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Design of Wall Climbing Robot Using Pic Microcontroller

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Abstract: *The climbing robot comprises of two limbs. Each limb has two suction cups. The suction cups are used to stick on to the surfaces. The two limbs are connected to two servomotors, one for each. The air removal from suction cups is done using vacuum pump, controlled by solenoid valves. A microcontroller is used to control the relays that in turn switch electricity to solenoid valves. Suction pipes are used to connect solenoid vales to suction cups. Up and down, right and left movements are controlled by the controller PWM signals, applied to the servomotors. Gears and joints are used to convert the rotational motion of the servos to linear motion of the robot limbs. An air reservoir is mounted on the climbing robot platform as well. The entire platform can find applications in wall cleaning for high rise buildings, wall painting application, sensing applications like weather monitoring station etc.*
Keywords: *Robot, suction cups, microcontroller, solenoid valves, wireless camera.*

I. Introduction

The last few years have witnessed a strong, renewed interest in climbing and walking robotic technologies. At the end of the decade, several different prototype robots were developed for different types of applications. The design of a climbing robot is based on the pneumatic principle. Lizards, which move vertically on about any surface, on closer examination one can find that they possess suction cups along their limbs. Suction cups produce a kind of vacuum between the surface on which it moves and its skin which allows it to stick on the surface.

The microcontroller used is PIC 16F877A from Microchip corporation which has the following features

Table: 1 PIC16F877A Features

Device	Program Memory		Data SRam (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# single word instructions						SPI	Master I2C			
PIC 16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

II. Climbing robots in literature

Various robots have been designed for climbing applications, cleaning, surveillance and maintenance in the recent past. Currently there are some different kinds of
Kinematics for motion on smooth vertical surfaces: multiple legs, sliding frame, wheeled and chain track vehicle.

There are also four different principles of adhesion used by climbing robots: like vacuum suckers, negative pressure, propellers and grasping grippers. The robots with multiple- legs kinematics are too complex due to a lot of degrees of freedom. The kinds of robots which use vacuum suckers and grasping grippers for attachment to the buildings do not meet the requirements for miniaturization and low complexity. Generally the kind of robotics construction and control is very complicated, and does not offer the high efficiency and simple operation required by a wall cleaning robot.

The robots with the wheeled and chain-track vehicle are usually portable. The adhesion used by this kind of robot is always negative pressure of propellers, so robots can move continuously. One kind of robot has a pair of wheels actuated by electrical motors in its negative pressure chamber, so that it can move on the walls flexibly. But it can only deal with plane walls without any obstacles. A kind of pneumatic cleaning robot was developed for cleaning the embassy of Canada by a company in Japan, but it cannot walk sideways. Some modifications can be done to that such that it walks in all four directions.

III. Basic functions provided by climbing robot

The following might be the basic functions of any climbing robot. The paper is targeted to cover the basic requirements only. However, all of the functions can be implemented on the proposed climbing robot platform with a little bit of complexity.

1) Safe and reliable attachment to the surface
2) Movement spreading over all the working areas
3) The ability of crossing obstacles
4) Enough intelligence for the discrimination of obstacle situations
5) Working autonomously with the corresponding effective treatment
6) Motion control function
7) Effective cleaning/ surveillance/ sensing/ painting /glass cutting etc.

The climbing robot should be sucked to the surface on which it is climbing safely and overcome its gravity. That is the first difference between a climbing robot and an ordinary walking robot on the ground. The robot should have a function to move in both the up-down direction as well as the right-left direction to get to every point on the glass. Once the task signals are sent by the user, the robot should keep itself attached to and move on the surface while accomplishing the tasks of may be cleaning, surveillance, sensing etc. To meet the requirements of all kinds of functions, precise motion control is needed. The precise position control of the movement will begin automatically as soon as the signals are received. Finally efficient application execution is the objective of climbing robot for the mentioned applications.

IV. Materials and methods

Industrial applications, where a vacuum pressure is used include materials handling, lamping, sealing and vacuum forming. In terms of materials-handling applications, a pneumatic vacuum can be used to lift smoothly objects that have a flat surface and are not more than several hundred pounds in weight. Figure 2 shows a materials-handling application where a vacuum cup called a suction cup is used to establish the force capability to lift a flat sheet.

