IDEA-2015-ME01-Rope Climbing Robot

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MAY – 2016

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IdeaLab Project

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Under the mentorship of
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Declaration

We do hereby declare that the technical project report submitted is original, and is the outcome of the independent investigations/research carried out by us and contains no plagiarism. The research is leading to the discovery of new facts/techniques/correlation of scientific facts already known. This work has not been submitted to or supported by any other University or funding agency. We do hereby further declare that the text, diagrams or any other material taken from other sources (including but not limited to books, journals and web) have been acknowledged, referred and cited to the best of our knowledge and understanding.

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Annual/Final Report of the work done on the Idea Lab Project.

1. Idea Lab Project ID: IDEA-2015-ME01

2. Project Title: Rope Climbing Robot

3. Period of Project: 6 Months

4. (A) Name of Student (Roll No.): Sachin Panchal (12BME034)

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   (e) Name of Mentor: Mihir Chauhan

5. Project Start Date: 01/10/2015

6. (A) Total Amount Approved: Rs. 27000/-

   (b) Total Expenditure: Rs 14351/-

   (c) Report of the work done:

   I. Brief objective of the project:

   - To design and simulate the mechanical structure of the robot using the CAD software.
   - To develop a Rope Climbing Robot (RCR) that can climb on inclined rope of varying tension.

   ii. Work done:

   Developed a Rope Climbing Robot (RCR) that can climb on rope at various inclination.

iii. Results achieved from the work:

This project has not been presented anywhere before.

iv. Has all the objectives been achieved as per plan. If not, state reasons.

Yes, all the above mentioned objectives has been achieved satisfactorily.

v. Please indicate the technical difficulties, if any, experienced in implementing the project:

- Robot started slipping at higher inclination or less tension in rope.
- When tension in rope is less, it becomes difficult to maintain contact with all three pulleys.
- When tension in rope is less and all pulleys are not in contact with rope, robot sways side to side while moving.

vi. If the project has been completed, please enclose a summary of the findings of the study:

A Rope Climbing Robot has been developed and tested for various inclinations of the rope. Following are the major observations:

- Robot can travel steadily and easily on the rope with inclination up to 45^o.
- When tension in rope is low, rope does not maintain contact with all three pulleys. At such times, tension adjusting screw increases the normal force between rope and driving pulley, thus increasing frictional force, which allows robot to keep moving.
- When tension is low and rope in not in contact with all pulley, robot becomes unstable by swaying side to side.

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Report

Introduction

Nowadays due to the advancement in technology, robots are replacing humans for higher accuracy, reliability, speed and at places which are hazardous for humans. There are certain places which require development of special robots. These are:

- Robots that works at mining and nuclear power plant.
- Robots which can help at time of disaster.
- Robots to record real time sports event from many different angles.

One such robot is Rope climbing robot can be used at places such as detecting faults in voltage transmission line, to transfer any necessity during any calamity or disaster from one place to another and record any event at from various angle. The robot can inspect the wire rope at any height which is dangerous for humans to do. Also it is used in places like bike racing, rowing and field games such as cricket and football where we require the camera to travel along with racers or cover whole field very quickly. Also such type of robot can climb at any inclination of rope, it can climb vertical rope and horizontal rope.

Figure 1 below shows the major requirements of a rope climbing robot.

