Skyscraper's Glass Cleaning Automated Robot

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Abstract -The automated robot is one of the robots that have emerged in recent decade. This robot can be used in large buildings. The main target is to design a robot that can clean exterior glass surface of skyscrapers efficiently and rapidly even in dangerous and hazardous places. The robot is being controlled using the Programmable Logic Controller (PLC), its motion is generated by the use of D.C. motors.

Index Terms – Automated robot, cleaning glass, PLC, skyscrapers, suction-cup

1 INTRODUCTION

THERE exists increasing demand for the development of various service robots to relieve human beings from hazardous jobs, such as cleaning glass-surface of skyscrapers, fire rescue, and inspection of high pipes and walls. This project is based on a climbing robotic system aimed to clean glasses of high-rise buildings, using suction cups for adhering to the glass.

Based on the results of interdisciplinary fields like mechanics, electronics and informatics the autonomous mobile robots are gaining more and more attention. The methods used for movement, actuation and none the last the ability to operate in unknown and dynamic environments give them a great complexity and a certain level of intelligence.

The human model is still a challenge for mobility and robot movement. Robot mobility is satisfactorily achieved, in some cases even better with other types of locomotion means, but technical solutions that rigorously reproduce human walking are not yet identified.

Feasible solutions can be found in the situation when human mobility reaches its limits (movement on planes with high inclination angles, including 90° – vertical and 180° – parallel to the horizontal plane – ceiling type). Autonomous robot mobility on planes characterized by high inclinations is less tackled in specialty literature, some encountered solutions being objects of patents.

The research in this field has a tremendous potential especially in providing new ideas and/or knowledge development. The field of professional and domestic services, especially the wall cleaning of high buildings, is one of the areas that are expected to obtain a strong benefit from the use of robotic systems able to displace on vertical surfaces.

The advantages of the technologies that use climbing and walking robots consist mainly of two aspects:

- Automatic cleaning of high buildings, improvement of technological level and of productivity of service industry in the field of building maintenance.
- Cleaning robots can be used on various types of building, avoiding thus high costs involved by permanent gondola-type systems (open platform-car or baskets) for individual buildings.

The most common attachment principle is the vacuum adhesion, where the robot carries an onboard pump to create a vacuum inside the cups, which are pressed against the wall. This system enables the robots to adhere on any type of material, with low energy consumption. Vacuum adhesions are suitable for usage on smooth surfaces, because the roughness can influence a leakage loss in the vacuum chamber.

The mobile robots endowed with platforms and legs with cups are widely spread impractical applications due to high relative forces of locomotion, mobility and good suspension. The disadvantage of increased overall size less disturbs in applications of cleaning and inspection of large vitrified surfaces covering the buildings.

A new generation of cleaning robots is based on PLC. In this context, the original solution of a cleaning robot with vertical displacement and vacuum attachment system is being developed. The novelty of the approach consists of the robot capability to move on vertical surfaces, which involves basic studies enlarging the horizon of knowledge related to displacement cinematic structures, robot leg anchoring solutions, actuating solutions, as well as control system of such robots.

2 DESIGN OF ROBOT

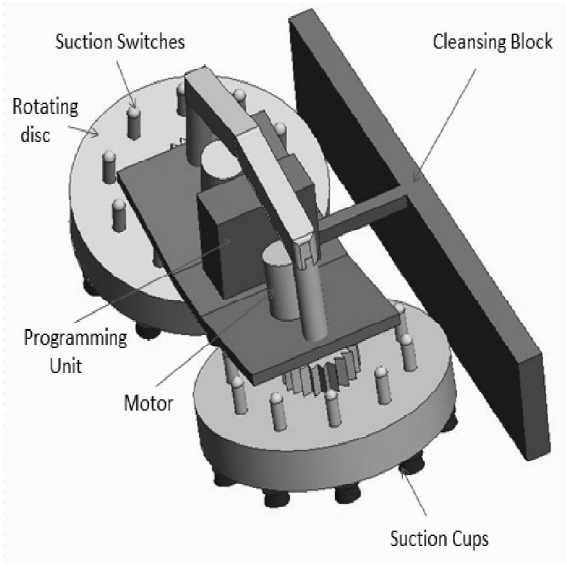

fig1. Robot's Design

There are two units in the robot. One is for motion of the robot and other is meant for cleansing purpose. The motion of robot is achieved through motion unit. The motion unit comprises of 2 rotating discs, suction-cups, DC motor.

