Design and Fabrication of an Automatic Window Cleaning Robot

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Abstract: - The rapid growth of advanced robots has given researchers unprecedented opportunities to explore and discover new fields of research where robots can be used to assist humans in their daily life. There are many applications that use robots and automation in different aspects of life such as industry, medical, domestic machines and etc. In this paper, the work has been devoted for the use of robotics and robots in cleaning process. The window cleaning robot is one of the robots that have emerged in recent decay. This robot can be used in homes, offices and large buildings. The main target is to design a robot that can clean glass windows efficiently and rapidly even in dangerous and hazardous places. The robot will be controlled using the Programmable Logic Controller PLC. The motion will generated by three servo motors.

Key-Words: - Robotics, Mechatronics, System design, PLCs, DC Drive.

1 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. They have conquered nearly all environments that humans have put them through. Cleanliness is one of the important aspects in human life. Our prophet (SAW) said that the cleanliness is part of our faith. Because of the importance, many kind of cleaning mechanisms are invented to ease the human daily chores such as vacuum cleaners, window cleaners which are to clean glass windows. Nowadays, with the large increase in development of tall and smart buildings in urban areas, the window cleaning robot become a nicassity.

1.1 Development of window cleaning robot

In the previous time the problem of cleaning the window has a great importance as it is now where the man was responsible for manual cleaning regardless what he uses facing tiredness and danger for the man until the man invented a machine to lift him to high building or the places which man can not reach it .this invention has a great progress and a big factor and helpful for the man until the invention of robot where the man found in this invention the comfort that is because robot is a group of mechanical systems carry out the mans orders. So we can find that the windows cleaning process take many stages represented in the following; manual stage, manual stage with the help of machine and machine stage only.

1.1.1 The manual stage

This stage is considered to be the first stage in windows cleaning process where the human was the basic element in the cleaning process. The human cleans the windows in a manual way as shown in Figure 1. If the window was near he would reach it and clean it. if the window was far away he can not reach it and this lead to many problems until the man began to use the stairs or ladders to clean the high places. The disadvantages of this stage can be summarized in the following points:

- Difficulties to reach windows in high places.
- no precision in cleaning process.
- time consuming.

Fig.1 The manual stage in cleaning process

1.1.2 The manual stage using amachine

This stage is considered to be more advanced than the first stage. In this stage, the human still does the cleaning process in manual way. However, the human has benfitcd from the advancement of technology by inventing a machine called forklift. This machine lifts the human to the upper places and reduces the consuming time in the cleaning process. Figure 2 shows the manual stage using a machine. This stage also has some disadvantages such as:

- this process costs much money.
- there is a danger on human's life.
- no precision in cleaning process.

Fig.1 The manual stage using a machine

1.1.3 The amachine stage

The industrial robot is considered to be a mechanical devices which can carry out the human jobs in dangerous and hazard areas. This is to stop danger on the human's life. Moreover, robots can repeat the job task more frequently with precision and shorter time. The window cleaning robot is operated by itself which will not require an operator. In this new millennium, technology has been developing rapidly and every day, new invention appeared in order to make human life easier. The window cleaning robot itself is in evolution to make it intelligent and move by itself without man to operate it. Some of those robots had been already produced. They are intelligent and autonomous cleaner with different features. To make the robot move by itself, we have to fix a system which could drive the robot to move. By integrating the wiping mechanism with mobile robot, we will have our own automatic cleaning robot which can move by itself intelligently while we are reading our daily newspaper. Besides having our smart cleaner moving by itself, we also want our cleaner to be smart enough to differentiate the capacity of the dirt so that it can use lower energy for not-so-dirty surfaces and more energy for heavy dirt. By this, we will not only save the human energy and time but saving the electricity and cost for the bill too. This will avoid waste of energy and money while the dirt will be cleaned as we wish. The robot not only moving by itself, and smart to differentiate the dirt, it is also required to clean the dirt properly and in various surface conditions. This will benefit in cleaning the dirt properly and saving the energy. By these three important aspects, what else we want our cleaner to be? We will have a smart, energy-saving, cost-saving, environment-friendly and human friendly cleaner we ever had. The advantages of the window cleaning robot which is shown in figure 3, can be summarized as follows:

- no danger for human life.
- precision in work.
- fast cleaning.
- repealing the cleaning process in some cases.

