UNIVERSITÄT SIEGEN

Institut für Echtzeit Lernsysteme (EZLS)

Department of Electrical Engineering & Computer Science

Institut für Echtzeit Lernsysteme(EZLS)

Design & Simulation

Of a new structure for an autonomous stair climbing robot

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1. Introduction

Taking stairs by a robot is always a challenge for engineers. Optimization of several engineering fields should be done to reach this goal. Due to the various applications of stair climbing robots the design of each one is unique.

Because of high price of electrical and mechanical components in a stair climbing robot every new design in this field should be simulated by suitable simulation tools to test the reliability of that. Even the performance of a robot could be modified by simulation.

In this project a stair climbing robot has been designed and simulated to take stairs to be used in oil industry. So the stability and precise of robot are so important in this case.

2. Conceptual Design

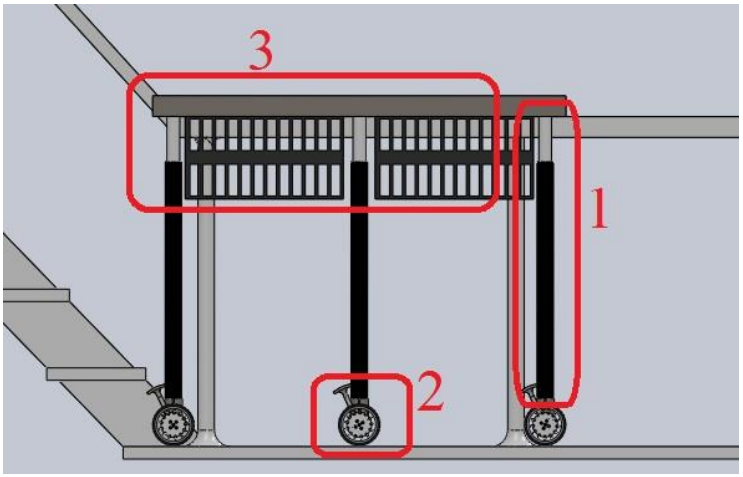
A robot is made of several components in which chassis and powertrain have the most importance and priority to design. A robot is defined by its chassis and powertrain, so at the first to design a robot these two parts must be identified.

Specially for this project to design a structure which leads a robot to go up from the stairs, all the chassis and powertrains which can be used in this kind of robot must be evaluated to design a structure which is fully fulfil for the final desired. In this chapter all the powertrains and chassis is evaluated to choose the best system to be used in the detail design step.

After checking all kinds of chassis and powertrains, a solid chassis which is added to a standard powertrain with standard wheels have been chosen. The advantages of this system are low-price and design procedure which is not too complicated.

3. Detail design

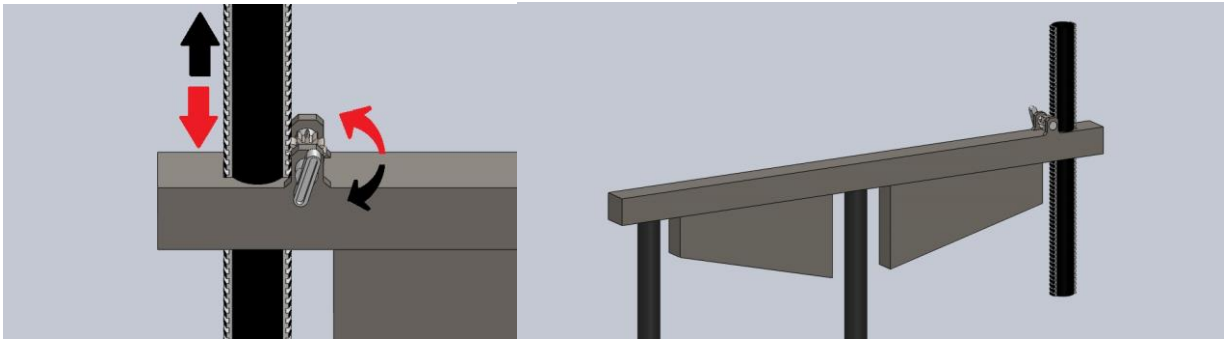
Here to design a stair climbing robot a normal chassis with six wheels has been designed. Each wheel contains a telescopic hydraulic cylinder to lift the robot in stair climbing procedure.



Components of new system

1. Cylinder compact 2. Wheel compact 3. Chassis of the robot

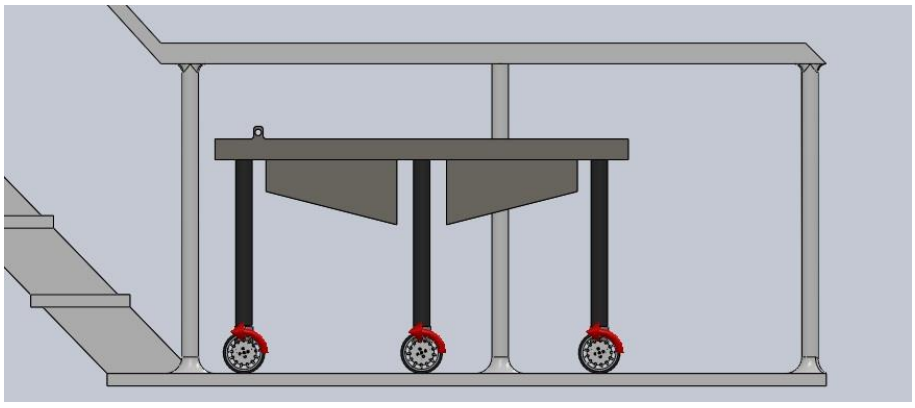
As it's shown here, a Rack and Pinion gear system is used to move the first row of wheels of the robot up. By help of this system, robot takes stairs with a static control strategy in which its chassis is horizontal all the time.