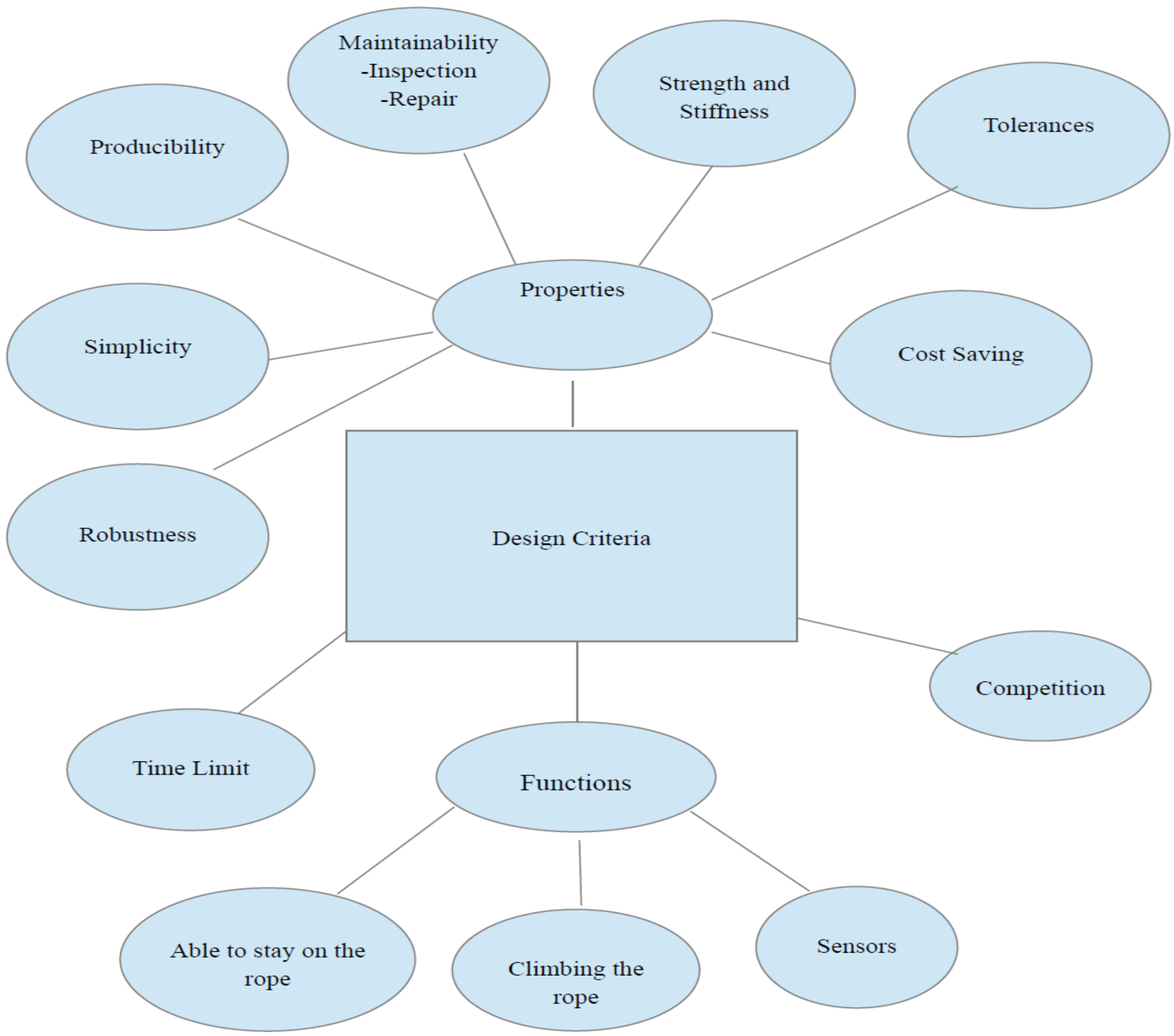


Figure 1: Major requirements of a RCR [1]

1.1 Literature Survey

From literature referred, different mechanisms with different gripper were studied. Few of them are as follows:

