WALL CLIMBING ROBOT FOR INSPECTION OF WALL USING DIGITAL IMAGE PROCESSING

A Report Submitted in Partial Fulfillment degree of
B.Tech and M.Tech Dual degree in Mechanical Engineering

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CERTIFICATE

This is to certify that the thesis entitled,

"WALL CLIMBING ROBOT FOR INSPECTION OF WALL USING DIGITAL IMAGE PROCESSING"

submitted by Mr. Abyarth Kumar Behera to National Institute of Technology, Rourkela, during the academic session 2010-2015 is a record of bona-fide research work carried out by him under my supervision and is worthy of consideration for the award of the degree of Masters of Technology in Mechanical Engineering with specialization in Mechatronics and Automation. The embodiment of this thesis has not been submitted to any Other University and/or Institute for the award of any degree or diploma.

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ABSTRACT

This paper presents a wall-climbing robot for crack detection on the surface of the wall. It uses active suction cups as the attaching components and servo motors and vacuum pumps to generate motion and adhering capabilities. The proposed robot can move on a wall by attaching suction cups to the wall and removing them from the wall. Active suction cups requires additional energy from the vacuum pumps to maintain adhesion. Therefore, the proposed robot can climb the wall but requires a constant amount of energy supply. The prototype has been designed, fabricated and tested. The primary objective of the robot is to detect cracks. For that purpose the robot uses digital image processing to aid visual inspection. Canny edge detection method is used to detect edges. Images are stored in the database and are later inspected visually by the operator.

A Li-Po battery was used to power up the robot. However due to load and large number of servos motors of high torque capacities being used, the battery drained quickly and could not supply continuous power. A new model which improves the powering problems is thus being designed.

CONTENTS

NOMENCLATURE

i. m = mass (Kg)
ii. g = gravitational constant(m/s^2) = 9.81(m/s^2)
iii. F_a = Adhesion force (N)
iv. F_n = Normal force to the surface(N)
v. F_f = Frictional force(N)
vi. μ = Frictional Coefficient

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CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

Inspection of concrete structures - Institute f¨ur Baustoffe

This paper gives stress on the need of an efficient system to detect corrosion in concrete structures. Chloride-induced corrosion, which slowly damages the structures cannot be detected by visual inspection. An electrical potential on a grid of points on the surface can be used to solve this issue. This paper provides a potential solution to the problem through a wall climbing robot with the ability to access large vertical walls of bridges and towers.

After going through this paper it was realized that the potential treat caused by damaged structures like buildings, towers and boilers is high and better solution for this problem is required. This project shows the implementation of such a robot. The robot is aimed reduce the time and cost for an inspection. Also to mention is the collaboration with a number of people with all different backgrounds. All their needs and wishes were (whenever possible) to be implemented on the robot. A complete other incentive is the fact that the project is very multidisciplinary. Mechanical design, electrical design, mechatronics and software development are all part of this work. Moreover, there is a project management part which involves getting all required parts of the robot in time or organizing and conducting tests in different environments. A third motivation was the fact that the project would lead to a physical product. It also involves some practical work in assembling the robot and conducting tests.

1.2 INTENTION

In this project we look for a way to perform measurements of concrete structures. The problem is that these structures often are difficult to access. Examples are cooling towers and boilers of power plants, the lower surfaces of bridges and high raised buildings. As these measurements are done for monitoring, we tried for a faster and easier solution. To reach all different points on the surface is dangerous, complex and expensive in cost and time. A robot which can move on vertical and upside-down surfaces quickly and effectively would solve the problem

1.3 SPECIFICATIONS FOR ROBOT

Given the goal to take pictures of the wall, it sets quite directly the important specification for the robot. The robot,

- must be able to reach the inaccessible heights climbing the wall
- must be able to change direction
- must be able to move around on the wall
- must hold a camera

To simplify the project the robot is intended for indoor use only, and it is expected that the terrain to move on is mostly even. This makes it feasible to calculate with the maximal adhesion force. The pictures taken could be either stored on board or loaded to the computer afterwards. Optionally, the robot should be able to deliver odometry data. The final goal is to store the pictures and process them using image processing algorithms and classify them through visual inspection.

1.4 NUMBER OF MODULES

This is a single module robot. The module consists basically of a base plate, microcontroller, servo motors, connectors, leg, vacuum pump and suction cup. This makes it the smallest unit which is able to adhere to and move on a surface. The power supply if external do not belong to a module. For the simplicity of the project, the number of modules was restricted to one. The system as a whole would become unnecessarily complex with increasing number of modules and even the steering for a human operator would be complex.

1.5 ESTIMATION ON THE WEIGHT OF THE ROBOT

An important base to assess the different configurations is the weight. If a configuration is heavier than what the adhesion force can pull, it certainly falls apart. For a movement on a ceiling, the mass m of the robot must be such that, $mg < F_a$ where g is the gravity constant and F_a is the adhesion force. For a movement on a vertical wall, the crucial role is on the friction force F_f. The friction force is calculated as $F_f = \mu * F_n$ where μ is the friction coefficient and F_n is the force normal to the surface. In our case, F_n corresponds to the adhesion force F_a. In order for the robot to hold on the wall, F_f must be bigger than the weight mg of the robot. The friction coefficient is assumed to be $\mu = 1$ which leads again to the relation $mg < F_a$.

The estimated weight of robot is about 2.9 kg. Each vacuum at a power supply of 12v can lift a wt. of 5kg. So using 4 vacuum pumps the robot can easily lift itself.

All elements corresponding to functionalities which are not needed in this project were cut away what led to the calculation as in Table 1.1. The power supply for the robot is external as explained in section 1.5 and hence not included in the table.

PART NAME	WEIGHT OF EACH PART	NO.OF PART (N)	TOTAL WEIGHT OF N PARTS
Base plate	200g	01	200g
Servo motor	25g	12	422g
Hinge	10g	16	160g
Leg plate	40.5g	4	160g
Electronics	100g		100g
Suction cup and pipes	50g	4	200g
Vacuum Pump	400g	4	1600g
Total			2842g=2.9kg approx.

Table 1.1 Estimation of Total Weight

1.5 POWER SUPPLY

The robot can be powered in three different ways. First, there is the possibility to use a battery. Then there are two solutions with an external supply and a cable connected to the robot. One solution consists of a direct supply with 12V, the other has a voltage converter on board which allows to feed the power at a higher voltage. Both solutions with a cable are a tradeoff between a thicker cable with more weight and a thinner cable with more resistivity. The resistivity is a problem for two reasons. First is that the resistivity causes a loss of the voltage available on the robot. This loss depends on the current which flows in the cable. Therefore, it is changing when the power demands of the robot change. This might cause problem as the electronic parts on the robot need a (more or less) constant voltage. The second problem is the heat caused by the resistivity. Especially when the cable is on a cable roller, the heat might melt the cables. Another general problem using a cable is that the cable might get stuck somewhere.

1.5.1 BATTERY

Using a battery is probably the simplest solution. The battery guarantees to have a constant voltage on board independent from the power consumption of the robot. The big disadvantage is that there is always a limitation in the operation time. A Li Po-battery with 11.1V and 3000mAh has a maximal operation time of roughly 20min. The weight of the battery was 237g. The operation time can be changed simply by the size of the used battery. But after some point a bigger battery gets too heavy to be carried by the robot. Given that, it might be difficult to exceed the operation time of 30min using a battery.

1.5.2 EXTERNAL SUPPLY WITHOUT CONVERTER

This solution needs a power cable from the robot to the base station. The most critical point is the weight of this cable, which needs to be carried by the robot. Using different calculation methods and starting parameters, different results were obtained. A load of 1kg from the cable could easily be reached with less than 10m of Cable. Given that, the solution without converter is not recommended. Especially for concrete inspection, where long traveling distances occur, this solution will not work.