Fig.3 The window cleaning robot

2 System Design and Components

In this paper, the automatic window cleaning robot consists of hardware and software design. The hardware part deals with the mechanical and construction design, electrical and electronic circuitry. The software parts deals with the programming of the PLC to control the motion of the process. Figure 4 shows the block diagram of the designed system.

2.1 Hardware design and construction

In this section, the mechanical design and construction as well as the electrical and electronic circuitry of the window cleaning robot are

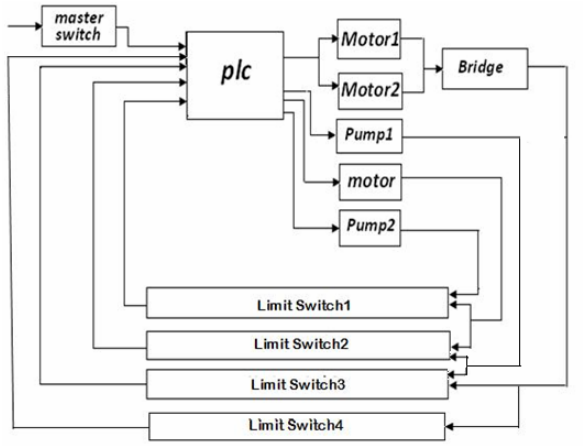

Fig.4 Block diagram of the system

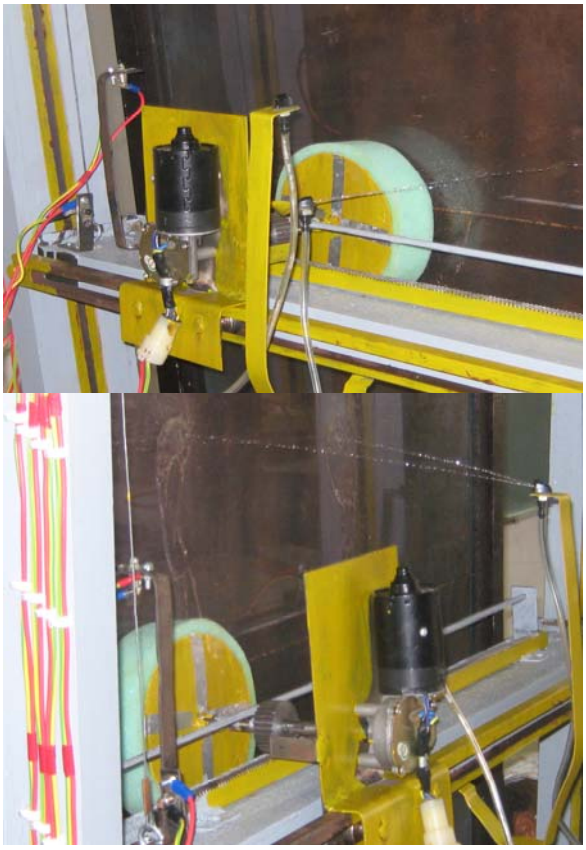

Fig.5 The wiping bar with water pump

presented. There are tree DC motors used in this prototype. Two motors are used to move the wiping arm up and down and the third motor is used to move the wiper right and left. Two small tanks are used in this system. One of those thanks is for the water and the other one is for the washing liquid. There are two pumps to spry the water and the washing liquid. There are four limit switches to ensure that the motion of the whipping bar stay within the holding bars and also to ensure that the wiper does not go beyond the window dimensions. The wiping bar is made of toothed bar. Figure 5 shows the wiping bar.

2.1.1 The permanent magnet DC motor

The permanent magnet motor uses a magnet to supply field flux. Permanent magnet DC motors have excellent starting torque capability with good speed regulation. The motor is connected to 16 V dc supply through a circuit comprising a transformer and a bridge rectifier as shown in figure 6.

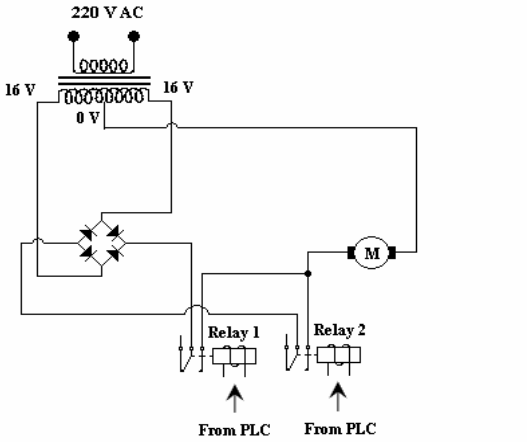

Fig.6 The feeding circuit of the DC motor

2.1.2 Limit Switches

A typical limit switch consists of a switch body and an operating head. The switch body includes electrical contacts to energize and de-energize a circuit. The operating head incorporates some type of lever arm or plunger, referred to as an actuator. As shown in figure 7. The standard limit switch is a mechanical device that uses physical contact to detect the presence of an object (target). When the target comes in contact with the actuator, the actuator is rotated from its normal position to the operating position. This mechanical operation activates contacts within the switch body.