1.1.1 Piston based mechanism

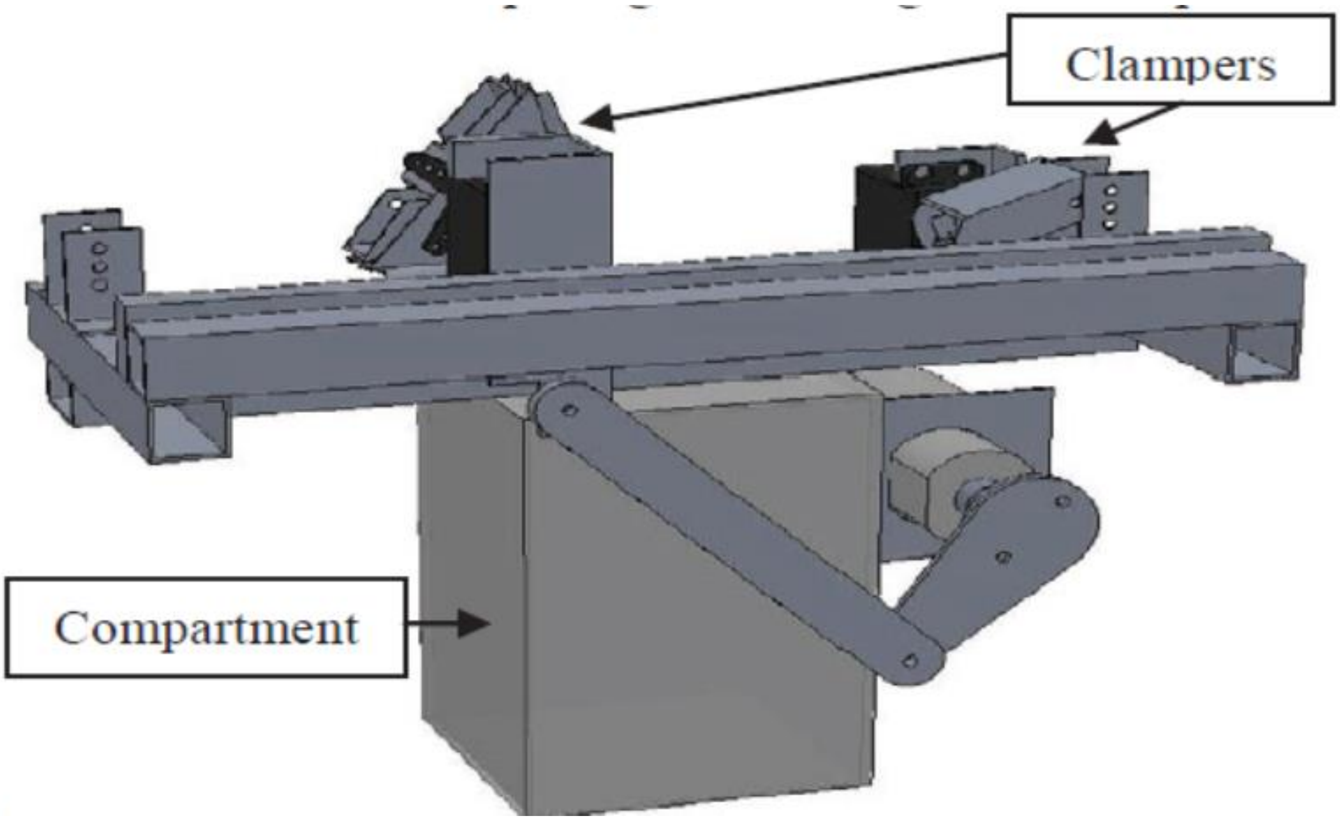


Figure 2: Piston based mechanism for RCR [2]

Figure 2 shows a very basic design which works similar to the piston cylinder assembly. It consists of two clamper, which operate alternatively. When first clamper is clamped on the rope, second one which is attached to the linear slider will advances ahead till the slider length and then it will clamp the rope. Now, the first gripper leaves the rope and process repeats itself again.

Advantages: It provides large displacement in a single stroke. It convert rotary motion into linear motion.

Limitations: It requires large space. It is slow in motion. It is not feasible for heavy loads.

1.1.2 Sloth Type

Figure 3: Sloth's walking style [4]

The above Figure 3 shows the sloth which is Animal which climb on the branches of tree in a similar fashion of rope climbing robot.it consists of four links, out of which the link on the same side moves at a time while the others two on the opposite sides move at a time.

The links are given such a shape that it generate the optimum friction required so that it can grip the rope rigidly. It has good load carrying capacity and can operate at moderate speed. It starts to slip when the inclination of the rope is increased beyond the specified limit.

Figure 4: Robot inspired from sloth's walking style [4]

1.1.3 Caterpillar Inspired design

It is basically used for vertical climbing of the rope or wire. It this basically a wheel is there which follow the contour of the rope or wire. Along with this wheel it consists of few more wheels which consists of ultra-high molecular weight poly ethylene instead of having the contour. This poly ethylene provides a good friction force between the wheel ant the rope or wire and hence gives rigid gripping.

It is basically used for determining the strength of the rope or wire used in the suspension bridge. At very high height of the cables it is very difficult for the human to go there and inspect the strength of the cables, so the caterpillar based design is used which can easily detect the flaws and analyses the strength of the cable. Below Figure 5 shows a caterpillar inspired robot.

Figure 5: Caterpillar Inspired RCR [4]

It is very heavy in weight**.** Self-weight is a major issue in this design. Also at heavy load the poly ethylene starts losing its properties.

1.1.4 Humanoid Type design for RCR

It consists of gripper which are similar to the human hands. It is basically used where we require high accuracy and precision work. It is light in weight and used for lighter load. Also it is slow in motion, but good gripping force.

Mainly used in application like clamping of soft material as we can adjust the gripping force. It is also used in pneumatic and hydraulic applications. Below Figure 6 shows a humanoid type robot.