The design of first row of wheels of the robot

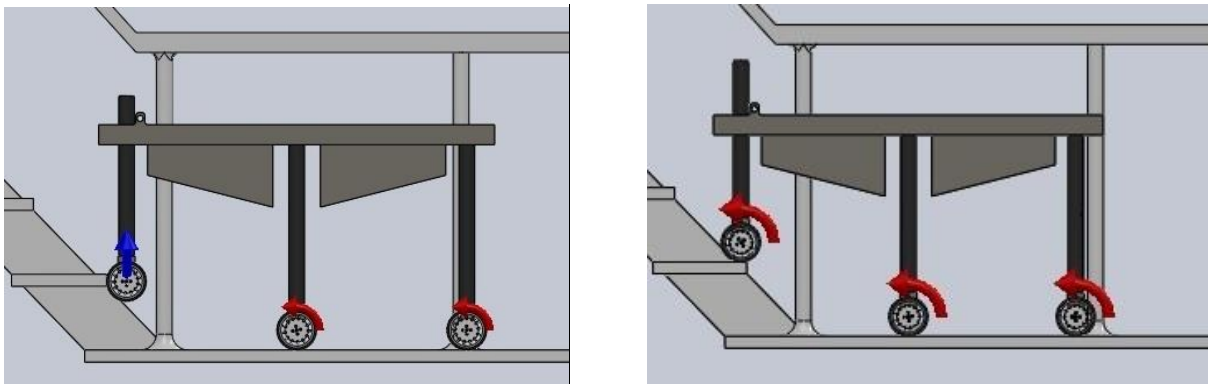
3.1. Control strategy

1. The robot moves so simple in horizontal paths. All the cylinders in this time are in the lowest length to increase the stability of the robot.



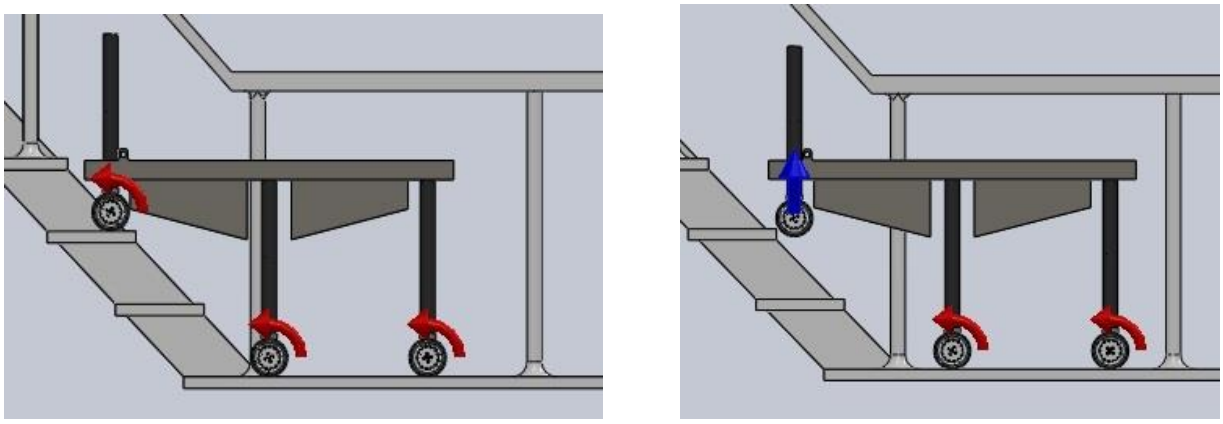
Horizontal paths

2. When sensors sense the first stair, robot will stop and the servo motors of the rack and pinion system will lift the first row of wheels up to take the first stair. At this time all the wheels are stopped to make robot stable. When the robot took the first stair and first row of wheels has been lifted enough, wheels start to rotate to move forward. By this method the first row of wheels will take the first stair smoothly.



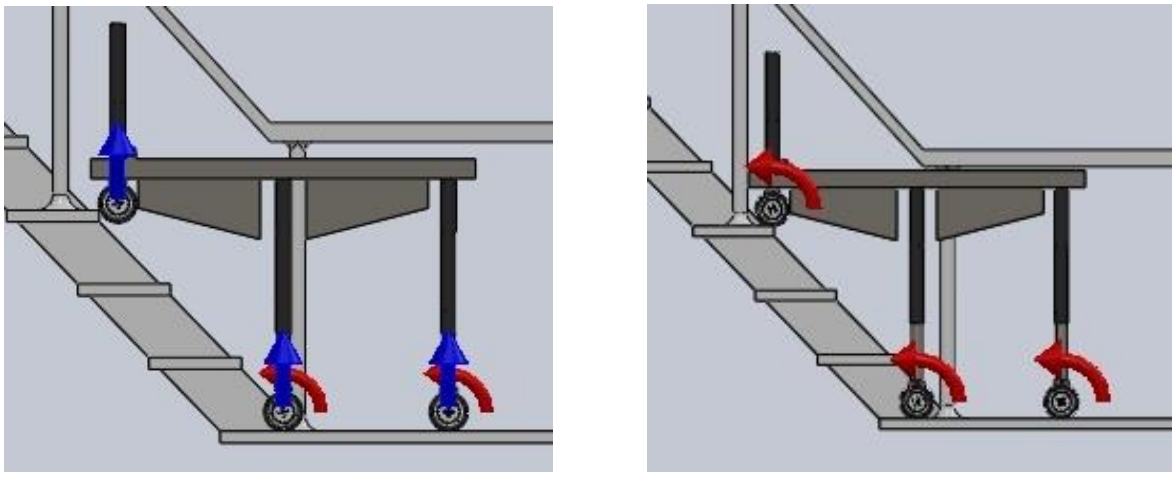
Taking the first stair by the first row of wheels

3. By sensing the second stair by first row of wheels the control unit of the robot can repeat the step number 2 again to take the second stair.