1.5.3 EXTERNAL SUPPLY WITH CONVERTER

Compared to the solution without converter, most advantages and disadvantages remain the same. Transporting the power at a higher voltage leads to a lower current. Therefore, using a converter allows to use an overall smaller and more lightweight cable. On the other hand, the weight of an onboard converter needs to be carried. This solution was found to be feasible also for a longer cable. A problem might be to find a lightweight converter.

In this project we are using an external power supply without converter. The power supplied is through a 6V SMPS.

CHAPTER 2

LITERATURE REVIEW

There are a need of potential requisitions of robotics to wall climbing operations that can guarantee effectiveness and security. Wall climbing robots can possibly provide a revolutionary venture in doing unsafe tasks that are generally performed by people for example window cleaning in high raised buildings, carrying inspection work after an earthquake, inspection of pressure vessel etc. One of the most important issues after an earthquake is to ensure that the buildings or other structures are safe for usage. For this purpose there have been many demands for wall inspection robots. Apart from walls and concrete structures, inspection is also required in industries in case of boilers and chimneys. The prerequisites for little, lightweight and compact wall inspection robot, for the purpose of initial inspections is in need.

The purpose of this project is to create a robot that can inspect a wall using image processing techniques. Keeping this in mind our motive was to fabricate a machine that can climb on walls and take pictures and send them back to computer system for analysis. After going through the literature by the past searchers, suction cup method was selected to stick the robot to the wall. In suction cup method, the robot utilized installed pump that made a pressure drop inside the vacuum cups. As the vacuum cups are pressed against the wall, the on board pump will start to pump the air in the vacuum cup out to the surrounding. After sometime, the pressure inside the vacuum cup becomes lower than that outside it and it can stick onto the wall.

Various techniques were studied before finalizing the method of adhesion. Several journals and papers were used as reference during the project.

2.1 SUCTION

In suction method, a vacuum pump and a suction cup is used. Vacuum pump sucks air out of the cup and suction cup grips the wall due to external pressure. A semi-independent Wall Climbing Robot with Scanning Type Suction Cup was created and tried by Tomoaki Yano, Tomohiro Suwa, Masato Muraxami and Takuji Yamamotq [1]. This robot used two vacuum pumps. The robot was connected with the gears on the ground through the electric power cables. Experimental results showed that the robot was able to walk on walls, clear steps, and stick on cracks and crevices with high effectiveness.

A mini wall climber equipped with two smart robotic feet (SRF) was developed and tested by Gregory Wile and Dean M Aslam [8]. It was controlled automatically by a PIC16F876 microcontroller. Each SRF contained a suction cup with a diameter of 40 mm, a vacuum pump, a pressure sensor, and a micro valve. Two servo motors were used to drive the robot. Apart from climbing vertical walls, it was designed for effective transition between a floor and a wall, as well as to automatically change direction while walking on a surface.

In another effort a wall climbing robot with four-landscape versatile legs and fundamental versatility were at that point exhibited by the produced model NINJA-I [2]. As the first step to consider a general walk issue of a quadruped wall climbing robot, this paper examined a step of the robot on a vertical and level wall. The gait was analyzed with the criterion to maximize the locomotion speed under the constraints of predetermined conditions of the supporting-legs position, order and phases of swing legs to prevent turn over motion. As a result of the analysis, the optimal standard gait, named "Wall Gait", was shown to maintain foot posture and moved the leg in the order of leg1 - leg2 - leg4 - leg3 in static walk and the order of "pace" in dynamic walk.

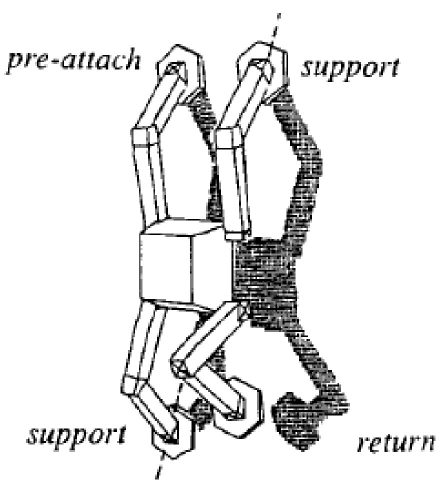


Fig 2.1 Wall Gait [2]

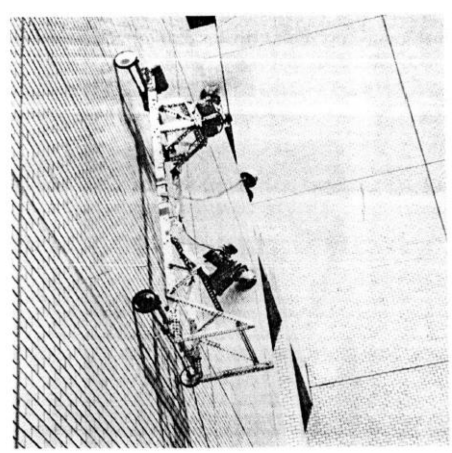


Fig 2.2. Propeller type wall climbing robot [3]

2.2 PROPELLER TYPE

A wall climbing robot utilizing thrust energy of propellers was produced [3]. The thrust power was inclined a little to the wall side to prepare the frictional force between the wheels and wall. As the solid wind was anticipated on the wall surface of structures, the direction of thrust energy was controlled to remunerate the wind force acting up on the robot. A frictional energy augmenter was then used, which is an aero foil, to produce the lift force directed towards the wall side by the cross-wind. Its impact was tested in the wind tunnel. The general execution of the robot was analyzed by computer simulation and a model was tested on a wall. Figure 2.2 shows the robot being tested on a wall.

2.3 STATIC ELECTRICITY

Another way of sticking a robot to the wall is by the use of static electricity [18] [19] [20]. Robot is powered by high voltage supply which induces opposite charges on the wall. Due to the opposite charges there is attraction between the wall and the robot and this holds the robot attached to the wall.

Use of electro adhesive caterpillar to climb various vertical wall surfaces has been done. Power supply which provides a high voltage to electro adhesive caterpillar is connected to conductive electrodes deposited in the caterpillars for produce adhesion force. The following papers [4] [5] [6] described the mechanisms of electro-adhesive robots and their roles. The basic mechanism is that when the electrode panels are positioned near the wall surface, the electric fields set up by the high voltage between the electrodes induces opposite charges on the wall surface and thus cause electro-static adhesion. Ordinary bipolar electrodes require a lot of time to get sufficient adhesion force. So thin interdigital electrodes having many boundaries were used [7] as it can be observed that the electric field in the vicinity of the boundary of the electrodes is relatively stronger than that far away from the boundary and this implies that the collection of induced and polarization charges occurs more quickly in the vicinity of the boundary. Hence, it is advantageous to form many boundaries with different potentials in the electrode pattern, to reduce the excitation time of the electrostatic adhesion force. Flexible electrode panels should be used in case of non-industrial climbing robots as the wall surfaces are not smooth and a little flexibility can be an advantage.