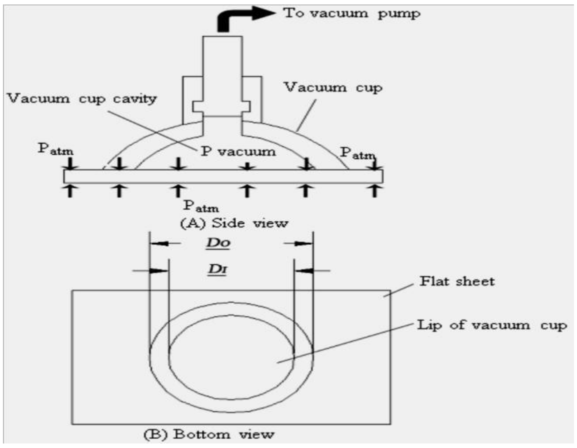

Fig. 1: Vacuum cup used to lift a flat sheet

The cup is typically made of a flexible material such as rubber so that a seal can be made where its lip contacts the surface of the flat sheet

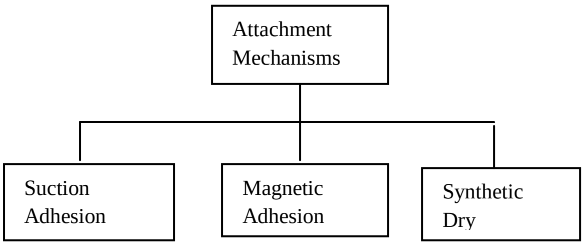

Fig. 2: Climbing Robot Attachment Methods in general

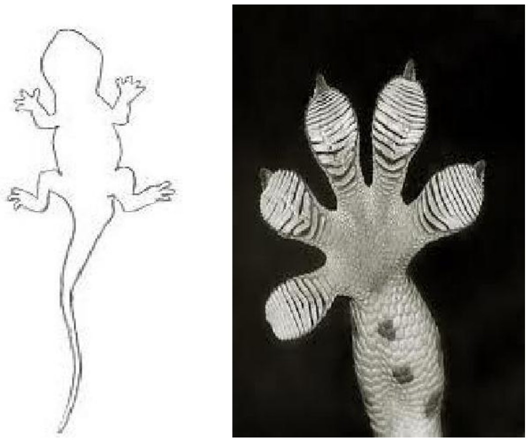

Fig. 3: Exemplary Lizard movement observation

A. Wall-climbing robot design

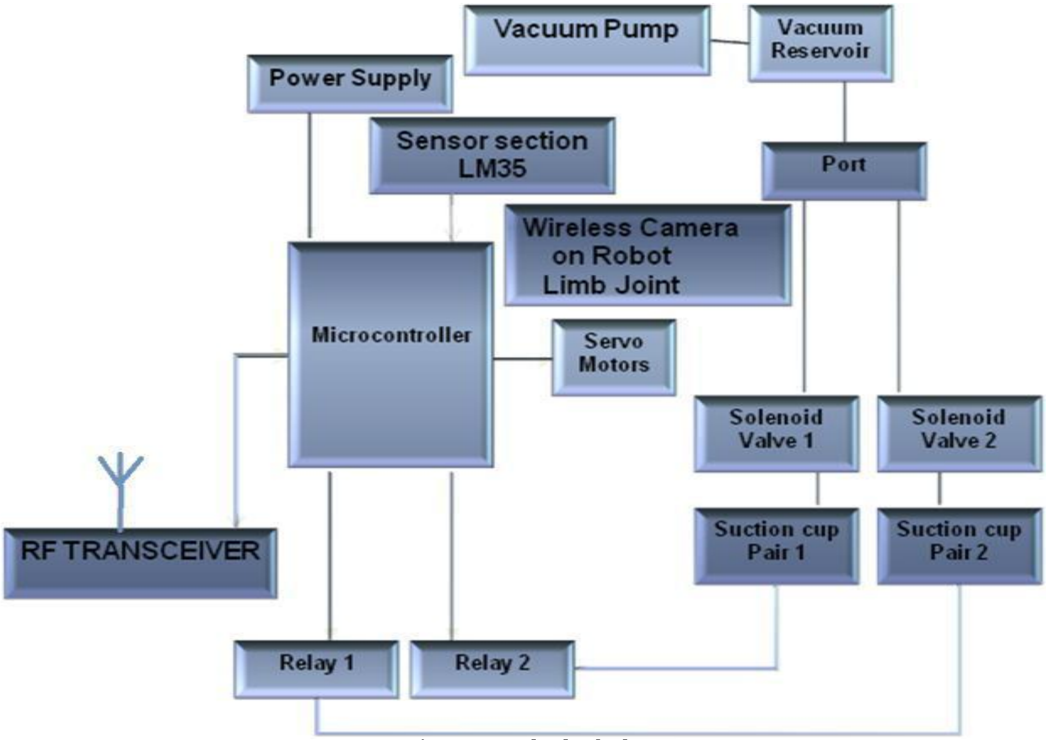

Fig.4 : Total Block diagram

The problem, how to hold on the wall is solved by many methods. There are many factors, which effect in holding, all forces, robot movement and mechanical design.

We keep on finding answers to the following questions during the design phase.

What are the design elements?

What is the principle employed in the design? What is needed for the robot to stick on? What makes the robot to climb?

What are the constraints of the design ?