Taking the second stair by the first row of wheels

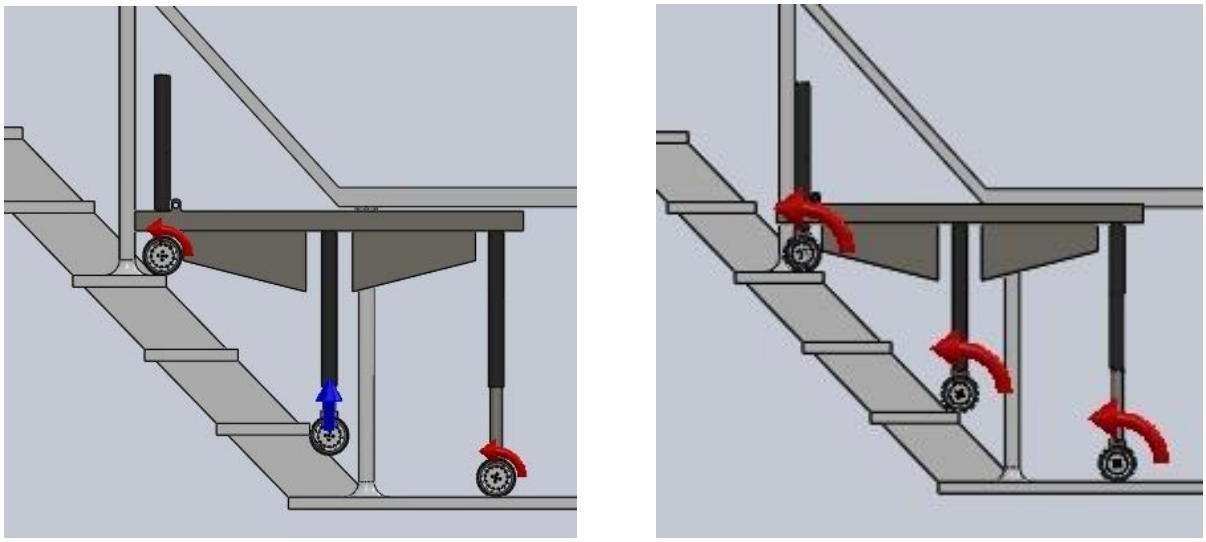
4. By sensing the third stair a new strategy to control the robot will be started. Till now all the hydraulic cylinders were off but from this step the control unit uses them. After first row of wheels reaches the third stair, the servo motors and Rack and Pinion will lift the first row of wheels. Because of dimensions of the stairs, the robot need more length to take third stair so two other rows of wheels will use their hydraulic cylinders to lift the robot. Just like the step number two as soon as the robot catch the third stair, wheels will start to rotate to go forward.



Taking the third stair by the first row of wheels

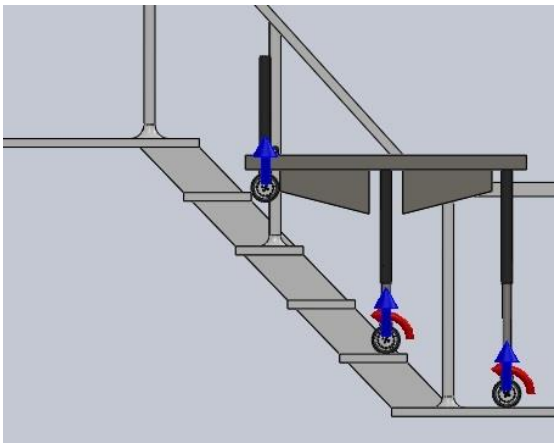
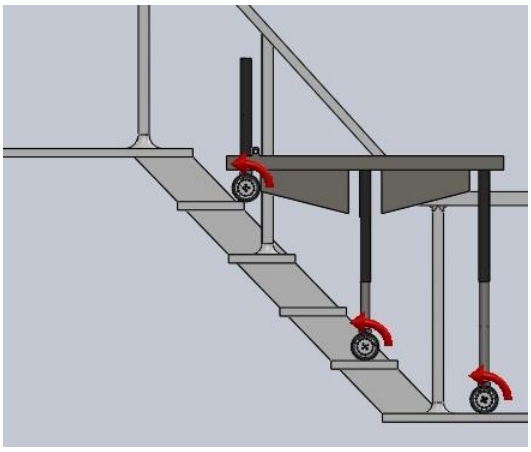
5. Due to the sizes and the ratio between wheels and stairs before the first row of wheels takes the forth stair, the second row of wheels senses the first stair so the servo motors will be off and instead of that the second row of hydraulic cylinders will lift the second row of wheels to take the first stair. As soon as the second row of wheels is lifted enough, two other rows of wheels will start to move to go forward.

   Notice: As it's shown here, always at least two wheels are on the ground in all the steps to make robot stable very well.