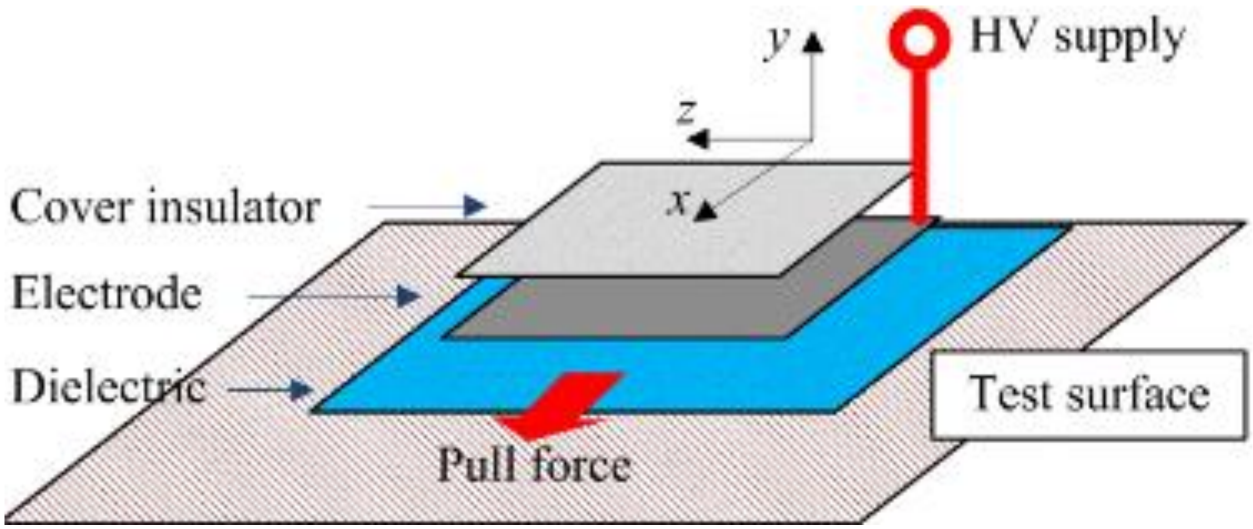
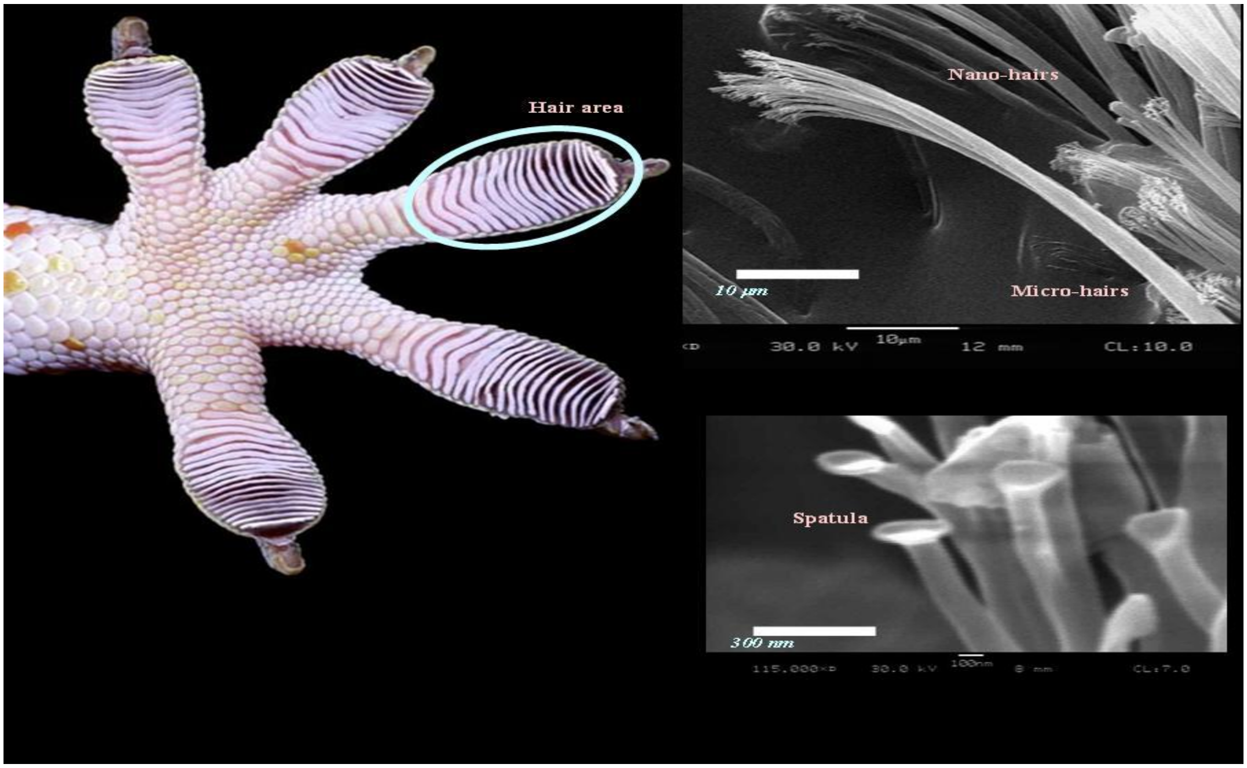


Fig. 2.3. Schematic of the electro adhesion actuator. [18]

2.4 GECKO

Geckos' ability to climb surfaces, whether smooth or rough, has always generated keen attention. Geckos use their micro/nano-scale high aspect ratio beta-keratin structures underneath their feet, to adhere to almost any surface with a controlled contact area. Large no. of hair like structure give it a large surface area and the adhesion is mainly due to van der Waals forces [9]. Every fiber comprise of a smaller scale hair seta of approximately 5 microns in measurement, and on each of these smaller scale strands sit several spatulae which are of 200 nanometers in distance across. There are somewhere around 100 and 1,000 spatulae on the end of every seta. Despite the fact that the surface region of each of the hair tips is little, the blend of the zone of billions of these hairs makes the compelling surface territory substantial, and van der Waals strengths get to be critical. The produced grip power can be as high as 10N for every 1cm2 [10].

Dry adhesion is more robust than the suction adhesion mechanism, if the dry adhesion pad encounters a crack or gap, there will still be adhesion on the parts of the pad that have made contact. This behavior permits a robot using dry adhesion to climb on a wider variety of surfaces. Fig 2.4. Shows the detailed image of a lizards feet.



2.5 IMAGE PROCESSING

Digital image processing refers to manipulation of digital images through a computer using software like MATLAB and OpenCV. The input of that system is a digital image and the system process that image using efficient algorithms, and gives an image as an output. This technique can be used to detect cracks in a wall or any metallic surface.

A automated technique to detect cracks in pavements by means of digital image processing has been proposed by B.Santhi, G.Krishnamurthy, S.Siddharth, P.K.Ramakrishnan in 2012 [14]. This technique detects cracks on buildings, pavements, soils, roads and metallic surfaces. In this process the images were first passed through a gray scale morphological processing [14] [15] [16]. The final result was obtained by filtering the images (Butterworth filter) and then applying the edge detection operators (canny edge detection). There are various filters for filtering the images ex Gaussian filter, wiener filter etc. By visual inspection, contented detection results are obtained through this method.

Image processing using neural network is another method that has been developed for crack detection [17]. Cracks were distinguished from background image easily using the filtering, the subtraction method, along with morphological operations. Back propagation neural network was used to classify the images. The algorithm was tested using real surface images of concrete bridge. Back-propagation neural network was trained using 105 images of concrete structure, and the trained network was tested for new 120 new images with up to 90% accuracy.

CHAPTER 3

DESIGN

Design is a very important part of any project. It brings the imagined project into the view of the world and the rest of the world can relate to the work through the design. A design should be simple as possible and at the same time should be effective enough to capture the interest of the world. In this project the design was kept simple. A basic quadruped model was selected. As we are trying to replicate the gait of a lizard, we chose to use three joints for the limbs and a single module.

The parts were designed in SOLIDWORKS.