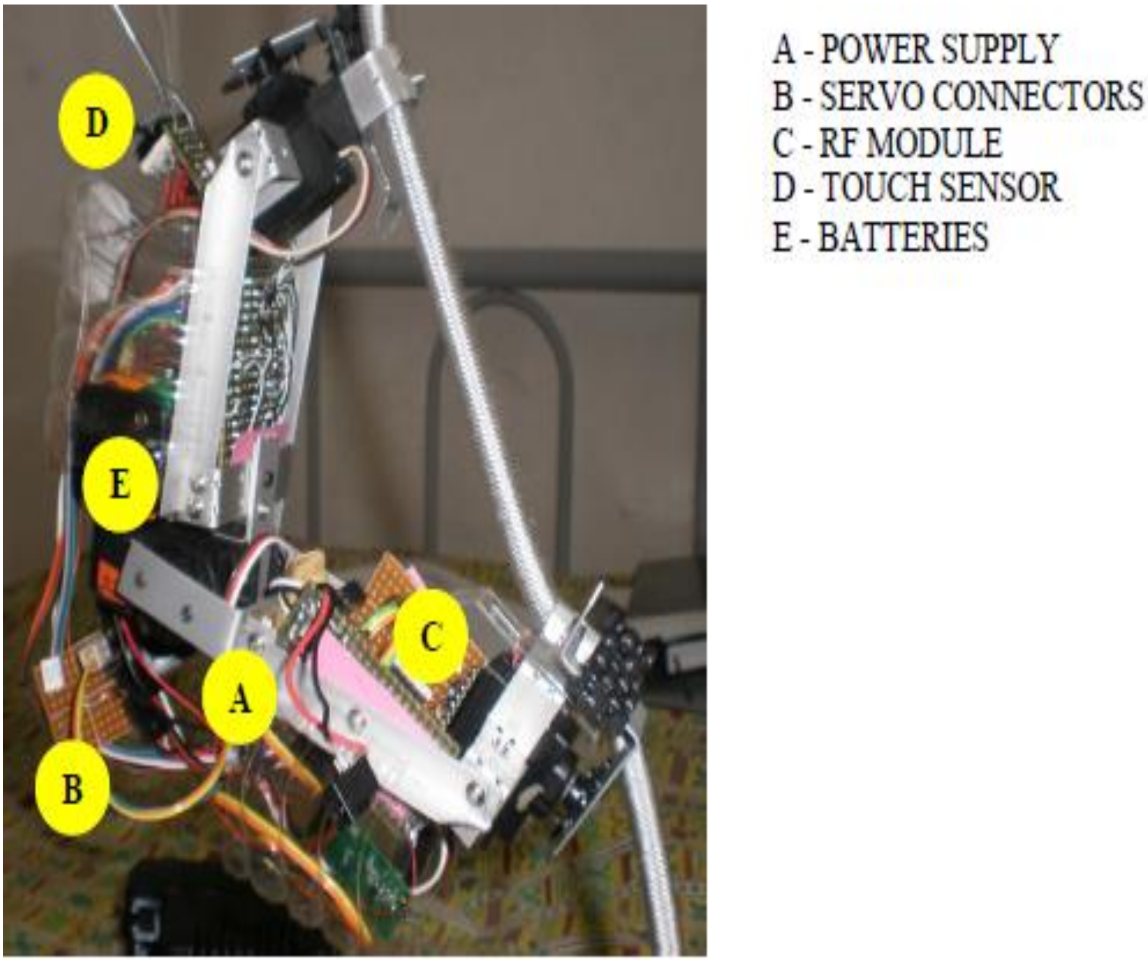


Figure 6: Humanoid type RCR [5]

1.1.5 Flying Cable Cam

This is the most efficient design among all the design so far discussed. It consists of three pulley which are arranged in such a way that rope will always remain in tension. Here the above part consist of two pulley while at the lower part it consists of single pulley. The lower pulley is the driving pulley while the other two pulleys are driven pulleys. Here we can modify the design by placing the driving pulley instead of in middle we can keep it near to any of driven pulley so that the friction generated would me very high. Also we have the attachment of sliding the pulley so that the friction force between the pulley and rope can be adjusted according the rope diameter. Below Figure 7 shows a flying cable robot.

Figure 7: Flying cable Cam [11]

These systems are point to point (AB) zip line type cable cam systems which use a single cable anchored between two points. They require no heavy expensive and energy hungry ground based winches. The Fly Line systems employ a DC motor on the trolley to “drive” along the cable. They are able to drive up a slope of slightly over 15 degrees at weight of around 30lb. They can travel on a level slope at up to 50lb all up weight. Power is provided by on-board lithium polymer battery packs. It is possible to reach speeds of up to 45mph (65kph) on a horizontal cable or move as slow as 18″ per minute (0.5m per minute) for smooth slow motions.

Braking is done electrically and is known as Asynchronous Regenerative Braking (ARB). ARB is accomplished with our industrial robot motor driver which means you’re putting power back into the battery when you decelerate or apply the brakes. Much like newer electric automobiles now do. The results with ARB are staggering. Putting as much as 50% of the power back into the battery for each acceleration/deceleration pair. The benefit is of course is greater duration/distance from a set of charged batteries.