Design elements :
Suction cups, vacuum pump, microcontroller

Principle employed :

Vacuum pump principle,
Suction attachmen: needed for robot to stick
Servo motors: To make the robot to climb
Constraints of the design : Timing

B. Implementation of climbing robot

As shown in the block diagram, a microcontroller controls all the required actions. A wireless hand set is used to control the direction of the robot in all four directions. The corresponding LED flashes to indicate the direction. The signals are sent and received using an RF tranceiver. An LCD display is facilitated to display the sensed values sent by the microcontroller of the climbing robot. When the direction control signals are received by the microcontroller, it acts according to the program written in the memory.

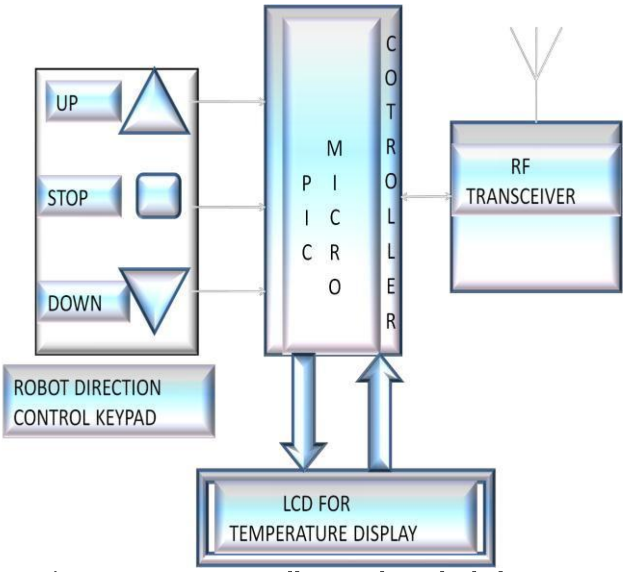

Fig. 5: Direction controller Handset Block diagram

When we power up all the electronic circuits initially, a piece of code will be executed in the microcontroller to make the robot limbs stick the walls microcontroller to make the robot limbs stick t the walls compressor/ vacuum pump must be turned on. So the relay 3 in the diagram will be activated to power up the air compressor. Now it's the turn of the solenoid valves to open and let the air to be sucked by the compressor. Therefore relays 1 and 2 must be activated to provide electricity to the solenoid valves. Now the four suction cups are stuck to the surface, usually a wall.

In order to make movements, the controller receives the direction controlling signals from the user's handset. Controller, now executes the piece of code to free one limb i.e one pair of suction cups by letting air into the suction cups, from the air reservoir. For this controller needs to turn off the air compressor by de activating the relay3. Now one limb is free to move up and down. Now controller provides the specified movement with the help of servos. After achieving the required movement, now again the free limb i.e the pair of suction cups need to stick on. For this, air compressor must be turned on by activating the relay3. In the similar fashion the other limb of the climbing robot can also be controlled to move up and down by the microcontroller. The joints which are connecting the limbs with the servos plays a vital role.

V. Results

The force analysis is guarantee that the robot can hold and move on the wall. On analysis, force acting with the wall that the wall should have only slope from 0° (parallel with the ground) to 60° (slant line). All forces are acting on the slope of the wall can show in free-body diagram. Figure.10 shows free-body diagram that consists of all forces, vacuum force, reaction force, robot weight and friction force. The vacuum force is exerted by pressure difference between atmosphere pressure and inside vacuum cup pressure. The robot weight is force, which depends on the robot Mass (M) and acceleration of gravity (9.81 m sec-2), which has downward direction. Friction force is due to the irregularities of the surfaces in contact.

At equilibrium condition, we express all forces in equilibrium by sum all forces that equal zero. We thus obtain the following two equilibrium equations that the sum of the X-Component and the sum of the Y-Component of given forces must be zero:

Fig.6: Total experimental setup at a glance

The climbing robot is operated to climb a glass wall. It was tested for surveillance and sensing applications by having a wireless camera mounted on the climbing robotic platform. During the test, the results were satisfactory.

VI. Conclusion

As expected, the results of the project came out to be satisfactory and the important observations are summarized as follows. The robot is facing difficulty in climbing the normal surfaces where air leakage is a problem. The robot is facing difficulty in climbing more than 90^0 slant angle on walls. Robot is capable of carrying loads of weight around 4 kg. Compared to normal walls, it is working fine on glass walls and wooden walls. Wireless camera placed on the robot body is transmitting good quality video output up to 10 m. Direction control headset is working fine and properly transmitting the navigation (Up, Down) signals and also receiving the sensor data effectively. Similarly the robot is receiving the direction control signals and changing the directions as expected up to a distance of 100 ft. he suction mechanism is working satisfactorily. The temperature sensor placed on the robot body is also functioning properly.

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