PROPERTIES	BASE PLATE	HINGES	LEG PLATE
MASS (grams)	68.27	9.68	11
VOLUME (mm^3)	24380.69	3455.61	11722.47
SURFACE AREA (mm^2)	26870.74	5291.16	10841.07
MATERIAL	Brushed 2014 T4 Aluminum	Brushed 2014 T4 Aluminum	Brushed 2014 T4 Aluminum

Table 3.1 Properties of Parts

3.1 BASE PLATE

The base plate is plays the role of a backbone of the robot. It supports parts and keeps them together so it should be strong, flexible and lighter. For the purpose stated above, the base plate was designed in the shape as shown in figure 3.1. The base plate is also a housing for servos. The servo motors will be attached to the slots made in the base plate. The plate will also be a housing for the microcontroller and other electronic circuitry.

Material chosen for base plate is Brushed 2014 T4 Aluminum as the material is light as well as good in aesthetic point of view.

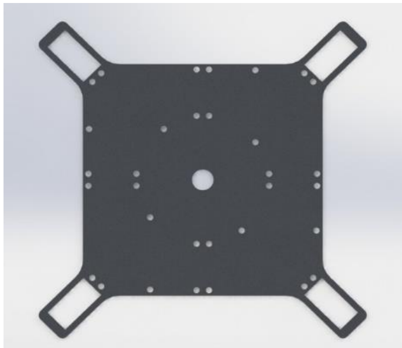


Fig 3.1. Base Plate

Fig 3.2. Hinge

3.2 HINGE

Hinges are required to connect the servo motors together. This will lead to the movement of servos relative to each other and will be instrumental in imparting motion similar to that of a gecko. Hinge was accurately designed as shown in fig 3.2. Material chosen for base plate is Brushed 2014 T4 Aluminum.

3.3 SERVO

Modulation	Analog
Torque	4.8v: 3kg-cm 6.0v: 3.2kg-cm
Speed	4.8v: 0.18sec/60º 6.0v: 0.16sec/60º
Weight	36.00 grams
Dimension	40.8mm X 20.1mm X 38.0mm
Motor Type	Brushed
Gear Type	Plastic
Rotation	Dual bearing
Rotation Range	120º
Pulse width	900-2100μs

Table 3.2 specification of servo motor

Total weight and dimension of the robot has to be estimated before selection of the servo motor. This is important because the servo motors has to do the load carrying work and hence a servo of lower capacity would not be able to move the robot forward. After rough calculation we found the robots weight to be in the range of 2.5-3kg. FEETECH FS5103B servo was chosen as it satisfied our requirements

Fig 3.3 LEG PLATE

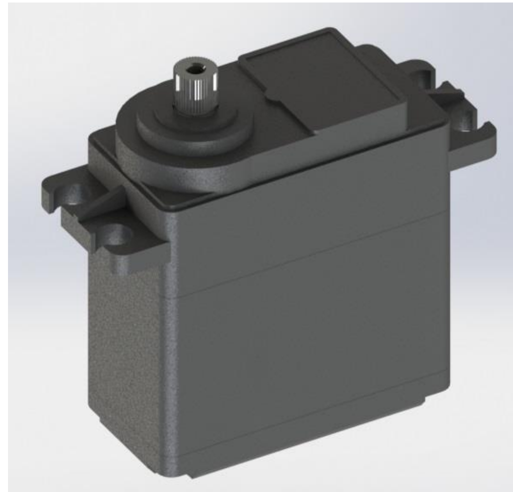


Fig 3.4. FEETECH FS5103B

3.4 LEG PLATE

The leg plate is a link that connects the last servo motor to the suction cup it is also the part that helps in moving the legs forward. As we have decided to move one leg at a time, so the design of the leg should be such that, the legs are light, slightly flexible and of proper length to clear obstacles. The design of the leg is shown in fig 3.3.

3.5 FINAL ASSEMBELED DESIGN.

The final assembled design is as shown in figure 3.6. The base plate holds four servos, one at each corner. Those servos are connecter to another set of servo through hinges. Another series of servo connection comes after that which completes the motion mechanism of the robot. The final set of servos are connected to the leg pieces. The vacuum pump are connected underneath the body for better distribution of pressure and to decrease load from the feet. This arrangement also reduces the complexity arising due to connection of pipes between the pump and the suction cup. The electronics are fitted above the base plate and have not been shown in the figure to avoid complexity.

