ICEST-2K24 [International Conference on Engineering, Science and Technology]
In Association with
International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN - 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)

Smart Glass Cleaning Robot

Mahesh. M. Zade, Yogesh Bhosale, Himanshu Singh, Dadasaheb Maske
SPVP's S. B. Patil College of Engineering, Indapur, Maharashtra, India

ABSTRACT
With the rapid advancement in robotics and automation technologies, there has been a growing interest in developing intelligent systems for various household tasks. One such task is the cleaning of glass surfaces, which often requires precision and efficiency. In this study, we present the design, implementation, and performance evaluation of a Smart Glass Cleaning Robot (SGCR). The SGCR is equipped with state-of-the-art sensors, actuators, and control systems to autonomously navigate and clean glass surfaces of varying sizes and shapes. The robot employs a combination of computer vision techniques, including object detection and localization, to identify the areas requiring cleaning and to avoid obstacles in its path. Furthermore, machine learning algorithms are utilized to adaptively improve its cleaning performance over time based on user feedback.

Keywords: Robotics, Intelligence system, Performance, Sensors, Machine learning.

I. INTRODUCTION

Robots have been created to assist or replace humans in various dangerous and difficult tasks. Robots have been used in construction, manufacturing, security and etc. This is because they are able to adapt to different environments and situations.[1]It is difficult to clean the exterior side of windows due to the risk of accident as for apartments or high-rise buildings; dedicated cleaning businesses use rope or gondola hanging from the top of building to clean exterior side of windows. Since exterior side of windows are unlikely to be periodically cleaned for the reasons of risk of safety accident, work efficiency, and economic burden, those exterior side of windows are often left dirty. The studies for equipment to clean exterior side of window have been so far reported for vacuum adsorption or rope lifting [3] The last few years have witnessed a strong, renewed interest in climbing and walking robotic technologies. At the end of the 1990s several different prototype robots were developed for different types of applications in different areas. In this paper the emphases for discussion are on the wall cleaning robot for high-rise buildings. There are a large number of high-rise buildings with curtain glass walls in modern cities. External cladding of buildings not only provides an attractive exterior appearance, but also increases their durability. These walls require constant cleaning which is presently typically carried out using a costly, permanent gondola system hanging from the roof of the building.[4] Window cleaning is a two-stage process; application of cleaning fluid, which is usually achieved by using a wetted applicator and removal of cleaning fluid by a squeegee blade without spillage on to other areas of the facade or previously cleaned areas of glass. This is particularly difficult for example if the window is located on the roof of a building and cleaning is performed from inside by the human window cleaner [5] Until now, several types of window cleaning robot

with special locomotion have been proposed. Most of them are using vacuum sucker as an adhering unit. Some of them have the driving wheels to make continuous movement on the window, others use the legged locomotion to make a discrete walking on the window. However, it is difficult to apply these kinds of vacuum sucker-based window cleaning robots to the real domestic environments. To be the practical window cleaning robot for the home, a small office and a shop, it should be small, light and energy efficient to such an extent as to need no external line for portability. In addition to this, it should be safe from falling down and autonomous operating system with no human concern during the entire cleaning stage. Most of vacuum sucker based window cleaning robot do not meet all conditions addressed above, they generally have a external power line or a vacuum pipe line because keeping vacuum state is very energy consuming and they are not safe from falling down in system malfunction situation losing controllability to keep vacuum state [7].

II. LITERATURE SURVEY

Requirements of glass cleaning and development of climbing robot systems: The benefits of developing glass wall cleaning robots include two aspects. Development and application of a kind of cleaning robotic system can free workers from this hazardous work and realize an automatic cleaning of high-rise buildings,furthermore improve the technological level and productivity of the service industry in the building maintenance. At the same time, the cleaning robotic system can be used on different buildings and save the expensive cost of investment for permanent gondola systems at the individual building.[4]