2.1.3 Rack and pinion

A rack is a toothed bar or rod that can be thought of as a sector gear with an infinitely large radius of curvature. Torque can be converted to linear force by meshing a rack with a pinion: the pinion turns; the rack moves in a straight line. Such a mechanism is used in automobiles to convert the rotation of the steering wheel into the left-to-right motion of the tie rod(s). Racks also feature in the theory of gear geometry, where, for instance, the tooth shape of an

interchangeable set of gears may be specified for the rack (infinite radius), and the tooth shapes for gears of particular actual radii then derived from that. The rack and pinion gear type is employed in a rack railway. Figure 8 shows the fabricated rack and pinion.

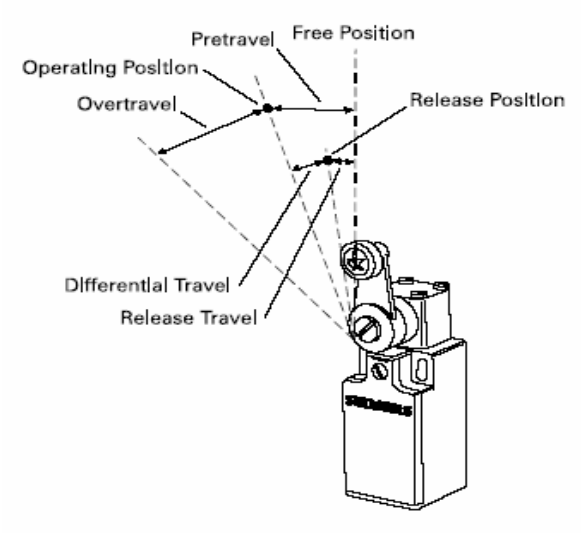

Fig.7 Limit Switch

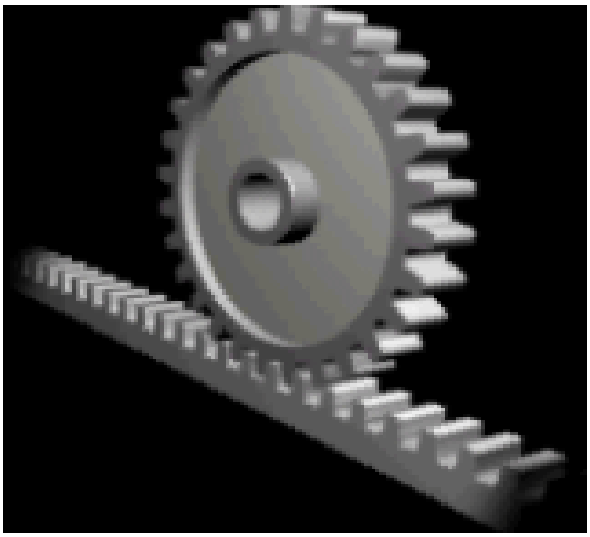

Fig.8 The fabricated rack and pinion

2.1.4 The S7-200 PLC

The S7-200 series of micro-programmable logic controllers (Micro PLCs) as shown in figure 9 can control a wide variety of devices to support our automation needs. The S7-200 monitors inputs and changes outputs as controlled by the user program, which can include Boolean logic, counting, timing, complex math operations, and communications with other intelligent devices. The compact design, flexible configuration, and powerful instruction set combine to make the S7-200 a perfect solution for controlling a wide variety of applications.

Fig.9 The CPU222 of the S7-200 PLC

eneral structure of the gate system. Figure 8 shows the fabricated prototype of the designed intelligent gate system. It has been decided to use the sliding gate design. The purpose of this design is to ensure smooth motion in the opening and closing stages. The body of the gate is made of steel and is mounted through a gear system to a permanent magnet DC motor as shown in Figure 9.