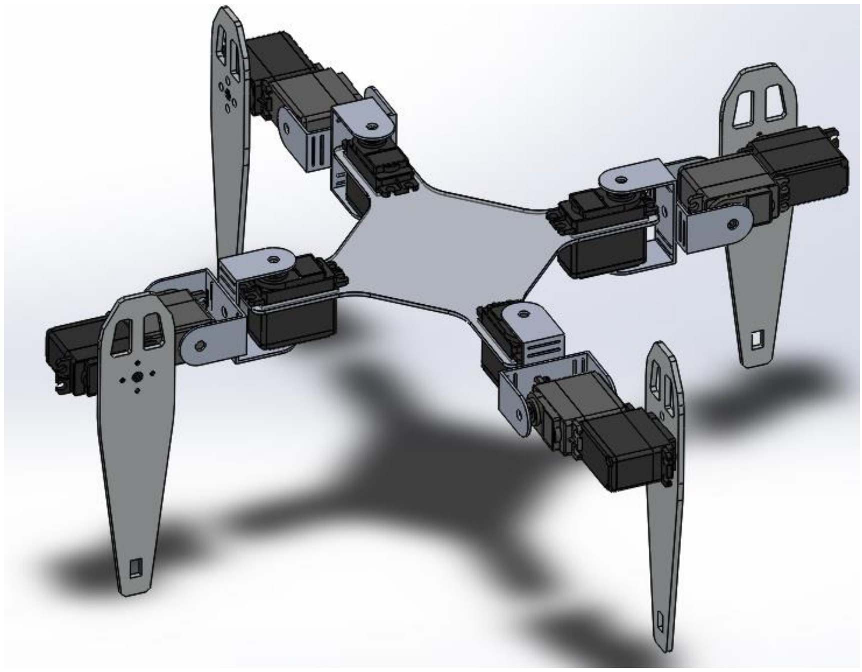


Fig 3.5. 3D modelling of Wall climbing robot designed using solid works

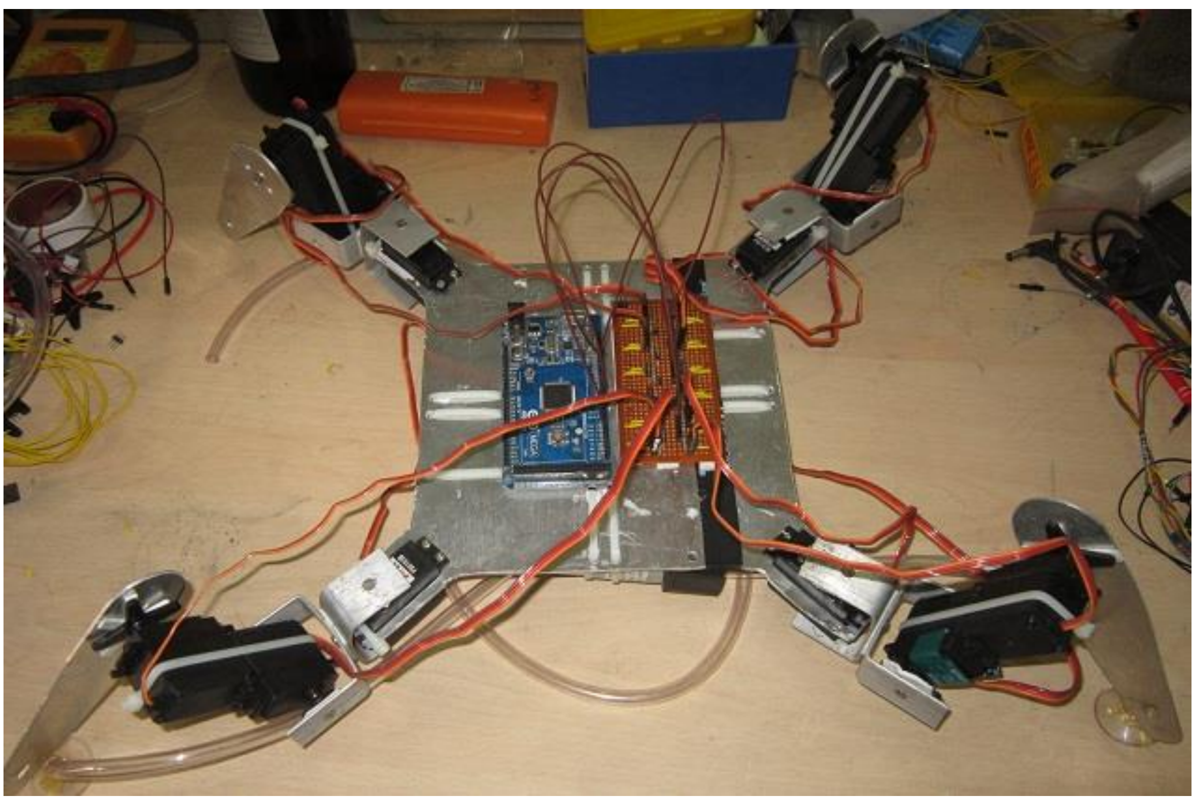


Fig 3.6 Assembled view of the wall climbing robot.

CHAPTER 4

IMAGE PROCESSING

The main objective of this project was to detect cracks on the surface of wall through image processing. Various algorithms and image processing methods were studied and analyzed as mentioned in the literature survey part.

Image processing basically consists of a series of process, after which data is extracted from the image. The processes are

- Obtaining the image
- Applying filters to smoothen the image
- Application of algorithm for required data extraction
- Data extraction

Fig. 4.1 Image Processing Flowchart

After studying various image processing methods, we decided to go for edge detection in image using Canary Edge Detection method. Every crack in the surface will have edges and separating out edges from the image will give us a particular section in image where we can look for cracks. The final confirmation of crack detection was done through visual inspection.

4.1 CANNY EDGE DETECTION METHOD

Canny edge detector or CED is an edge detection operator which uses a multi-stage algorithm to detect edges in images. It was developed by John Canny in 1986.

The Process of Canny edge detection algorithm can be broken down to 5 different steps:

1. Application of Gaussian filter for image smoothening to remove the noise
2. Calculating the intensity gradients of the image [23]

$$Edge\_Gradient\ (G) = \sqrt{G_x^2 + G_y^2}$$
$$Angle\ (\theta) = \tan^{-1}\left(\frac{G_y}{G_x}\right)$$

3. Application of non-maximum suppression to eliminate of spurious response to edge detection

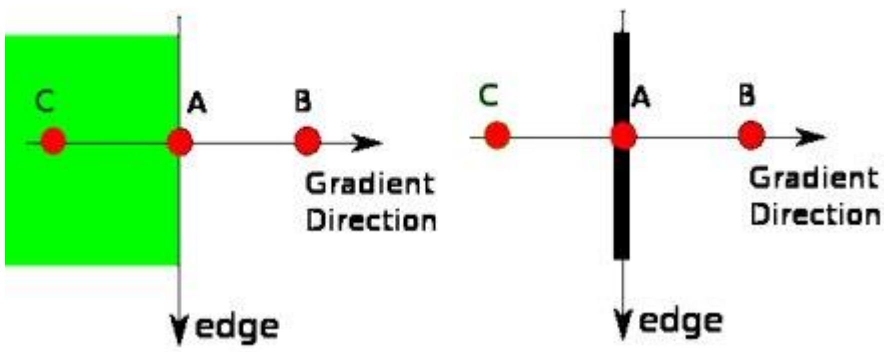


Fig. 4.2 Non-Maximum Suppression [23]

A full scan of the image is done in the magnitude and direction obtained in step 2. This step remove unwanted pixels. Every pixel is checked is if it is the local maximum in its neighborhood in the direction of the gradient. The process is shown in Fig 4.2. As shown in the Fig, point A is on the edge. Gradient direction is normal to the edge. Point B and C are in gradient directions. Now point A is compared with point B and C to see if it is the local maximum with respect to others. If yes, it is considered for next stage, otherwise, it is suppressed and eliminated and this step is continued till all the images are covered.

The final result in this is a binary image with thin edges.

4. Application of double threshold to determine potential edges

In this stage we need two threshold values, minValue and maxValue. Any edge with intensity gradient more than maxValue is a sure edge, while the gradient with value less than minValue are sure not part of any edge and should be discarded.

5. Tracking edges by hysteresis: Finalizing the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

Those pixels whose intensity lies between the maxValue and minValue are classified as edge or non-edge depending on its connectivity. Point C in Fig 4.3 lies below the maxVal. However it is still considered a part of the edge due to its connectivity with point A. Edge B is discarded as none of its pixels are above maxValue.

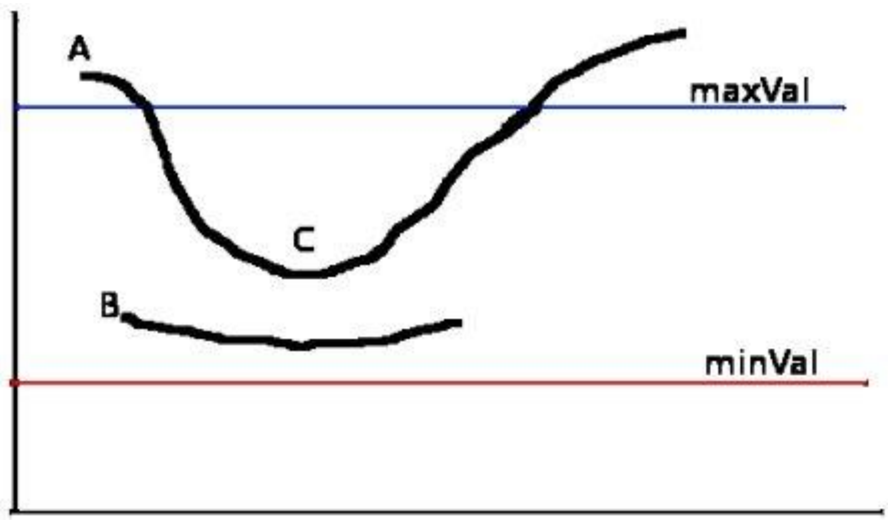


Fig. 4.3 Tracking by Hysteresis [23]

It is very important to select proper threshold values to get the desired result.

This stage eliminates small noises on assumption that edges are long continuous lines.

4.2 CANNY EDGE DETECTION IN OPENCV

In OpenCV all the above features are put in a single function, cv2.Canny (). The first argument is the input image while the second and third arguments are minValue and maxValue respectively. Sobel Kernel is used to find the image gradients which by default is 3.

4.3 IMAGE PROCESSING USING CANNY EDGE DETECTION

We applied the process explained above to a few samples before implementing it into our project.

First we applied it to a sample wall image with cracks on it. The cracks were visible and distinguishable through visual inspection. First we applied the threshold values minValue = 100, maxValue = 200. The result is as shown in Fig 6.4.