A. Robot Control System For Window Cleaning

Window cleaning is a two-stage process; application of cleaning fluid, which is usually achieved by using a wetted applicator and removal of cleaning fluid by a squeegee blade without spillage on to other areas of the facade or previously cleaned areas of glass. This is particularly difficult for example if the window is located on the roof of a building and cleaning is performed from inside by the human window cleaner. Simulation studies were conducted to demonstrate the feasibility of a robot system to act and mimic the human operator an end effector had to be designed to accommodate different tools such as applicator and squeegee; the pay load for tool handling; sensory feedback requirements; force and compliance control; and finally, the cost of the overall system had to be feasible.[5]

B. Window Cleaning System with Water Circulation for Building Façade Maintenance Robot

Recently, most of buildings have been constructed with façade systems such as a curtain glass wall rather than with concrete as a traditional way. The contemporary high-rise buildings with the glass facades require periodic maintenance, especially window cleaning, due to excessive dust and pollution in the city.1 Conventional maintenance usually relies on human labours and a gondola that is suspended by cable-driven system. However, these methods require experienced labours, are inherently danger, and sometimes cause emergency situations when occurring wind gust or earthquake. For these reasons, many studies have been conducted on the subject of automating window cleaning work of high-rise buildings. Since the building walls are always vertical and are in the direction of gravity, the ability of locomotion on the vertical surface has been important issues.2,3 Thus, there have been many studies regarding how to generate the holding force against the gravity, such as magnetic force,4,5 suction force,6-10 suspended cable,11-20 guide rail built-in the building wall facade,21-24 and

biomimetic adhesion force.25-27 However, only the suspended cable and built-in guide rail based systems have been applied to real buildings, since others are not reliable enough yet.[6]

C. Smart Window Cleaning Robot

We introduced the smart window which is the follow-up model of the window developed toward the commercialization for domestic use such as the show window of a shop, the window at home and so on. In order to improve the windrow's weakness, the smart window adopts additional units such as an autonomous magnetic force control unit, a vertical position estimation unit and a corner cleaning mechanism. The smart windrow becomes more intelligent and achieves higher cleaning performance through these improvements.[7]

D. Portable Autonomous Window Cleaning Robot

Normally cleaning of wide windows on tall and multi-story buildings is quite tedious and very dangerous procedure. It can be done outside either using hoisting machines with manual cleaning or very rare by sophisticated, complex, large, heavy and very expensive automatic cleaning machines operated manually from the ground floor. These large machines, besides, have to carry a bunch of umbilical pneumatic and electrical cables while cleaning the windows.[8]

III.PROPOSED SYSTEM

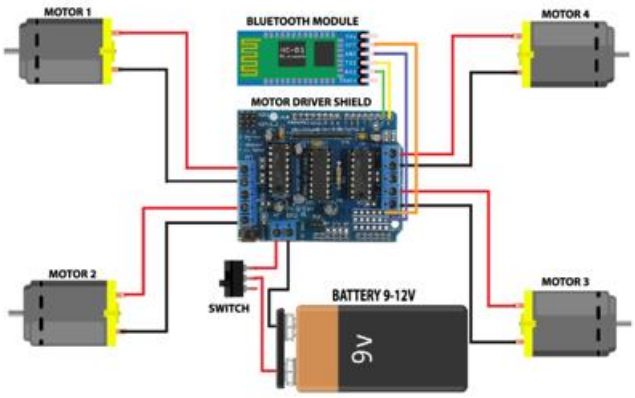

Figure 1: Circuit Diagram for Smart glass cleaning robot

The circuit diagram of the Smart Glass Cleaning Robot is very simple. At the very top in the circuit diagram is the 5v regulated Power Supply which is based on the LM7805 voltage regulator. The 5 volts from this regulator is used to power up the Atmega328 microcontroller and is also connected with the +5v pins of the L298N Motor Drivers. The 5volts from the LM7805 are also used to power up the HC05 Bluetooth Module. The entire circuit is powered up using the Lipo Battery.

The Bluetooth module is connected with the Atmega328 TX and RX pins. The TX pin of the Bluetooth Module is connected with the RX pin of the Atmega328 microcontroller while the RX pin of the HC05 Bluetooth Module is connected with the TX pin of the Atmega328 microcontroller. While uploading the program into the Atmega328 microcontroller disconnect the TX and RX pins. Otherwise, you won't be able to upload the program.

