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Façade Cleaning Robotic System

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Abstract: Façade cleaning in most places includes human cleaner therefore studies were conducted to demonstrate the feasibility of a robotic system to act and mimic the human operation. Several robots for façade cleaning have been designed over the years; however, most of the robotic systems are too expensive to be introduced in the market or are incompatible with the shape or height of the facade. Also, most automated systems can only cope with very simple completely flat glass façade. Our project aims at construction of a fully automated façade cleaning robotic system at a lower cost. Since the robotic system is fully automated there is no human intervention required.

Keywords: Façade cleaning robot, Automatic cleaning, Climbing robot, Low cost robotic system

I. INTRODUCTION

The number of buildings with large glass of flat facades is increasing nowadays all over the World. The contemporary high rise buildings with facades require regular cleaning and maintenance of facades due to excessive pollution and dust. The general conventional methods of cleaning of facades usually rely on human worker with gondolas that are suspended by cable driven systems. In these methods the workers work under heavy risk condition and inherently dangerous conditions. The cost of cleaning depends on a lot of factors such as the façade characteristic/material, the cleaning periodicity or the total surface to be cleaned, cost per sq. meter, etc. In India, the cost for façade cleaning varies between Rs.50 to Rs.80 per square meter. The use of automatic or semi-automatic system can lead to around 50% saving over existing practice. There are a lot of problems and risks associated with the current facade cleaning method which is difficult and dangerous. To overcome all these problems we must undertake automated robotic technologies. The robotic technology allows an environmentally friendly façade cleaning service, thus reducing the cost and the current worker safety systems difficulties and dangers. Since there has been a massive increase in the high rise building a lot of effort have been taken place in the previous few years to develop automated cleaning systems.

One example can be considered of World's tallest building with the total height of 829.8m and a roof of height of 828 m, the Burj Khalifa has its facades cleaned in a more traditional way with workers, gondolas, cables not only is extremely dangerous and risky even for a skilled worker but also involves a lot of time. It was estimated that it takes about 3 months to complete this task. Majority of these systems are in use or in testing phase in Europe, Japan and China. The first automated cleaning system for high-rise building was used in Japan in the middle of the 80's. Systems like these are mainly designed for specific buildings, meaning, they are designed in such a way that they can be used to clean only that particular building and not the other ones. In the past 10 years, development has been excellent in the field of cleaning automated system. Previously a lot of practical applications of this system mostly failed because of either improper safety concept, expensive initial or operating costs or poor cleaning quality.

II. STRUCTURE OF THE ROBOT

The system completely revolves around the mechatronics zone. The automatic cleaning robotic system consists of a mobile climbing robot, two vacuum pumps, and a bristle brush system.

The robot adheres on the glass surface to perform the cleaning. The supporting vacuum pump supplies pressure to the suction cup and a water source is also available if the glass is too unclean. The robot has a length of 60 cm and a width of 30 cm. In the robot body, two-rod cylinders are placed perpendicular to each other as shown in Fig. 1. The alternate in and out motion of these two-rod cylinders with the help of the 12 V 60 rpm motors installed, each for horizontal and vertical motion help the robot to move in the X or Y direction. For smooth and aligned movement of the rods four metallic sliders are used. In Z direction, an aluminum block is made which holds the moving brush as well as the sliders. A bristle brush is installed at the intersection of two-rod cylinders along with 200 rpm Grade A Johnson DC motor for cleaning purpose. The robot uses four suction pads for adhesion on the glass. One suction pad, each with a diameter of 55mm, is installed on each foot of the robot. Each suction pad can hold up to weight of 2.5 kg thus providing a suction force enough to withstand the weight of the whole robot. The robot uses sticking-moving-sticking mechanism for the movement. The automation of the robot is achieved because of the sensors installed on the main body which help to sense presence of surface which to be cleaned.

Robot structure created using SolidWorks software

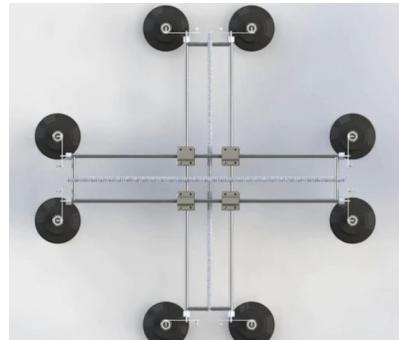


Figure 1 : Basic Robot Structure

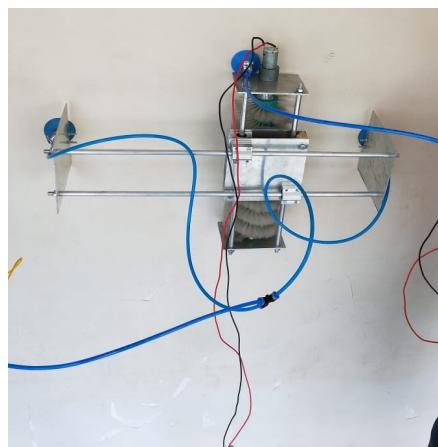


Figure 2 : Testing of the robot

III. COMPONENTS USED

The major components required in making automatic façade cleaner are:

A. Suction Cups

The system uses four suction cups, one in each direction. The suction cups are of FESTO VAS-55-1/4-PUR. These cups are used for adhesion of robot on to the facades of the building. Each cup can hold weight up to 2.5 kg which means four cups can hold a weight of 10 kg. The diameter of each cup is 55 mm. The most comfortable ambient temperature is between -20 to 60°C. The operating medium is atmospheric air and the operating pressure is -0.95 to 0 bar. The suction cups are made of Polyurethane (PUR) which give a long service life and is useful for a wide range of application.