When the PLC gives command to motor to rotate in either forward or reverse direction, the motor rotates. A gear is attached with shaft of the motor which drives the rotating disc. Suction-cups are attached to the bottom of this disc. There are 10 suction-cups under each disc, which makes a total of 20 suction-cups. And the arrangement is made such that, at a time 4 suction-cups from each disc gets active. So, total 8 suction-cups are active at a time.

For activating suction-cups, activation switches are used, which when pressed activates the corresponding suction-cup. This switches are used because, the vacuum is only needed in 8 suction-cups at a time. But if switches are not provided then, unnecessarily suction pressure is reduced, which leads to poor vacuum in the required suction-cups.

To support the rotating disc aluminum plate is being used. On this plate both the rotating discs are fixed. A tilt of 10 degree is provided on both the sides of plate, where rotating discs are mounted. This tilt helps in the activation and deactivation of suction-cups. Due to this tilt at a time only 8 suction-cups get in contact with the glass surface.

In order to make this robot as light weight as possible, the material for rotating discs is Poly Propylene which is the lightest and most economical fiber material.

The cleansing unit comprises of 2 cylindrical rotors, a wiper, and a water dripping mechanism. Water continuously drips on the glass surface. The 2 rotors rotate continuously. Both are attached back to back. The first cylindrical rotor is meant to remove the solid dust particles. The second one is made-up of sponge, which provides a smooth cleansing. And at the end wiper is attached which wipes the glass-surface evenly.

3 Motion of Robot

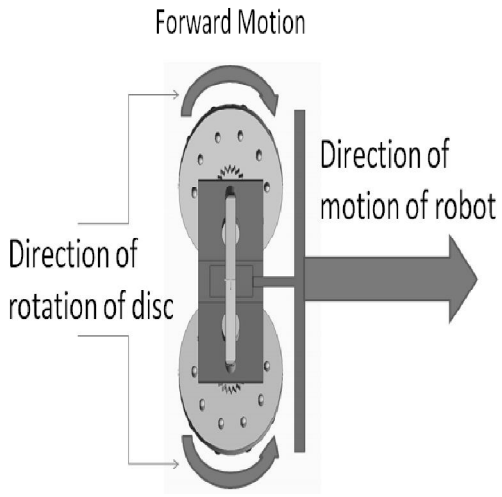

fig2. Forward Motion of Robot

In order to achieve forward motion, motor M1 rotates in anti-clockwise direction and motor M2 rotates in clockwise direction. Which in turn rotates the corresponding rotating disc and robot moves in forward direction.

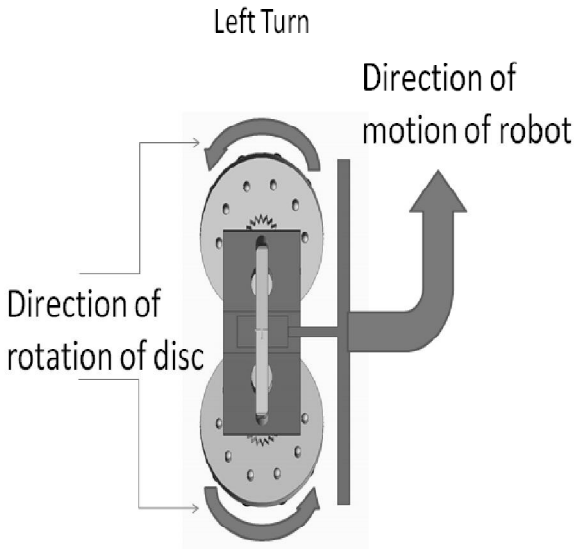

fig3. Left Turn of Robot

In order to take left turn, motor M1 rotates in anti-clockwise direction and motor M2 also rotates in anti-clockwise direction. Which in turn rotates the corresponding rotating disc and robot takes a left turn.

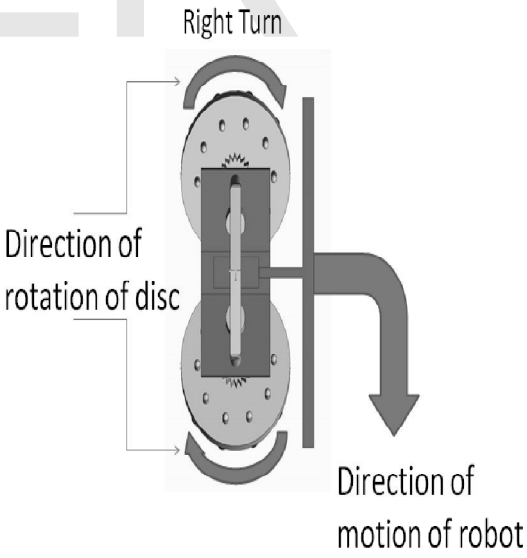

fig4. Right Turn of Robot

In order to take right turn, motor M1 rotates in clockwise direction and motor M2 also rotates in clockwise direction. Which in turn rotates the corresponding rotating disc and robot takes a right turn.