As you know each L298N Motor Driver can be used to control 2 motors. As you know in this project 4 motors are used, so, it means we will need two L298N motor drivers. All the 4 motors are connected with the outputs of the Motor Drivers" L298N" which can be clearly seen in the circuit diagram. The input pins of the L298N Motor Driver are connected with the Atmega328 microcontroller. All the pins are clearly labelled.
The PWM pin of the Brushless Motor is connected with the Atmega328 pin number 11 which is the PWM pin. Pin number 11 is used to control the speed of the Brushless Motor. A variable resistor is connected with the Analog pin of the Atmega328 controller, this variable resistor is used to control the speed of the Brushless motor. By rotating the Knob of the Variable Resistor, the speed can be adjusted

A. Precautions

One of the most important things that you really need to take care of is the weight of the Robot. Use lightweight parts. Instead of using the large controller boards, like Arduino Uno or Mega2560 make a custom-made controller board. This way you can reduce the price, size, and weight of the circuit board. Use very small Dc Gear Motors. While working on this project the only thing that I focused on was the weight of the Robot. For the best understanding, I designed a basic 3D model of the Smart Glass Cleaning Robot using SolidWorks 2016.
I recorded the dimensions of all the electronic parts using a Vernier Calliper and then designed each part in the SolidWorks. I roughly started with a 200×200 mm base frame. Luckily a frame of this size could accommodate all the parts. Then I started searching for a 200×200 mm lightweight sheet and luckily, I found a PCB Copperplate of the same dimensions. To overcome the bending problem, I cut the corner edges of the Copperplate and then fixed the 6v 60RPM Mini Dc Geared motors.

B. Hardware Requirements

Hardware: Arduino UNO Atmega328p -Vin, 3.3V, 5V, GND, L293D Driver, BLDC Motor, Bluetooth Module HC-05 - Operating Voltage: 4V to 6V, N20-6V-60 RPM Micro Metal Gear-box DC Motor, ESC BLDC Motor Driver,

IV. RESULTS AND DISCUSSION

A. Functionality Evaluation

- Assess the performance of the robot in cleaning various types of glass surfaces, including windows, mirrors, and glass doors.
- Discuss the effectiveness of the cleaning mechanism in removing dirt, dust, and streaks from the surfaces.
- Evaluate the robot's ability to navigate autonomously across different environments, considering factors such as obstacles, edges, and surface irregularities.

B. User Experience

- Gather feedback from users who interacted with the robot during testing and evaluation phases.
- Discuss the ease of setup and operation, as well as any challenges or limitations encountered.
- Explore user satisfaction regarding the cleanliness achieved by the robot and the overall convenience it offers in glass cleaning tasks.

C. Performance Metrics

- Present quantitative metrics used to evaluate the robot's performance, such as cleaning efficiency, coverage area, and battery life.
- Compare these metrics with initial project goals and expectations to determine the level of success achieved.

D. Safety and Reliability

- Highlight the safety features implemented in the robot to prevent falls, collisions, and other hazards.
- Discuss any instances of malfunctions or unexpected behavior encountered during testing and how they were addressed.
- Evaluate the reliability of the robot in performing its intended tasks consistently over time.

E. Future Improvements

- Identify areas for potential improvement based on feedback from users and observations during testing.
- Discuss ideas for enhancing the robot's performance, reliability, and user experience in future iterations.
- Consider incorporating advanced features or technologies to further optimize the robot's capabilities.

TABLE I COMPARISON BETWEEN HUMAN GLASS CLEANING AND ROBOTIC GLASS CLEANING

Parameter	Human glass cleanings	Robot glass cleaning
Speed	Slow	fast
Efficiency	Low	high
Autonomy	Manual	Atomic
Safety	Low	high
Cost	Low	high

V. RESULTS AND DESCRIPTION

After uploading the program and installing the Android application. I powered up the Smart Glass Cleaning Robot using the SMPS Power and adjusted the speed of the Brushless Dc Motor. My first test was to test the suction created by the Brushless Dc Motor. The Smart Glass Cleaning Robot stuck to the Wall Surface. I could feel that force.My initial test was a great success. Then I performed some tests on Wooden sheets, Walls, and Glass. On the Wall and Wooden sheet surfaces the Smart Glass Cleaning Robot could move without any problem, but on the Mirror surface there was the sliding problem. For the extremely smooth surfaces, the suctions cups can be used.