3 The proposed technique

It has been decided to use the Programmable Logic Controller (PLC) with combination of the relays and limit switches as a brain of the automatic window cleaning system. The PLC is widely used in many applications due to its flexibility. The use limit switches is relatively cheaper than other types of sensors to be used as a mean of detection. When some components are not so expensive, we can buy many other components to make our work more meaningful and sophisticated one. There are other methods of detection such as cameras, and RF transmitter and RF receiver. The main objective of our project is to control the motion of the motors to accomplish the cleaning process. The proposed technique of the system is divided into two stages. The first stage is the ascent and the second stage is the descendant.

3.1 The ascent stage

When the main switch is on the system starts to work and the control unit sends orders to start motors 1 and 2. These motors will lift the wiping bar upward to the starting position. Once the wiping bar in the staring position, the control unit will send a command to motor 3 to start the wiping and at the same time spraying water on the glass which we want to clean until the connector reach to the sensor to finish the ascent process.

3.2 The descendant stage

Once the ascent stage is done, the descendant program starts automatically according to the designed program in (PLC) and the descendant process starts by motors 1 and 2. This process happen in many steps according the limit period in each step and in each step the wiping motor begun to work to do the wiping process by moving right and left and this step two pumps work .the first pump spray cleaning materials and two sensors control in each step according to the designed program and this process continue until all the limit step finished according to the height of the building.

4 The operation procedures

The system is started by the main switch where the cleaning process start by giving order to motors 1 and 2 to move the wiping bar upwards to the starting position. Once the wiping bar in the starting position, the cleaning process start as follows:

1- At the beginning of the cleaning process motor3 will be on the left hand side of the frame where the limit switch 1 senses the presence of the frame bar and sends signal to the PLC. Then the PLC will give an order to motor 3 and pump 2 to start working. In this process, motor 3 is responsible for wiping during its movement in the right direction and pump 2 is responsible for spraying the washing liquid on the surface as shown in figure 5.

2- When motor 3 reaches limit switch 2 on the right hand side of the frame. The limit switch will send signal to the PLC which gives an order to turn over the poles of motor 3 to move in the opposite direction back to the left. In this stage, pump1 starts work to spray water only to remove cleaning materials as shown in figure 5.

3- When motor 3 reaches limit switch 1 which in turn sends a signal to the PLC, the PLC will give an order to stop motor 3 and pump1. Then motors 1 and 2 start moving in the opposite direction to lower the wiping bar for a certain distance depends on the size of the wiping brush. Then the process will be repeated again in a zigzag way until the wiping bar reaches limit switch 4 which is at the bottom of the window frame. This means that the cleaning process has finished. Then limit switch 4 sends a signal to the PLC which will halt the system as a whole.

4 Conclusions

The automatic window cleaning robot has been successfully designed and fabricated. The components used in this work are simple and cheap. The software programming is simple and can be modified and implemented easily. In general the system works adequately as anticipated in the design process. The cleaning process takes about (2.5) minutes to finsh a 1 m^2 glass window.This time depends on the speeds of the motors and the degree of dirtnees of the window. Finally, this system should be further developed so that it will have more features.

References:

[1] Bolton, W., *Mechatronics Electronic Control Systems in Mechanical and Electrical Engineering 2nd Edition*, Prentice Hall, 1999.

[2] Everett H. R., *Sensors for Mobile Robots, Theory and Application,* Massachusetts, A K Peters Ltd. 1995.

[3] Johnson, Curtis D., *Process Control Instrumentation Technology Sixth Edition*, Prentice Hall, 2000.

[4] McKerrow, P. J., Introduction to *Robotics*, Addison Wesley, 1995.

[5] Miles P., Carroll T., *Build Your Own Combat Robot,* McGraw-Hill, 2002.

[6] Predko M., *Programming Robot Controllers*, McGraw-Hill, 2003.

[7] Niku S. B., *Introduction to Robotics, Analysis, Systems, Applications,* Prentice Hall, 2001.

[8] John Webb and Ronald. R, Programmable Logic Controllers Principle and Applications, Prentice Hall company, 3rd edition. 1995.

[9] McKerrow, P. J., Introduction to *Robotics*, Addison Wesley, 1995.

[10] Gilles Michel, Programmable Logic Controllers Architecture and Application. Johnson Wiley and Sons, 1990.

[11] Predko M., *Programming Robot Controllers*, McGraw-Hill, 2003.

[12] Hugh Jack, Automating Manufacturing Systems with PLCs, Version 4.7, April 14, 2005.

[13] Reference Manual (SIMATIC S7) STEP 7-Micro, SIEMENCS

[14] www.plc.net.

[15] www.gears.com.