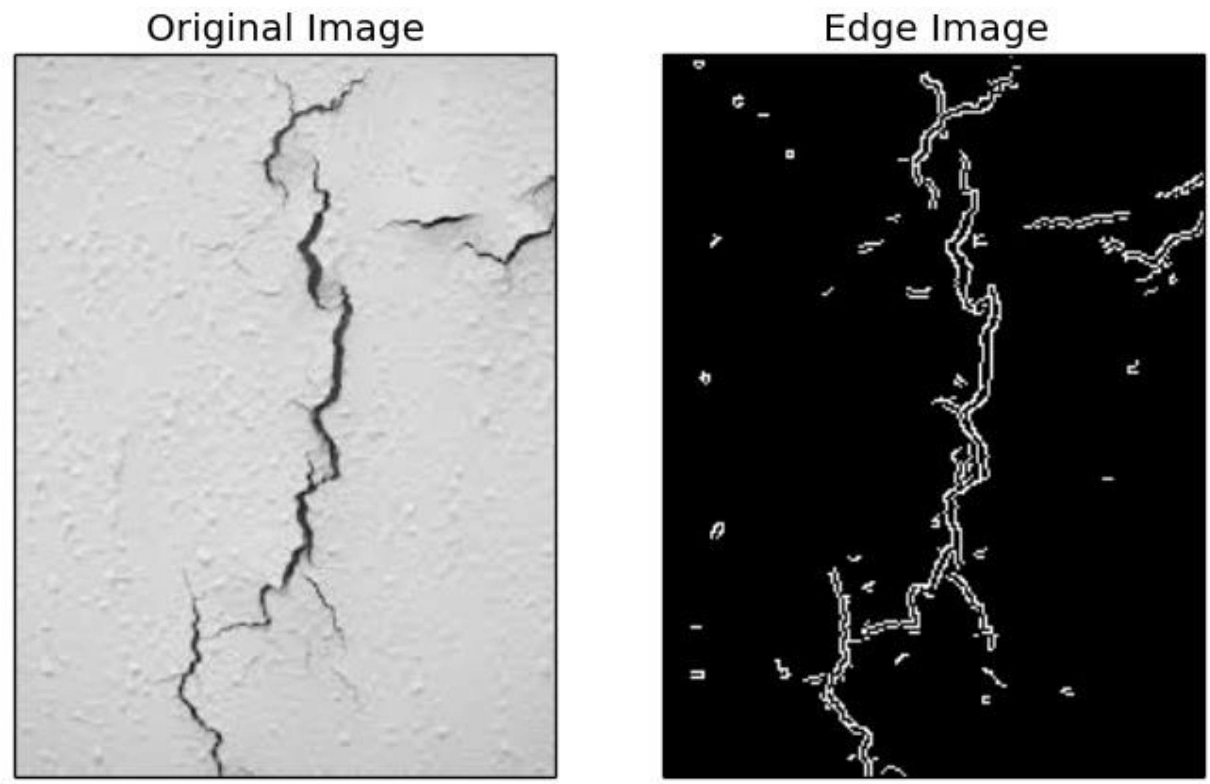


Fig. 4.4 Example of CED on a cracked surface, minValue = 100 maxValue = 200

Then we changed the threshold value to get a more refined output by increasing the maxValue to 400. The results are as shown in Fig. 4.5.

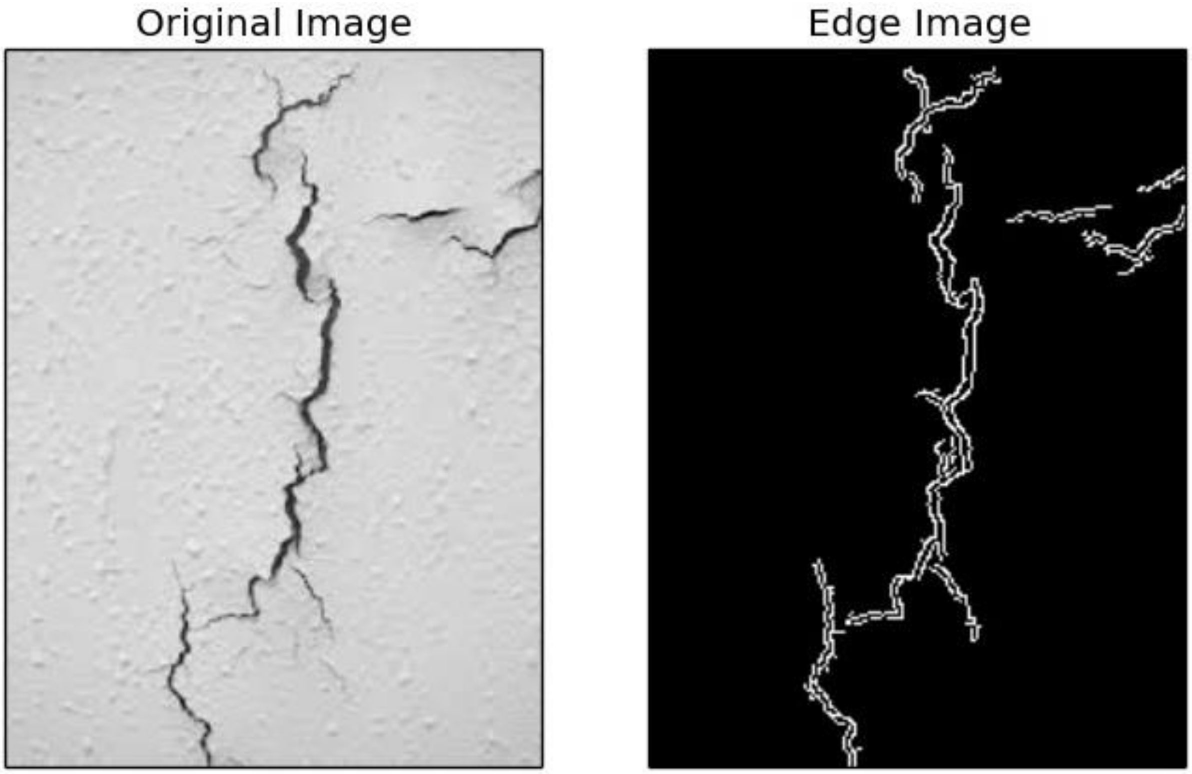


Fig. 4.5 Example of CED on a cracked surface, minValue = 100 maxValue = 400

Fig. 4.5. Gives a more refined image and removes all the unnecessary noises. This result was similar to the result we were expecting from our project.

After getting satisfactory results from sample image [24] we proceeded with the process and applied it to the images collected through our robot.

4.4 IMAGE PROCESSING USING CANNY EDGE DETECTION

We applied the process explained above to a few samples before implementing it into our project. First we applied it to a sample wall image with cracks on it. The cracks were visible and distinguishable through visual inspection.

First we applied the threshold values minValue = 100, maxValue = 400. The result is as shown in Fig 4.6.

Then we changed the threshold value to get a more refined output by increasing the maxValue to 600. The results are as shown in Fig.4.7.