It has various advantages like it can operate at very high speed, high gripping strength, dynamic stability and high load carrying capacity.

1.2 Major Objectives Proposed

The main objective is to design and fabricate a robot which can substitute human in each and every aspects. Suppose if we want to find faults in voltage transmission, then it is very dangerous if a human try to detect it. So here we use the climbing robot which can travel on the lines without any danger. Also we would be analyzing various mechanisms to perform various task and we would be coming with a common design which can be applicable to all the tasks. Also we would be analyzing the versatility of the common design i.e. "cable cam". Also we would be discussing the gripping force of the robot on different ropes which is a major problem.

1.3 Objectives Achieved

- ✓ Design and fabrication of a Rope Climbing Robot (RCR).
- ✓ Successful testing of RCR on various inclination of 0, 15, 30 and 45 degree inclination at varying tension.

1.4 Technical Difficulties Faced

- Robot started slipping at higher inclination or less tension in rope.
- When tension in rope is less, it becomes difficult to maintain contact with all three pulleys.
- When tension in rope is less and all pulleys are not in contact with rope, robot sways side to side while moving.

1.5 Design of Robot

Main component:

- Pulley
- Tension adjuster screw
- Sheet metal
- Selection of riving motor

1.5.1 Pulley

- There are two important dimension that needs to be found out about pulley:
    - Width of pulley
    - Radius of pulley

- Width of pulley depends on the diameter of rope that will be used. Here we have used ½ inch rope and thus allowing clearance, width of pulley is taken as ¾ inch.
- To calculate radius of pulley, we need to find the frictional force generated between rope and pulley under normal situations.
    - Weight of machine is supported on two pulley which is in turn countered by driving pulley. Thus, ideally normal load on driving pulley should be equal to weight of machine. But to take actual scenario in design we will take only 50 % of weight for design.
    - Assuming coefficient of friction as 0.2 to be on safe side.

$$\mu = 0.2$$

Normal Load = 0.5*Weight of machine

= 0.5*10 kg

=49.05 N

Thus,

$$Frictional\ force\ required, F = \mu * \ Normal\ Load$$

$$F = 0.2 * \ 49.05 = \ 9.81\ N$$

Now, motor torque available

$$T = 1\ N\ m$$

$$T = r * F$$

$$1\ Nm = r * 9.81\ N$$

$$r = 0.038\ m\ (approx.)$$

$$r = 1.5\ inch\ (approx.)$$

1.5.2 Tension Adjuster Screw

- This is a fail-safe feature of robot.
- This component increases normal load and thus increase frictional force between rope and pulley which may be useful in following conditions:
    - When rope is wet from water or oil.
    - If rope material is a slippery.

- If rope fails from one of ends; in that case robot will hang on robot, thus robot keeping himself and whatever load/ equipment it is equipped with, safe.

- This component thus has to provide normal load so that machine can at least stay steady at its position.
- To calculate normal load required,

  Frictional force between pulley and rope must exceed weight of machine:

$$Frictional\ force\ required = weigth\ \ of\ machine$$

$$Frictional\ force\ required = 98.1\ N$$

$$\mu * Normal\ Load\ required = 98.1\ N$$

$$0.2 * Normal\ Load\ required = 98.1\ N$$

$$Normal\ Load\ required = 490.5\ N$$

- Now, to apply this much normal load we shall use a power screw using standard nut and bolt.
- Formula for raising the load:

$$Tangential\ force\ for\ V - thread, F = w * \frac{\tan \alpha + (\mu / \cos \Theta)}{1 - \mu * \left(\frac{tan\alpha}{cos\Theta}\right)}$$

  Applying values from standard handbook, we get

$$F = 90.91\ N$$

  Thus,

$$T = F * r$$

$$1 = 90.91 * r$$

$$r = 11\ mm\ (approx.)$$

1.5.3 Cover plates

- Sheet metal forms the body of robot and has to take up self-weight of machine.
- So, the thickness of sheet metal should not shear upon its own load through bolts.

Thus,

$$S = \frac{F}{t * w}$$

$$3270000 = \frac{98.1}{0.01 * t}$$

$$t = 3\ mm\ (approx.)$$

1.5.4 Selection of driving motor

- Motor used in our proposed design is used to drive pulley which in turn rolls over rope using friction between pulley and rope and thus moving the machine.
- Here, we have used a motor with worm-gear gear box due to following reasons:
  - High torque
  - The machine does not slips back due to worm- gear arrangement in gear box which prevents machine from falling back while travelling on inclined ropes.
- Torque capacity will be taken as 1 Nm (approx.) which is most common in market. Using this as input we will design pulley.