Below are the images of our final project:

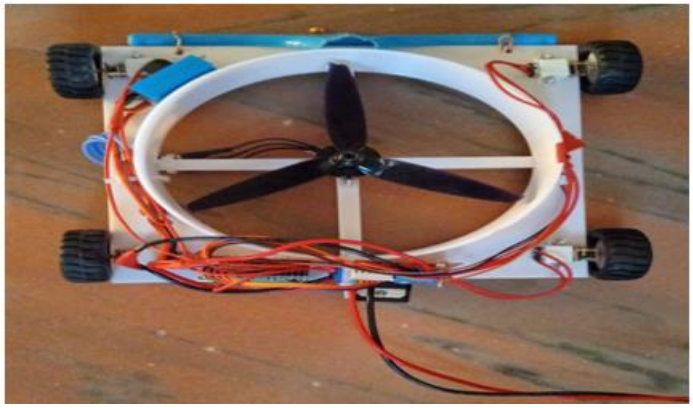

Figure 2: Final Project Prototype

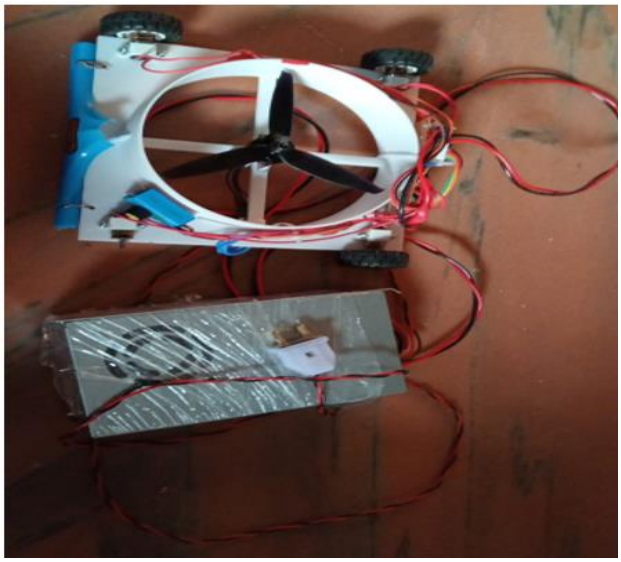

Figure 3: Final Project Prototype

VI. CONCLUSION

As we conclude our exploration of the Smart Glass Cleaning Robot, it is evident that its development represents not only a technological achievement but also a testament to the transformative potential of robotics in enhancing everyday life. Looking ahead, further advancements in robotics and artificial intelligence hold promise for expanding the capabilities of the SGCR, enabling it to tackle more complex cleaning challenges and integrate seamlessly into smart home ecosystems. The SGCR stands as a shining example of innovation in household robotics, offering tangible benefits in terms of time savings, convenience, and cleanliness. As it continues to evolve and mature, the SGCR is poised to become an indispensable companion in modern households, redefining the way we approach household chores and setting new standards for automation and efficiency.

VII. REFERENCES

[1]. Design and fabrication of an automatic window cleaning robot January 2010 [online ResearchGate].
[2]. Exterior Climbing Mirror Cleaning Robot based on Vilnius Gediminas Technical University,