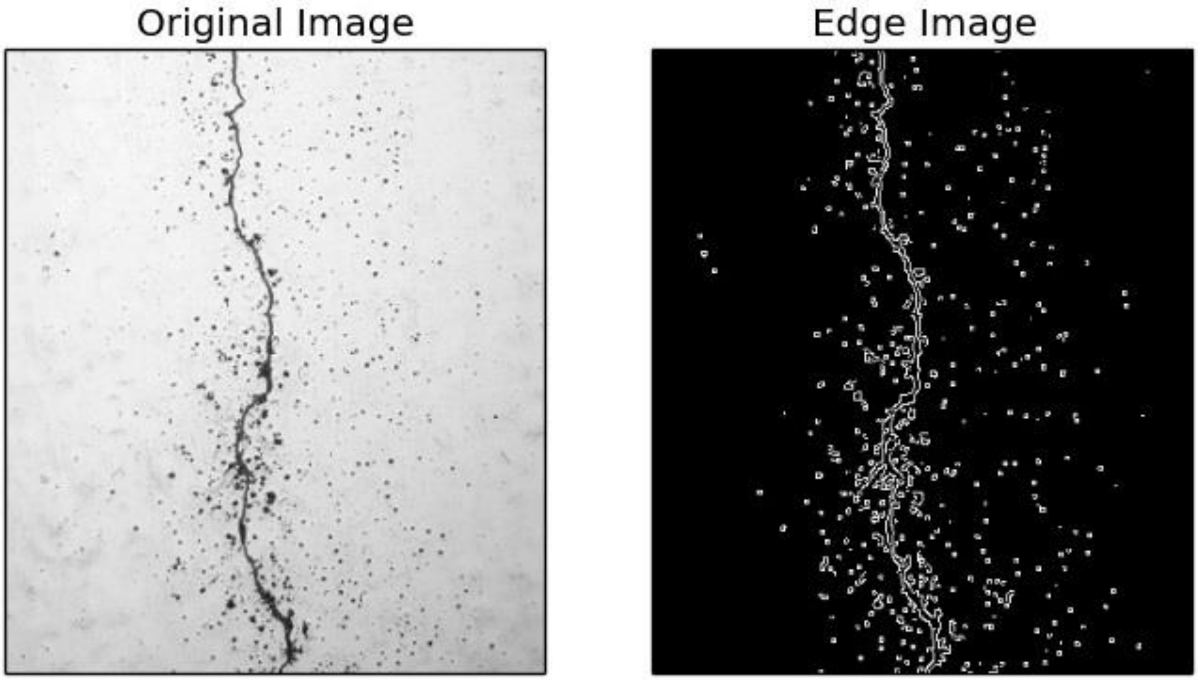


Fig. 4.6 Example of CED on a cracked surface, minValue = 100 maxValue = 400

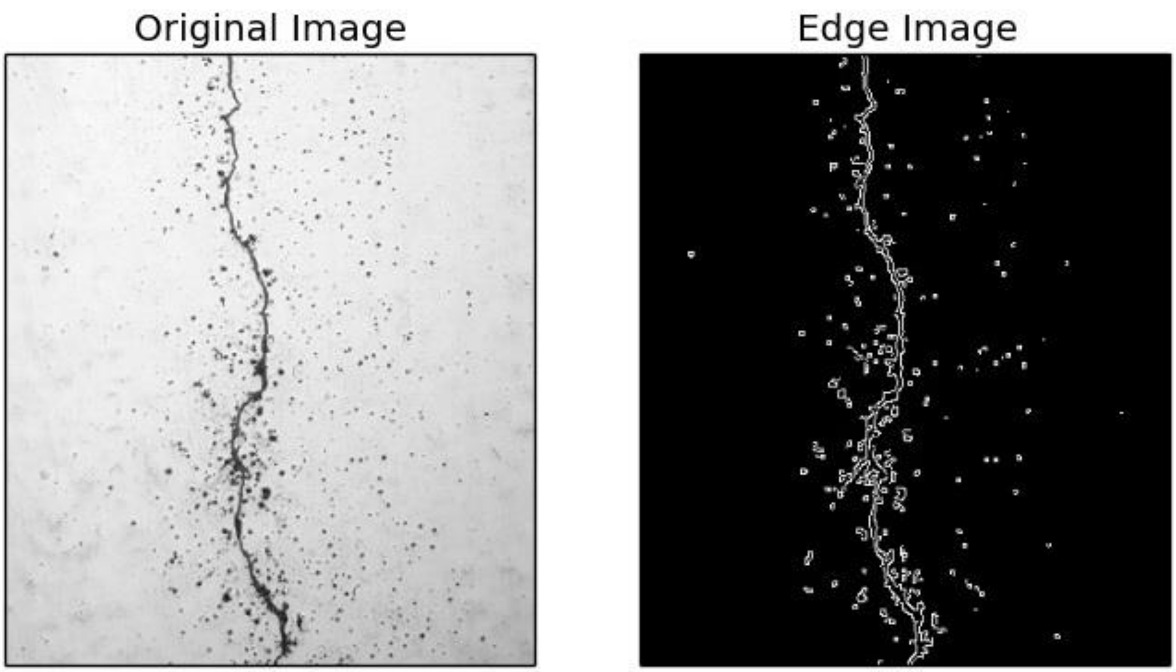


Fig. 4.7 Example of CED on a cracked surface, minValue = 100 maxValue = 600

Then we tested it on a surface where there were cracks only on the paint layer and not on the wall.

We applied the same range of threshold values. The results are shown in fig 4.8 and 4.9.

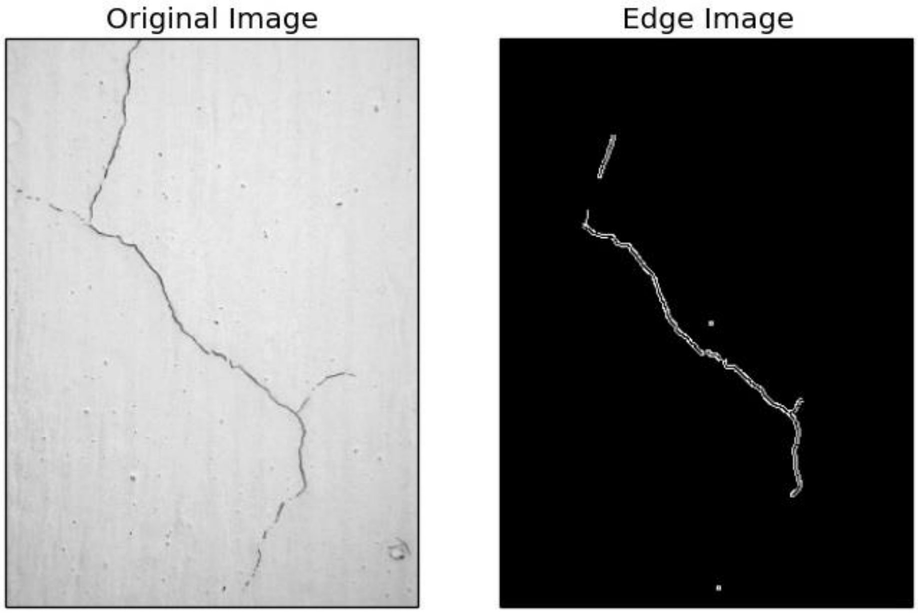


Fig. 4.8 Example of CED on a surface, minValue = 100 maxValue = 400

As shown in Fig. 4.9, at maximum threshold value of 600, the results clearly ruled out the existence of crack, which was the desired result.