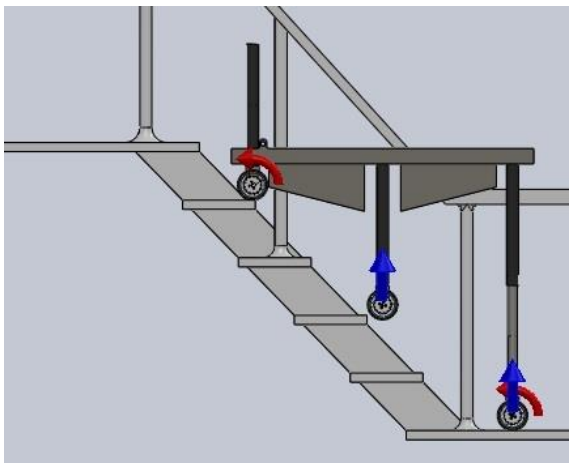
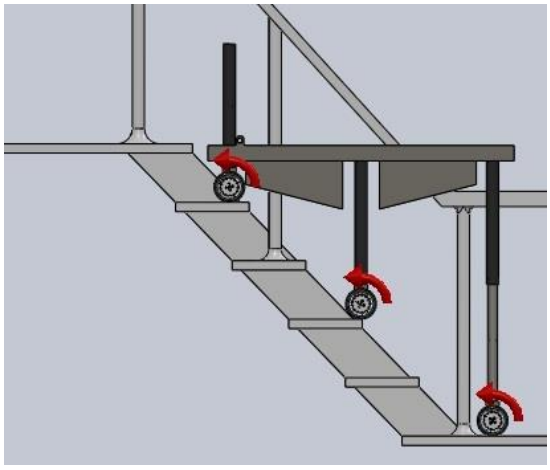
Taking the first stair by the second row of wheels

6. After taking the first stair by the second row of wheels, because of the size ratio between stairs and wheels, the first row of wheels will sense the forth stair. So the same strategy to take stair which has been used in step number 4 will be repeated.

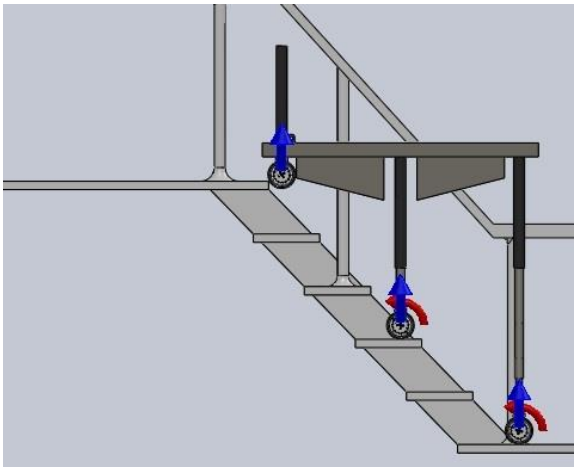
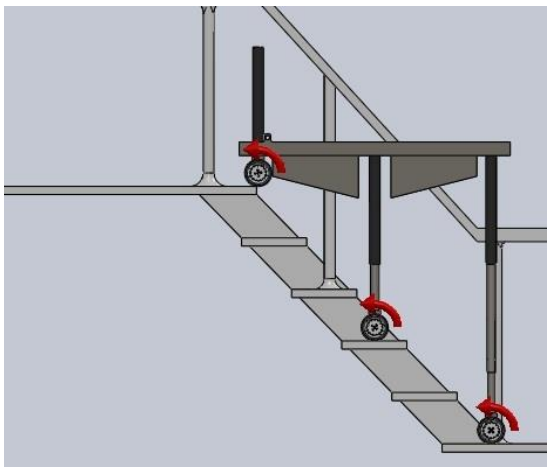
Taking the forth stair by the first row of wheels

7. Again the second row of wheels senses a new stair so the step number 5 will be repeated to take a new stair.

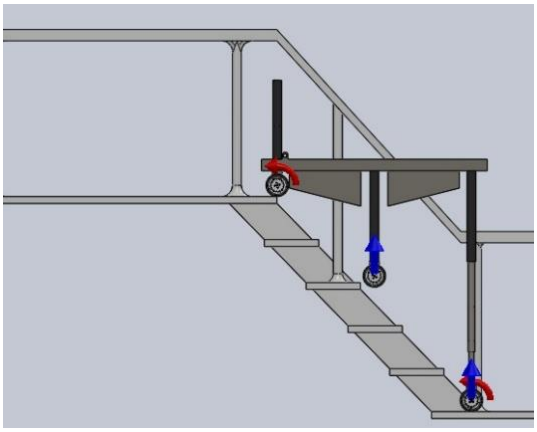
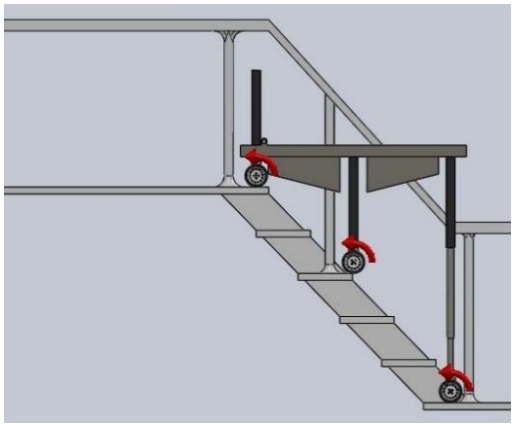
Taking the second stair by the first row of wheels