[3]. Department of Construction Economics &
[4]. PropertyHybrid Fuzzy-PID and Pneumatic Control System -2013 5th International Conference on Knowledge and Smart Technology (KST).
[5]. Calculation of Optimal Magnetic Force for Automatic Control Magnetic Force of the Window Cleaning Robot - 2013 10th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI) October 31-November 2, 2013 / Ramada Plaza Jeju Hotel, Jeju, Korea.
[6]. Requirements of glass cleaning and development of climbing robot systems- Conference: Intelligent Mechatronics and Automation, 2004. Proceedings. 2004 International Conference on February 2004
[7]. DOI:10.1109/ICIMA.2004.1384170. Source-IEEE Xplore.
[8]. ROBOT CONTROL SYSTEM FOR WINDOW CLEANING -WP8 = 4:20 Proceeding of the American Control Conference Baltimore, Maryland June 1994.
[9]. Window Cleaning System with Water Circulation for Building Façade Maintenance Robot and Its Efficiency Analysis - INTERNATIONAL JOURNAL OF PRECISION ENGINEERING AND MANUFACTURING-GREEN TECHNOLOGY Vol. 2, No. 1, pp. 65-72 JANUARY 2015 / 65
[10]. SMART WINDORO V1.0: Smart Window Cleaning Robot - 2012 9th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI) Daejeon, Korea Nov. 26-28, 2012.
[11]. Portable Autonomous Window Cleaning Robot - International Conference on Robotics and Smart Manufacturing (RoSMa2018).
[12].]. J. Zhu, D. Sun, and S. Tso, "Development of a
[13]. tracked climbing robot," Journal of Intelligent and
[14]. Robotic Systems, vol. 35, pp. 427-444, 2002
[15]. 10. A. Nishi, "Development of Wall climbing Robots,"
[16]. Comp Elect Eng, vol. 22, pp. 123-149,1996
[17]. Niku S. B., Introduction to Robotics, Analysis, Systems, Applications, Prentice Hall, 2001Y.H. Choi, K. M. Jung, “WINDORO: The World’s First Commercialized Window Cleaning Robot for Domestic Use”, International Conference
[18]. Engineering And New High-Tech Products Development–MECAHITECH’11, vol. 3,pp.258-267, 2011
[19]. Shinde Mayur et al.,“Automatic Window Washing Robot”, International Journal of Emerging Technology and Advanced Engineering, Volume 6, Issue 4, pp.59-62, April 2016
[20]. Engineering And New High-Tech Products Development–MECAHITECH’11, vol. 3,pp.258-267, 2011
[21]. Young-Ho Choi, Jae-Youl Lee, Jong-Deuk Lee and Ka-Eun Lee, "SMART WINDORO V1.0: Smart window cleaning robot," 2012 9th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI), Daejeon, 2012, pp. 116-119.
[22]. N. Imaoka, S. g. Roh, N. Yusuke, and S. Hirose, "SkyScraper-I: Tethered whole windows cleaning robot," 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems, Taipei, 2010, pp. 5460-5465
[23]. McKerrow, P. J., Introduction to Robotics, Addison Wesley, 1995
[24]. R. K. Mudi, N. R. Pal, “A robust self-tuning scheme for PI and PD type fuzzy controller”, IEEE Trans. Fuzzy Systems, Vol. 7(1), pp. 2-16, 1999.
[25]. R. K. Mudi, N. R. Pal, “A robust self-tuning scheme for PI and PD type fuzzy controller”, IEEE Trans. Fuzzy Systems, Vol. 7(1), pp. 2-16, 1999.
[26]. Johnson, Curtis D., Process Control Instrumentation Technology Sixth Edition, Prentice Hall, 2000

[27]. G.L. Rosa, M. Messina and G. Muscato, “A low-cost lightweight climbing robot for the inspection of vertical surface,” Mechatronics, no. 12, pp. 71-96, 2003.

[28]. T. Miyake, H. Ishihara, R. Shoji and S. Yosida, “Development of Smal-Size Window cleaning Rbot,”, International Conference on Mechatronics and Automation, pp. 1302-1307, 2006

[29]. M. Abderrahim, C. Balaguer, A. Giménez, J.M. Pastor and V.M, Padron, “ROMA: A Climbing Robot for Inspection Operations”, Proceedings 1999 IEEE International conference

[30]. Seo, T., Jeon, Y., Park, C., & Kim, J. (2019). Survey on Glass And Façade-Cleaning Robots: Climbing Mechanisms, Cleaning Methods, and Applications. International Journal of Precision Engineering