1.6 CAD design and fabricated setup

Following Figure 8 and Figure 9 shows the setup we made in CAD software (The model is shown upside down for proper understanding):

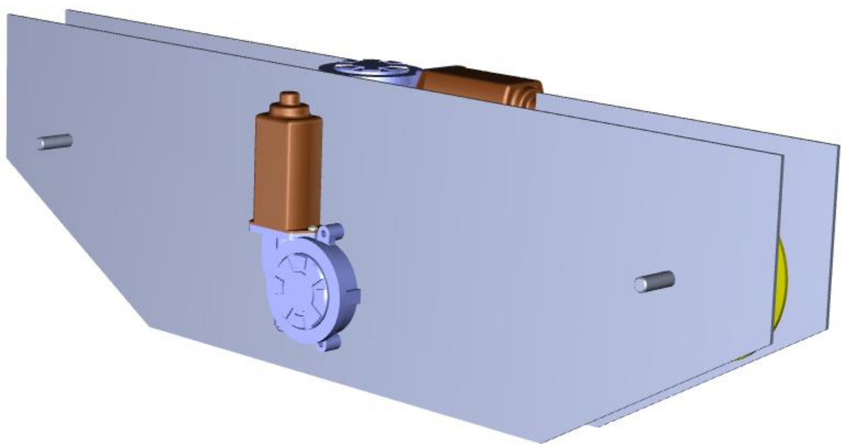


Figure 8: CAD Model of our proposed RCR

To illustrate properly the arrangement of pulleys, section view of RCR:

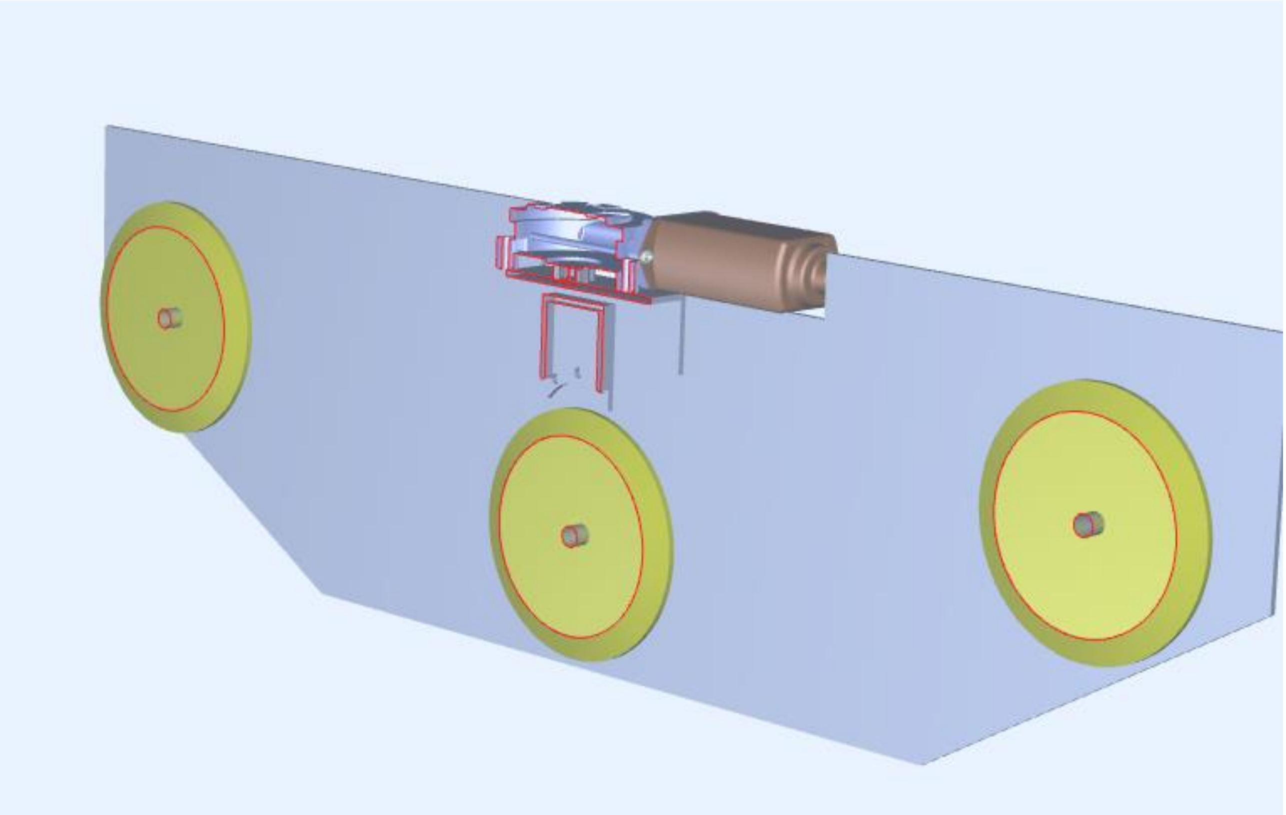


Figure 9: Section view of CAD model.

