by detecting bending states and corresponding signals. This flexible and durable TENG demonstrates potential applications in wearable devices, human-computer interaction, and intelligent sensing systems. [8]

Xiaonan Yang, Haopeng Zhang, Haocai Luo has proposed **"System Design of a Stair Climbing Disinfection Robot Based on C-Legged".** This paper presents a robust design for a stair-climbing disinfection robot using a C-legged structure inspired by the motion gait of cockroaches. The robot integrates a liquid storage tank and an atomization pump to achieve remote-controlled disinfection. The C-leg motor operates through a three-loop cascade PID control system for simultaneous speed and angle control, enhanced by a Buffer Zone method and finite state machine logic. Simulations and real-world experiments demonstrate the robot's stable movement on flat ground and efficient stair climbing. The system offers a promising solution for automated stairwell disinfection in practical applications. [9]

Prabakaran Verajagadheswa, Prathap Soundar Kandasamy, Karthikeyan Elangovan, Mohan Rajesh Elara has proposed **"A novel autonomous staircase cleaning system with robust 3D-Deep Learning-based perception technique for Area-Coverage".** Cleaning staircases is an essential task for commercial cleaning robots to achieve comprehensive cleaning of constructed buildings. While existing robotic platforms focus on ascending staircases, they lack the ability to perform both ascending and descending motions during cleaning, which is crucial for enhanced efficiency. This paper introduces the "sTetro_plotter," a reconfigurable cleaning robot capable of ascending and descending stairs autonomously. The proposed perception framework, built on PointNet++, enables the robot to traverse stairs and achieve area coverage using 3D point cloud data. This framework utilizes classification and regression techniques to generate bounding boxes for tracking staircase features. A sweeping LiDAR sensor is employed for environmental sensing. Real-world experimental results demonstrate the robot's capability to autonomously clean staircases with robust area coverage and efficient perception. [10]

Huy Do, Prabahar Veerajagadeshwar Fangbin Sun, Yujie Guo has proposed **"Combined Grid and Heat Conduction Optimization for Staircase Cleaning Robot Path Planning".** Staircase climbing in complex environments of multi-storey buildings presents challenges for robotics. By drawing an analogy between robot path planning and heat conduction, this paper introduces a novel path-planning technique that optimizes energy consumption for a self-reconfigurable staircase cleaning robot, sTetro. The sTetro robot features a shape-shifting mechanism enabling descent and ascent on staircases. The proposed method employs a grid-based optimization inspired by heat transfer principles, leveraging temperature gradients to identify optimal paths that minimize both path length and energy consumption. Simulation results across six virtual environments demonstrate effective path planning, with validation tests on the sTetro robot in two real-world staircase scenarios showing a 21% reduction in energy consumption compared to conventional methods. [11]

Muhammad Ilyas, Anirudh Krishna Lakshmanan, Anh Vu Le has proposed **"Staircase Recognition and Localization using Convolution Neural Network (CNN) for Cleaning Robot".** Multi-floor environments are often overlooked in designing autonomous cleaning robots. However, effective operation in such settings necessitates robots capable of traversing staircases. This paper introduces a deep learning-based approach using Convolutional Neural Networks (CNNs) for staircase recognition and localization. The system employs an object detection network to identify staircases in images and a contour detection algorithm to locate the target point (the center of the first step) and determine the angle of approach. Experimental results demonstrate the model's accuracy in detecting staircases and localizing their positions, using images from various types and angles of staircases. The method proves effective for autonomous navigation in multi-floor indoor environments. [12]

III. CONCLUSION

The Staircase Cleaning Robot represents a significant advancement in the field of automated cleaning systems, addressing the challenges of maintaining staircases in diverse environments. Our survey highlights the innovative integration of advanced sensors, modular cleaning tools, and autonomous operation to deliver efficient, safe, and effective cleaning. This technology not only enhances cleaning precision but also minimizes human effort, making it a practical and time-saving solution for residential, commercial, and industrial applications. Future work could explore the incorporation of AI for adaptive learning, improved energy efficiency, and customizations to cater to varied staircase designs and materials. The study underscores the potential of such robotic solutions in transforming traditional cleaning practices and promoting automation in daily tasks.

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