4 Robot Trajectory Path

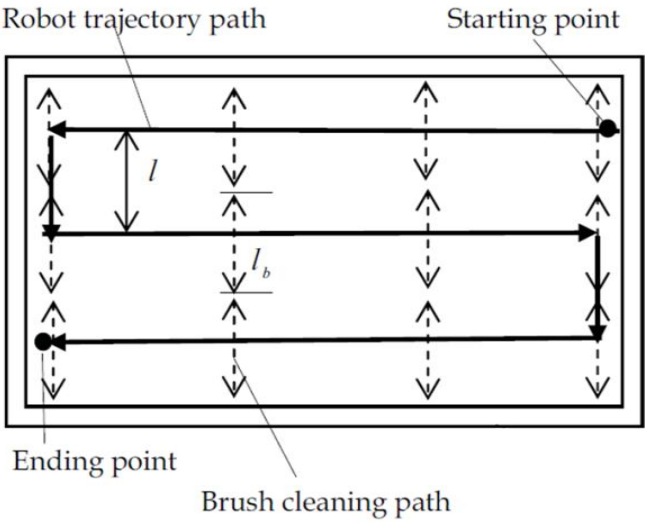

fig5. Robot's Trajectory

The robot moves toward the left side horizontally while cleaning the glass surface. When arriving at the boundary of the glass section, the robot moves down a distance l and then moves back to the right side horizontally.

Cleansing unit is attached with the robot, which keeps cleaning the glass's surface while motion of robot. So, as the robot moves, it keeps cleaning glass's surface simultaneously.

Note that the distance l is equal to the length l_b of the brush cleaning path, and l_b is determined by considering the size of the brush and the dimension of the glass section.

Repeating the above procedures, the whole glass section can be cleaned. The ending position is located in the down side of the glass section. During cleaning the sewage may drop down and makes the downside glass surface dirty. Therefore, the cleaning work should be performed from the upside to the downside.

5 Component List

Table 1 Component List

Component	Specifications
PLC	AC 500 SERIES
DC Motor	12 V
Optical Reflector Sensor	0-30 V NPN NO
Suction-Cup	6 kPa Pressure

5.1 PLC (Programmable Logic Controller)

fig5. PLC

Table 2 PLC Specifications

Supply voltage	24VDC
Program memory	128KB
Onboard Max. inputs/outputs	8/6
Data buffering	Flash memory

5.2 Optical Reflector Sensor

fig6. Optical Reflector Sensors

The sensors have modulated I.R. transmitter and receiver installed in the same housing. The installed receiver gives an output signal when the beam is reflected back towards it due to the object passing across the beam. The reflectivity of an object decides the sensitivity of this sensor.

5.3 Suction-Cup

Suction-cups are typically made up of elastic material such as rubber or soft plastics. Vacuum suction-cups can hold, lift or turn virtually any kind of material. The contact between a suction-cup and the object to be handled is soft and light, and the technique is simple and safe. Vacuum suction-cups are the link between the work piece and the handling system. They consist of the suction- cup (elastomer part) and a connecting element. Suction-cups are used to grip and move work pieces in a plant or on a robot.

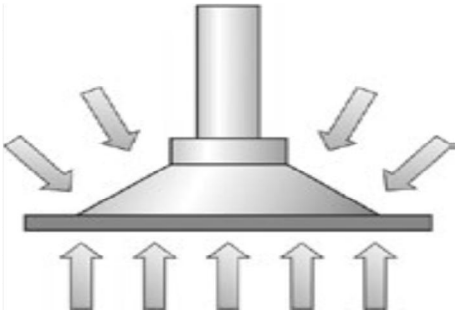

fig7. Suction-Cup

A suction-cup does not attach itself to the surface of a work piece. Instead, the ambient air pressure (atmospheric pressure) presses the suction- cup against the work piece as soon as the ambient pressure is greater than the pressure between the suction-cup and the work piece.

This pressure difference is achieved by connecting the suction-cup to a vacuum generator, which evacuates the air from the space between the cup and the work piece. If the suction-cup is in contact with the surface of the work piece, no air can enter it from the sides and a vacuum is generated.