8. Because of sensing a new stair by first row of wheels again, the step 4 will be repeated to take this new stair.

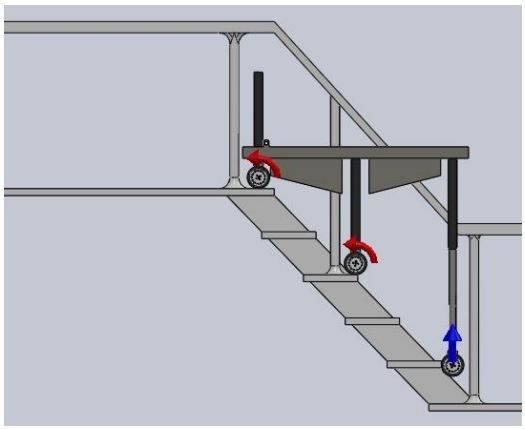
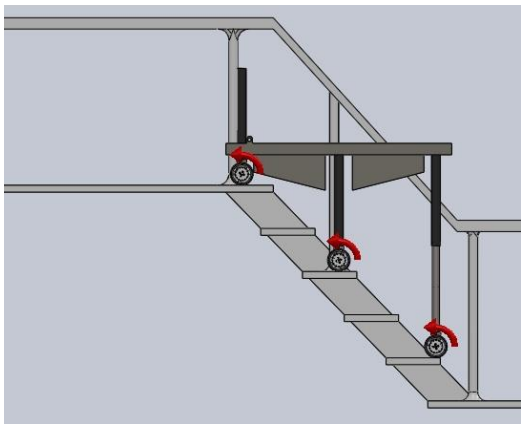
Taking the last stair by the first row of wheels

9. Again the second row of wheels of the robot senses a new stair so the step number 5 will be repeated to take this stair.

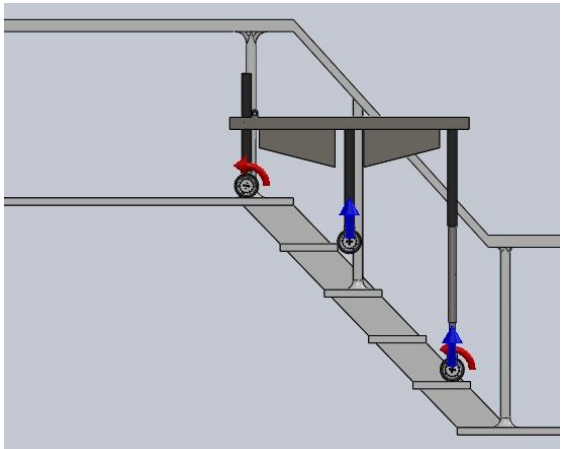
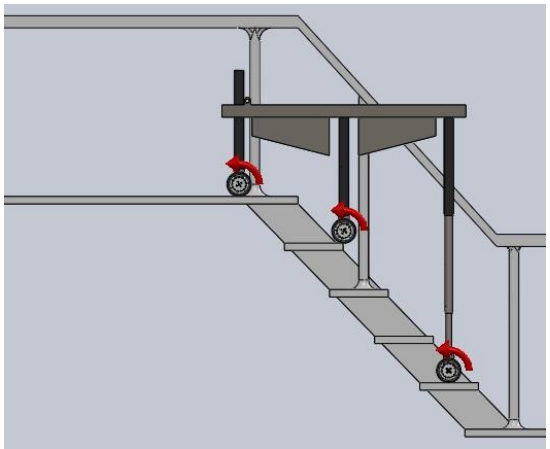
Taking the third stair by the second row of wheels

10. For the first time from the beginning of the movement the third row of wheels senses the first stair. So first of all the wheels will be stopped to make robot stable enough and the third row of hydraulic cylinders will life the third row of wheels. When the first stair is reachable by the lifted wheels then other wheels will start to go forward to take this stair.

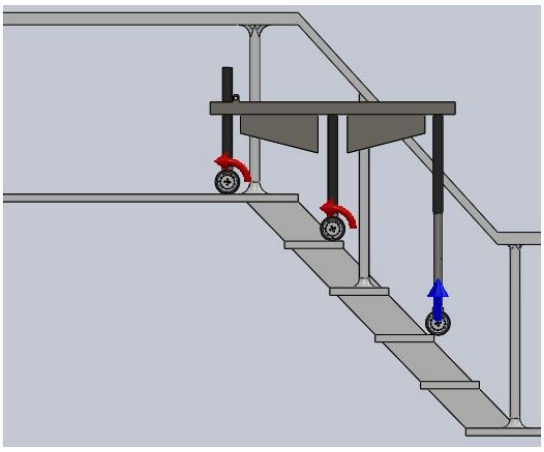
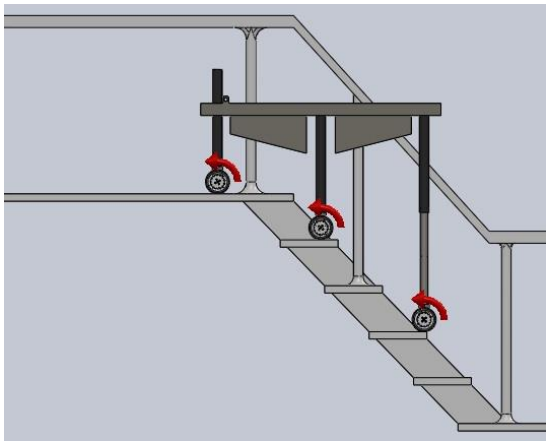
Taking the first stair by the last row of wheels