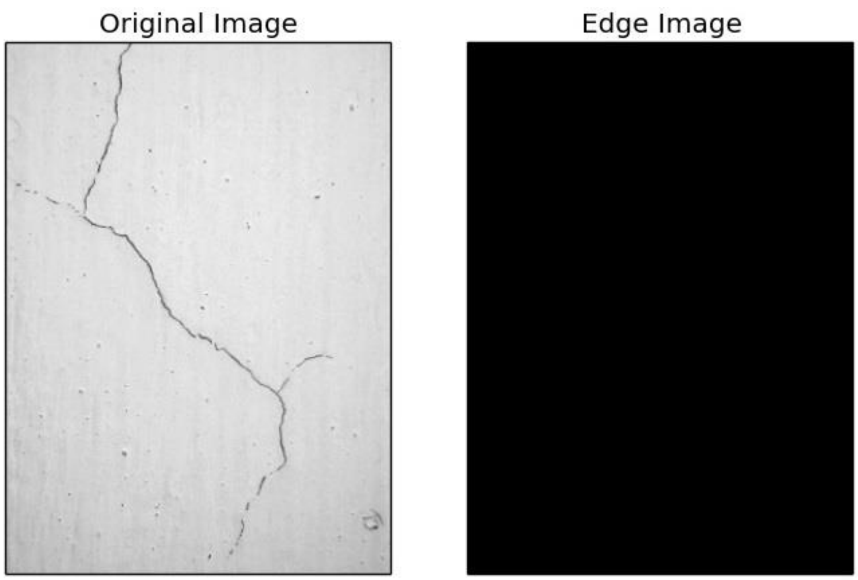


Fig. 4.9 Example of CED on a surface, minValue = 100 maxValue = 600

We then tested the process on a red coloured painted wall as shown in fig 4.10 and fig 4.11. The original image has a white scratch mark in the center. The process continues to show that mark as an edge even at higher threshold values and has to be ignored during visual inspection.

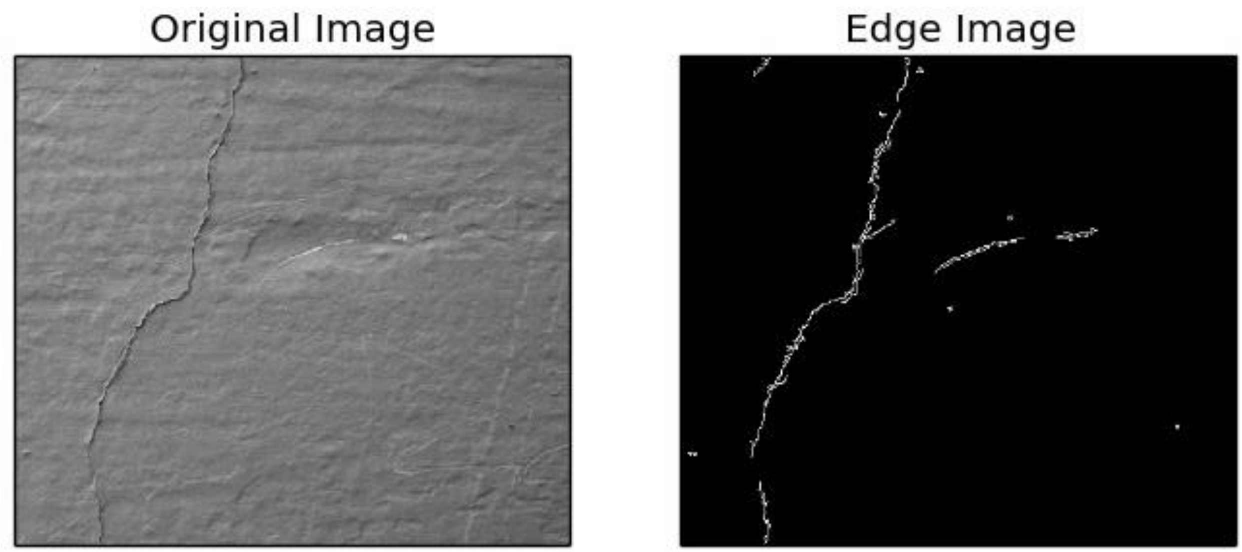


Fig. 4.10 Example of CED on a cracked painted surface, minValue = 100 maxValue = 400

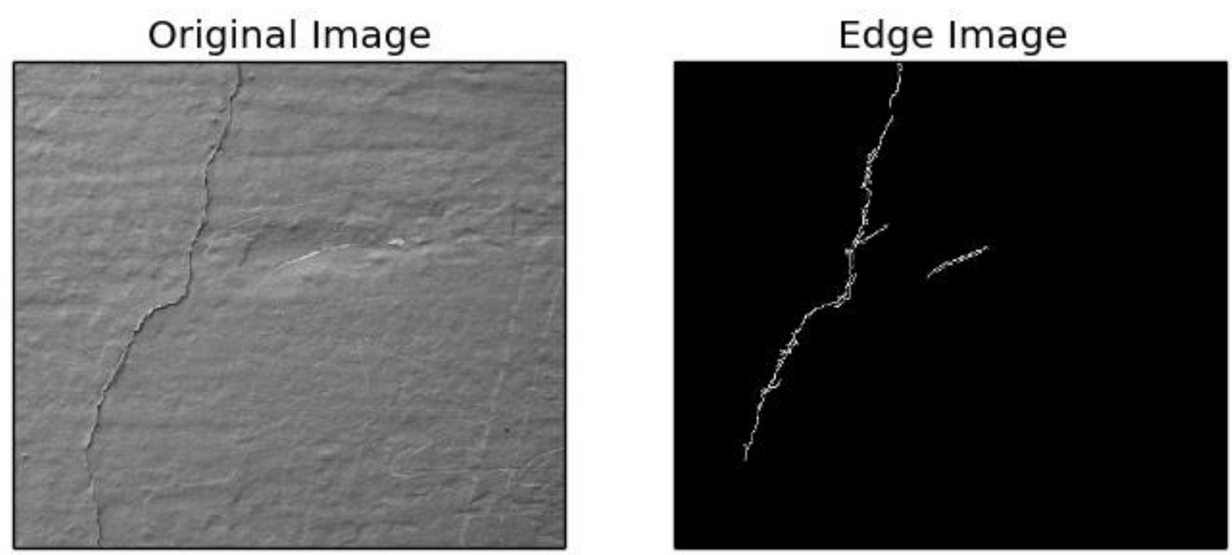


Fig. 4.11 Example of CED on a cracked painted surface, minValue = 100 maxValue = 600

CHAPTER 5

RESULTS AND DISCUSSIONS

This project involved designing, fabrication of the wall climbing robot and implementation of image processing techniques.

Various designs and Gait of geckos were studied and analyzed before selecting the design and conceptualizing the motion pattern of the robot.

Design was carried out using SOLIDWORKS.

Aluminum sheet was chosen for fabrication of parts. All parts were indigenously cut using CNC machine. CNC machine was carefully programmed for accurate cutting of the parts.

During the assembly difficulty was faced over the selection of power supply unit. Several power sources were tried and tested. A 12V battery was used as a power source, however it failed to supply constant power as the heavy duty servos drained more current.

After several attempts and trials, SMPS unit was found to be the most reliable power source. So the battery was replaced by a SMPS unit.

Various algorithms and processes K-Mean algorithm, Template Matching, Percolation Algorithms including Canny Edge Detection algorithm was selected for image processing.

While the algorithm clearly identified a crack in a lighter background, it showed fluctuating results under darker and colored backgrounds. Fluctuating results were obtained when tests were carried under lower illumination conditions.

Final crack identification was carried out using visual inspection.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

The current project is an effort towards detecting cracks on the surfaces of buildings and high structures. This will help reduce threat to human life in hazardous working conditions and will act as warning system by detecting the appearance of cracks in initial stages in critical points on bridges, buildings and pillars.

Image processing using Canny Edge Detection provided reliable solutions. But it still requires human observer to make the final decision about the presence of crack.

The future scope involves creating a fully automated robot which will have an internal power supply and decision making system.

The robot will have the ability to detect cracks and will have the ability to decide the level of danger it possess. This will make the robot completely autonomous and will not require a human observer.

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