Following Figure 10 is the robot fabricated by us:

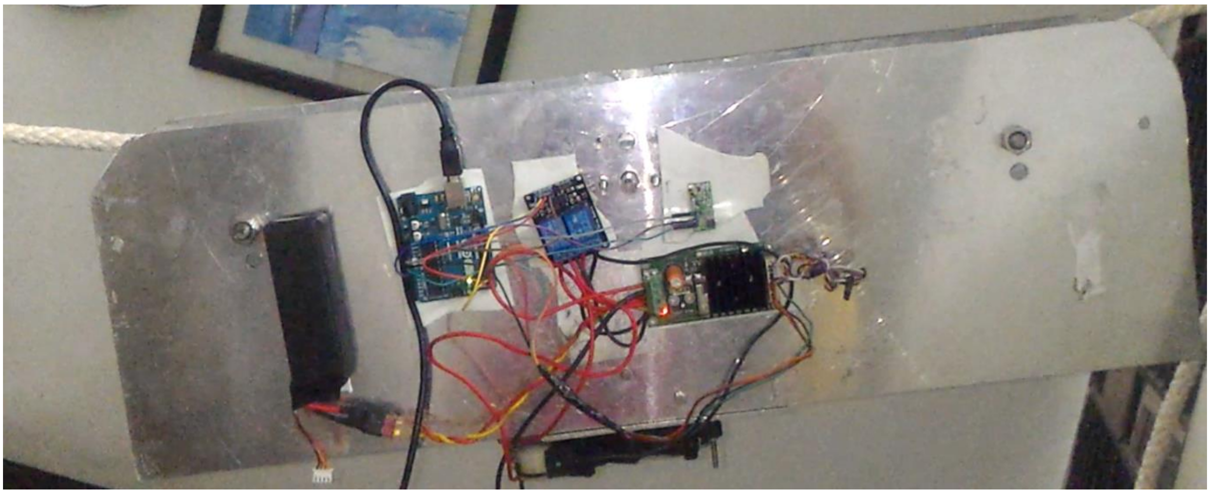


Figure 10 : Fabricated robot

1.6.1 Main Electronics Component

- Arduino UNO: Being an open-source AVR-based development board, Arduino is the most convenient platform for developing various hardware and software based projects.

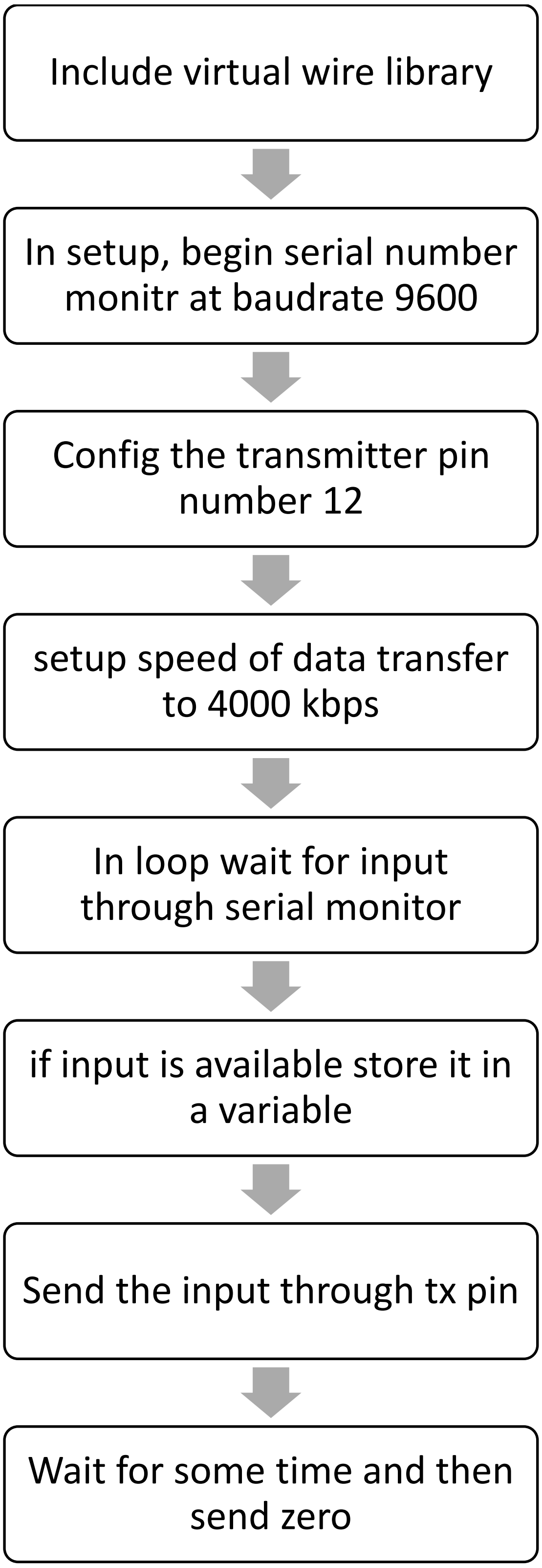
It is inexpensive as compared to other competitors and Arduino IDE can run on Mac OSX, LINUX and Windows. It is based on Atmega328 AVR microcontroller.