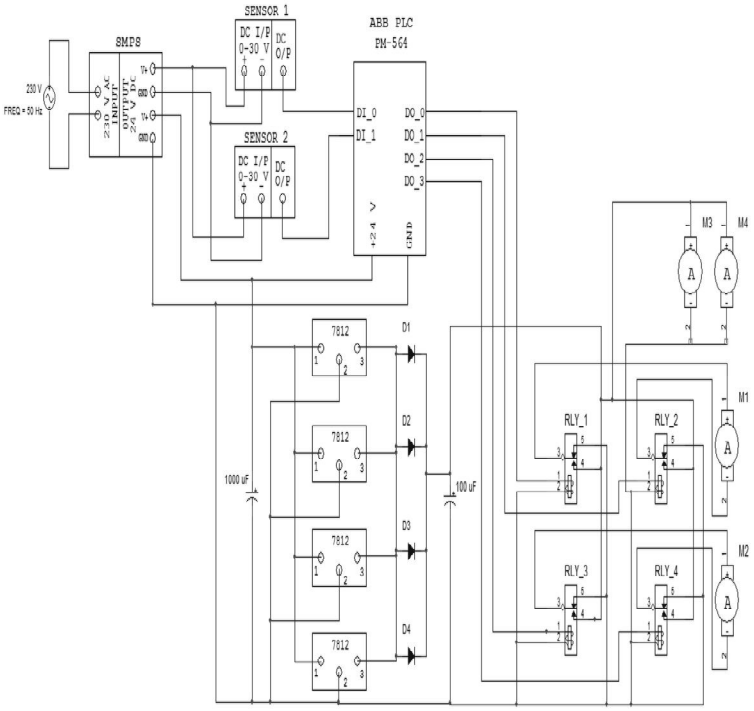

fig8. Schematic Diagram

6 Flow Chart & Schematic Diagram

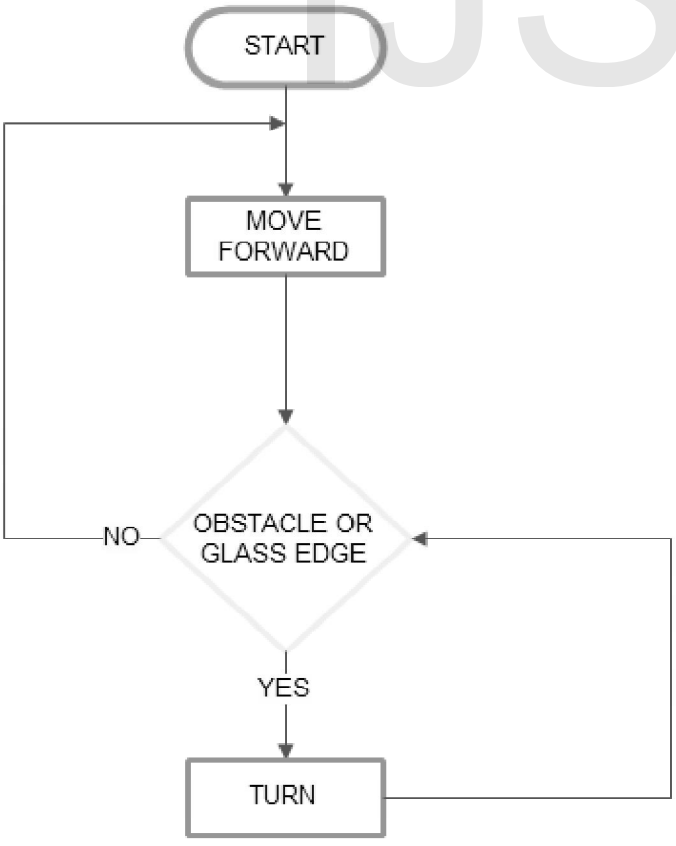

fig9. Flow Chart

7 Results

Dimensions of Robot:
(l X b X h) = 38 cm X 54 cm X 15 cm;

Weight of the robot, W = 6 kg;

Force acting on it, F = 6 N;

Effective suction-cup Area, $A = \pi r^2$

$= \pi * (3.5)^2 = 38.465\ cm^2$

$= 3.8465 * 10^{-3}\ m^2$

Safety Coefficient, S = 2;

Coefficient of Friction, μ = 0.5;

Pressure in the suction-cup, $P = \frac{F * S}{A * \mu}\ (Pa)$;

$= \frac{6 * 2}{3.8465 * e{-}3 * 0.5} = 6.239$ kPa

= 0.06239 bar = 46.79963 Torr

Total Pressure, P_T = 0.623 bar = 4.6799 Torr

Speed of the motor, S_m = 10 rpm;

Effective Speed of the robot, S_r = 10 cm/min;

8 Conclusion

This robot can work well for buildings having completely glass exterior. For future expansion the design of this robot could be modified to clean glass of buildings having sections.

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10 References

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