11. Again the second row of wheels senses a new stair so the step number 5 will be repeated to take a new stair.

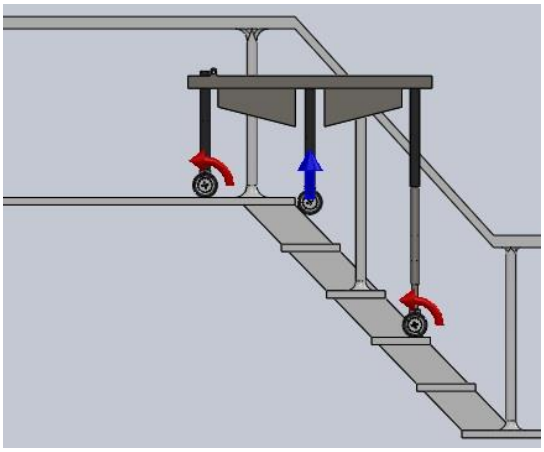
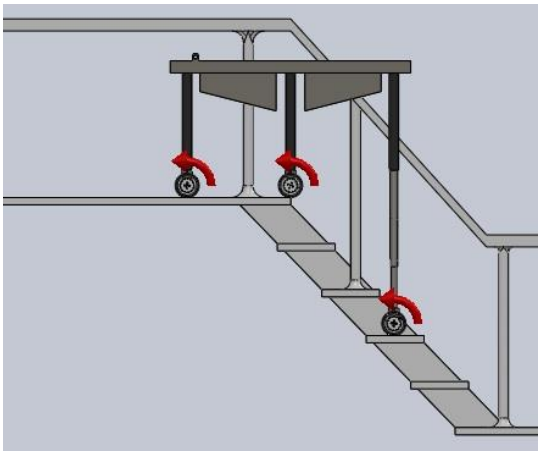
Taking the forth stair by the second row of wheels

12. Now by sensing a new stair by third row of wheels the step number 10 will be repeated to take a new stair.

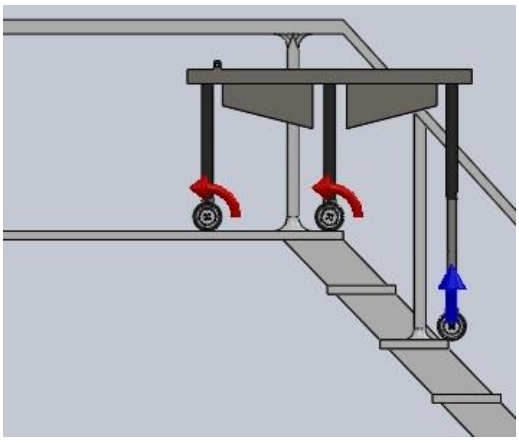
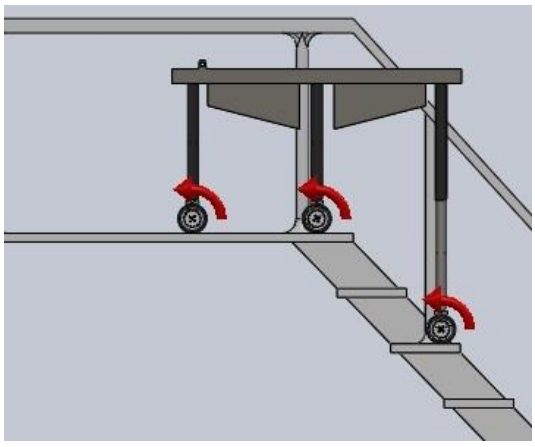
Taking the second stair by the last row of wheels