Figure 3 : Vacuum Pump

B. DC Motor

It is a simple DC motor featuring metal gearbox for driving the shaft of the motor. Basically it is a mechanically commutated electric motor supplied with DC power. The Johnson motor comes with side shaft also known as an off-centered shaft. The shaft of the motor equips metal brushes which makes these dc gear motors Shaft wear resistant. The shaft has a through and through hole for better coupling.

Our system uses a 12 volt 200 rpm Grade A Johnson DC motor is used for the rotational movement of brush.

We use two more Johnson A Grade motor of 60 rpm that operates on 12V. These motors are used to control the horizontal and vertical motion of the robot.

C. Vacuum Pump

The robotic system includes two KYK50BPM 12V DC micro air pump with current rating less than 850mA. the inflation time required way less than 8.5s (from 0 to 300mmHg in 100CC tank). Ambient temperature for the micro air pump is 0-50°C.

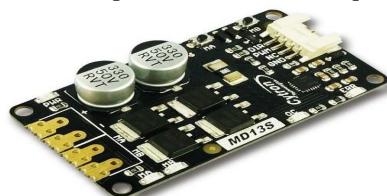
Each pump controls two suction cups. Its main function is to removes air molecules from a sealed volume and leave a partial vacuum behind. Basically, it is used to pull out air and gases from a sealed or confined space due to which the space is left out of any gas and air molecules.



D. Motor Driver

The robotic system implements a Cytron MD13S motor driver to control the speed and the direction of the motors with the help of microcontrollers. We made use of 5 motor drivers, one for each motor. The S in MD13S stands for SMD (Surface Mount Device).

It uses a Bi-directional control for 1 brushed DC motor which supports motor voltage range from 6 to 30 V. The maximum current is up to 13A continuous and 30A peak (10 seconds). The speed control PWM frequency is up to 20 kHz.



E. Timing Belt

A timing belt could be a non-slipping mechanical drive belt. The belt itself is made of durable materials like shaped polyurethane, synthetic rubber or welded ester with numerous standard or metric pitches.

A pulley is a wheel or a shaft that's designed to support the movement and alter a direction of a taunt cable. The drive component of the pulley system is a rope or a chain or a belt.



F. Lithium Polymer battery (LIPO)

12V 8000 mAh LIPO is used to provide power to the DC motor controlling the brush and the two vacuum pumps controlling the 4 suction pads (2 controlled by each pump).



G. Arduino Mega

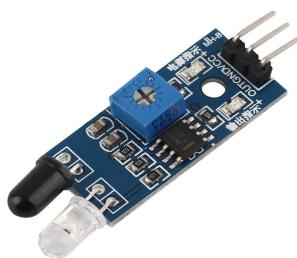
The Arduino Mega is a microcontroller board based on the ATmega1280. It contains everything needed to support the microcontroller. It is used to control the overall movement of the robot with the help of Arduino coding.



H. Sensor

IR infrared Obstacle Avoidance Sensor Module has a pair of infrared transmitting and receiving sections. The reflected IR waves from the obstacle are received by the receiving system. The on-board comparator circuit does the processing and flashes the green LED. The distance range is from 2 cm to 80 cm. The sensor has a potentiometer which can be adjusted to change the detection distance.

Four Infrared Obstacle Avoidance Sensors are used in the four ends of the robot to detect presence of surface. These sensors help in detecting the end of façade/wall.



IV. ROBOT MECHANISM

The system has two parallel rods both in horizontal and vertical direction. There is a suction pad at each end of the rods to stick and hold the device on the façade. The rods are aligned using sliders. The sliders ensure smooth movement of respective rods. At the center of the system a cleaning brush is placed which is driven by 200 rpm Grade A Johnson DC Motor. The batteries, Arduino mega, vacuum pumps are on the plate placed in the center of the system above the brush.

To begin with, the system is made to stick to the façade with the help of suction pads and vacuum pumps. For the vertical motion of the robot the suction of vertical rods is released with the help of vacuum pumps whereas, the horizontal suction pads are still stuck on the façade bearing the system weight. With the help of servo motor the motion of the vertical rod is controlled. Once the motion is completed suction on the pads of vertical rod is created again to help the system remain stuck to the façade. The same cycle is repeated for motion in the horizontal direction with help of the horizontal pair of components.

The above steps help in the robotic system to climb and stick to façade.

The infrared obstacle avoidance sensors are used to detect presence or absence of a surface. These sensors will be placed at the end of the rods and will help the system to detect an absence on surface or an end of façade wall. This will help the robot to decide its next direction of motion.

An 8000 mAh LIPO will provide power to the system. The system will be automated and hence every motion of the system will be controlled with an Arduino Mega along with the use of other components.

V. CONCLUSION

The study presents an application of the rising of an on façade cleaning robot for glass and wall clean-up service. It is built with 2 frames, suction cups and motor and will stick to the vertical surface with ease. The suction pads create vacuum pressure used to keep won the vertical wall.

The product of this research is economical and risk-free as compared to other cleaning systems available in the market. This system won't require any human help to clean the high rise buildings therefore, it avoids any kind of risk or danger to human kind. The system is designed and developed in such a way that it will be inexpensive as compared to the other systems available in the market. The small scale organizations working in glass buildings can easily afford this system since it is cost effective.

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