- Hercules 6V-16V, 16Amp Motor Driver: For driving motor we need a Motor Driver. Motor driver is basically an H-bridge capable of driving motor in either direction and at variable speeds. Hercules supports the peak current of up to 30A and is operated at 10 KHz PWM. It can be interfaced with microcontroller with 3.3V and 5V logic levels.

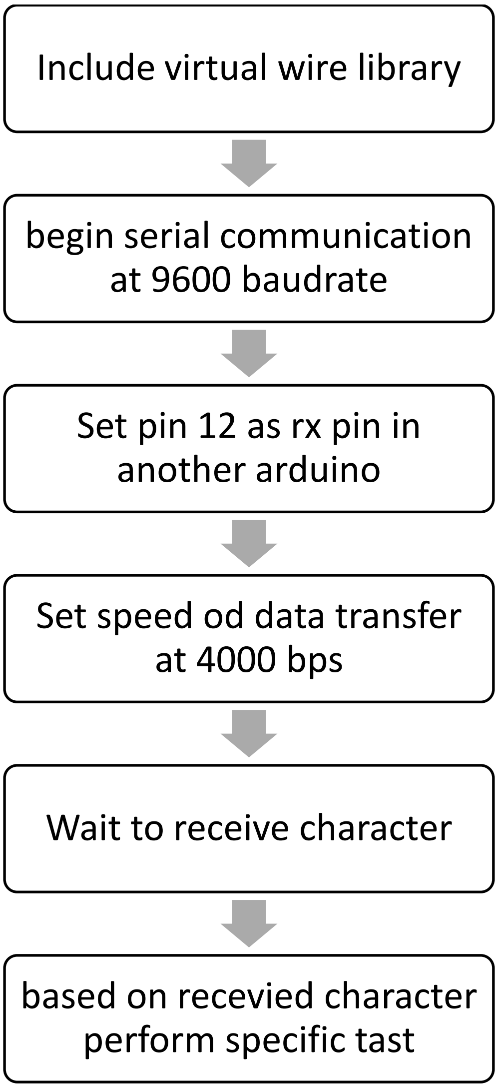
- RF-Module: Data can be transmitted wirelessly via different protocols and rules. One such method is RF transmission. In this project, for controlling the robot wirelessly RF-module are used. It has a range up to 100meters which is sufficient for the number of applications.
- Opto-Isolated 2 Channel 5v Relay Board: Relay board is another module for driving motor in different directions but at a constant speed. It uses a simple logic of applying forward and reverse voltages at the two terminal of motor for driving it in a different directions.

1.6.2 Algorithm

1.6.2.1 Transmitter algorithm



1.6.2.2 Receiver Algorithm



1.6.3 Commands

Commands	Task
W	Tension adjuster moves towards rope
S	Tension adjuster moves away from rope
A	Forward motion of robot for 1 second
D	Backward motion of robot for 1 second
Z	Continuously forward motion till stop command executed
C	Continuously backward motion till stop command executed
0 (zero)	Stop command

1.7 Budget Analysis

- Total Amount Approved: Rs. 27000/-
- Total Expenditure: Rs 14351/-

1.8 Conclusion

Thus, we have developed a robot climbing robot which can do following:

- Robot can travel steadily and easily on the rope with inclination up to 45^o.
- When tension in rope is low, rope does not maintain contact with all three pulleys. At such times, tension adjusting screw increases the normal force between rope and driving pulley, thus increasing frictional force, which allows robot to keep moving.
- When tension is low and rope in not in contact with all pulley, robot becomes unstable by swaying side to side.

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