13. Again the second row of wheels senses a new stair so the step number 5 will be repeated to take a new stair.

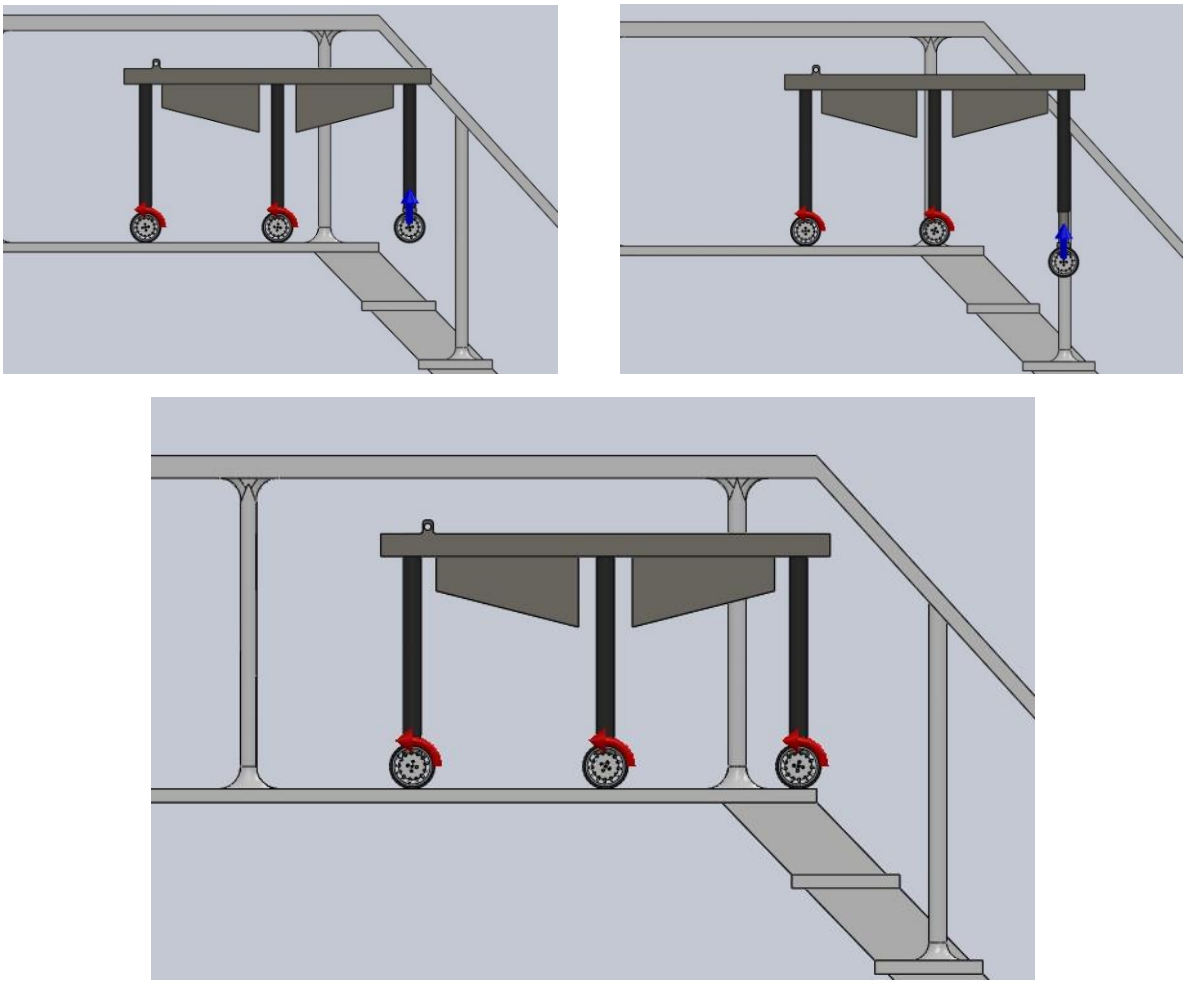
Taking the last stair by the second row of wheels

14. Finally first and second row of wheels are at the top of the stairs and at this time the third row of wheels of robot senses a new stair, so step number 10 is used again to take this new stair.

Taking the third stair by the last wheel

15. After sensing a new stair by the third row of wheels the third row of hydraulic cylinders lift robot to take two stairs at the same time, because other wheels are far enough from the final stair edge and due to the position of the center of mass of the robot to save time we can take two stairs together.

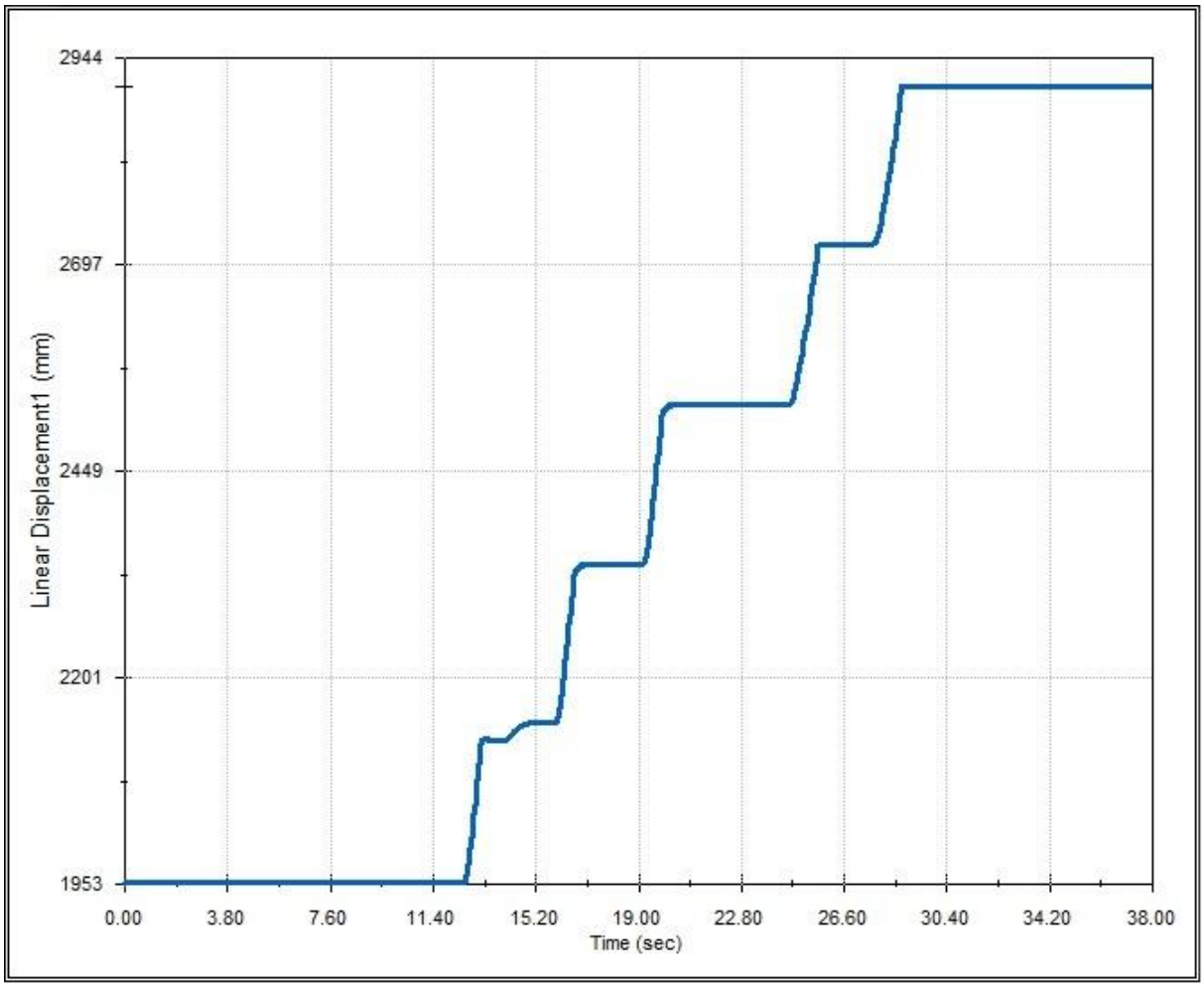


Taking the forth and last stairs by the last row of wheels

4. Results of Modeling and Simulation

To evaluate the motion of the robot, all parts of the robot have been simulated by Solid works and by help of Solid works Motion we implement our control strategy to taking stairs so the analysis of the motion has been done. The results have been shown here:

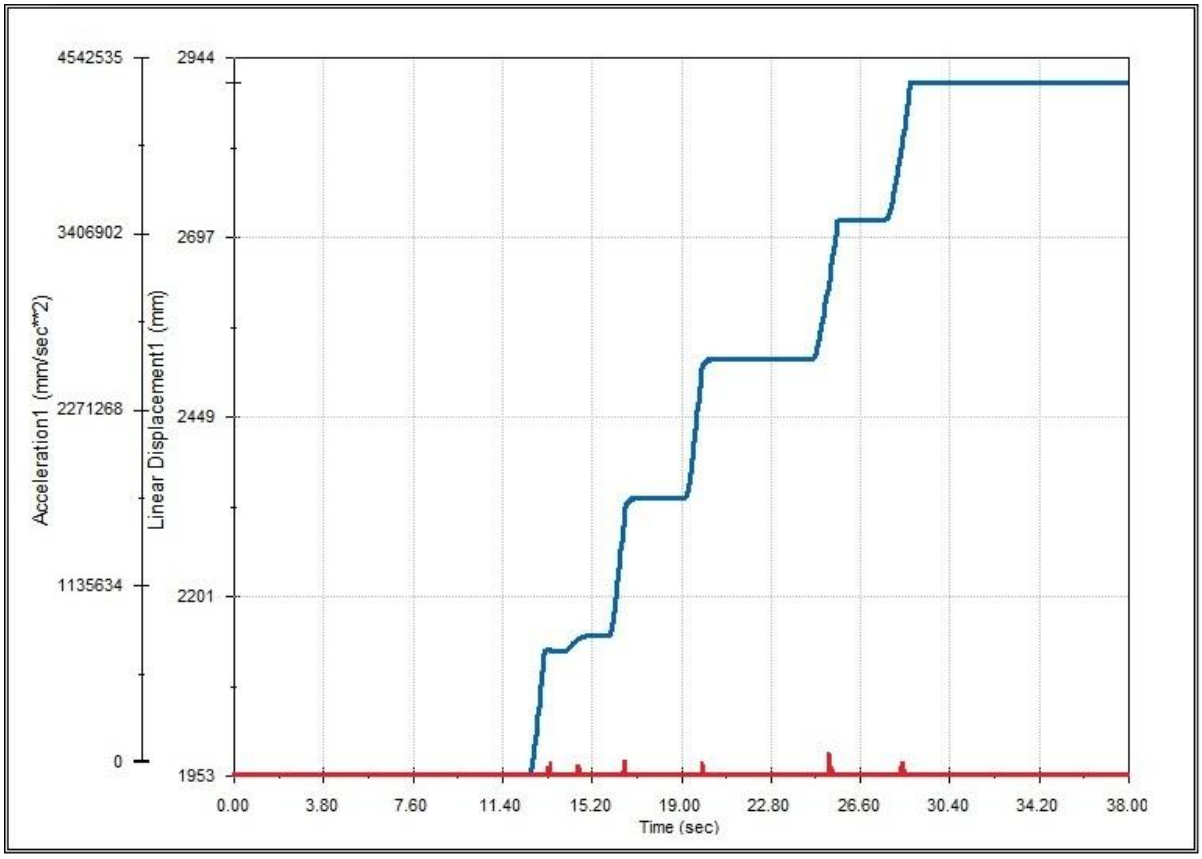
At the first we evaluate the curve of the center of mass of the chassis in duration of stairs climbing procedure:



Displacement of the center point of the chassis

As we see here the results show that the center of mass of the chassis use a very smooth curve in duration of the stair climbing. It means that robot is fully horizontal in duration of stair climbing. This feature helps robots to carry so sensitive staffs and even dangerous liquid in industry during robot takes stairs.

Here we can see the acceleration of the chassis in duration of stair climbing:



Acceleration due to displacement of the center point of the chassis

Because of the smooth movement, the acceleration during the movement is really acceptable and smooth. It means we have no unforeseen shocks in our chassis.

We can control the whole amount of acceleration by controlling the movements of hydraulic cylinders and servo motor.

Because of our control strategy which is almost a statically control, acceleration has no role in this time. It helps robot to being stable better.