Mysorebot

A Fruit Plucking Robot

Project Report Submitted by

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Contents

Chapter 1

Introduction

1.1 Context

Agriculture is one of our most important industries of any country. It provides food, feed and fuel necessary for our survival. With the global population expected to reach 9 billion by 2050 [4], agricultural production must double to meet the demand. With limited labor availability, lack of security for farmers in farmlands it would be nearly impossible to achieve the demand. Many developed countries are buying foreign land and beginning to farm there.

Agricultural Robot can solve the problem of labor to a large extent. Many countries have already adopted the robots in farmlands. But, many robots are specific for particular applications such as harvesting or plowing and it is not yet equipped to perform the difficult tasks such as plucking of ripen fruits. Considerable development and research are needed in the area of agricultural robots particularly for horticultural automation.

1.2 Proposed Solution

In this project a fruit plucking robot is modeled and simulated in Matlab Simulink Environment. The project proposes two kind of robotic vehicles: 4 wheel 3 DOF and 6 wheel 6 DOF robotic vehicle and a 5 link 5 DOF Manipulator. The two robotic vehicles are designed for different terrain environments.

The design of 6 Wheel 6 DOF rover was inspired by the design of the Rocky 7, Nasa's Mars rover [5] as shown in the Figure 1.1.

Figure 1.1: Rocky 7 [5]

1.3 Organization of the report

In following chapters, each robot is explained and its forward kinematics (DH parameter) is shown. For manipulator the inverse kinematics is also explained with matlab code, which is provided in the appendix A. The simulation model and block diagrams are explained for each model. Further the report provides the conclusion and the future work.

1.4 Gantt Chart

	Name	Duration	Start	Finish
1	Robotic Arm Selection and Kinematic Analysis	4d	10/29/2015	11/03/2015
2	Modeling of Robotic Arm and Wrist	10d	11/04/2015	11/17/2015
3	End Effector Modeling	5d	11/18/2015	11/24/2015
4	4 - Wheel Ground Vehicle Modeling	7d	11/25/2015	12/03/2015
5	Assembly of Robotic Arm and Ground Vehicle	4d	12/03/2015	12/08/2015
6	Final Testing	3d	12/09/2015	12/11/2015
7	Redesign of 4-Wheel Vehicle to NASA's 6 Wheel Rocky Mars Rover	14d	12/14/2015	12/31/2015

Figure 1.2: Gantt Chart

Chapter 2

5 Link 5 DOF Manipulator

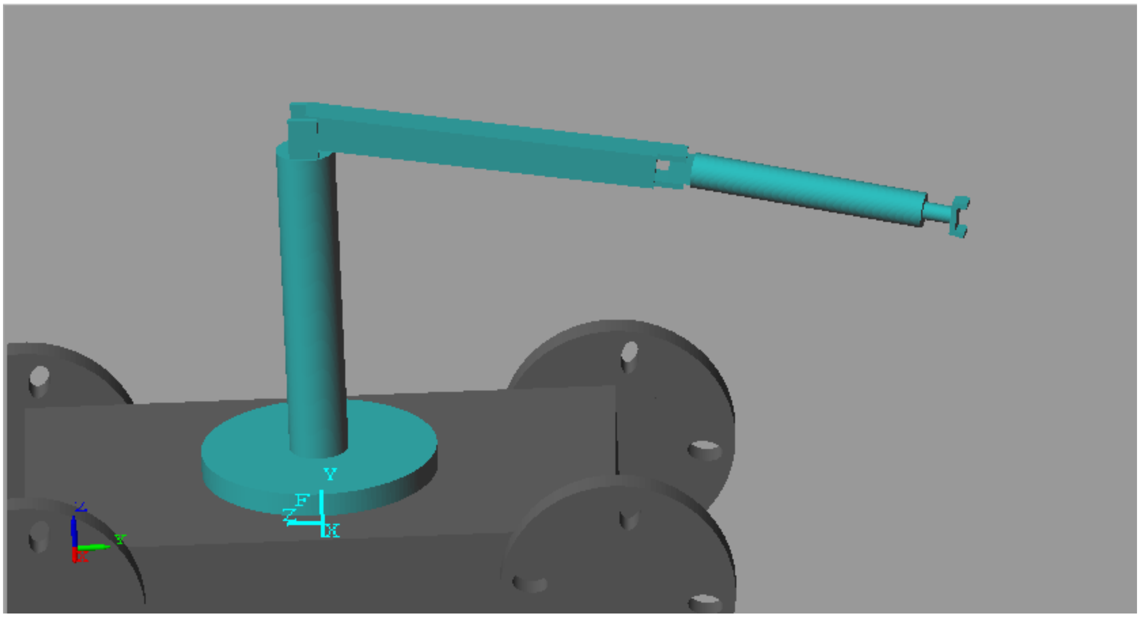

Figure 2.1: Simmechanic Model

2.1 Introduction

The Manipulator is optimally designed for the fruit plucking application. The gripper is designed such a way that it has both prismatic and revolute joint (Cylindrical joint). The prismatic joint is used to pull the fruit, whereas revolute joint is used for twisting the fruit when required.

In the following sections, Forward kinematics is shown in the form of DH parameters. Inverse kinematics is also discussed in subsequent section.

2.2 Forward Kinematics

2.2.1 DH Parameter

In Table 2.1 DH parameters are written with respect to the frames that are shown in Figure 2.2. One can write Jacobians and transformation Matrix as shown in the spong textbook, but it would be cumbersome to show all matrices in the report.

Table 2.1: DH parameter for Manipulator.

Frame	$\theta(deg)$	d(cm)	a(cm)	$\alpha(deg)$
1	θ_1^*	0	0	0
2	θ_2^*	300	0	-90^o
3	θ_3^*	0	300	$+90^o$
4	$\theta_4^* + 90^o$	0	100	-90^o
5	θ_5^*	100	0	0

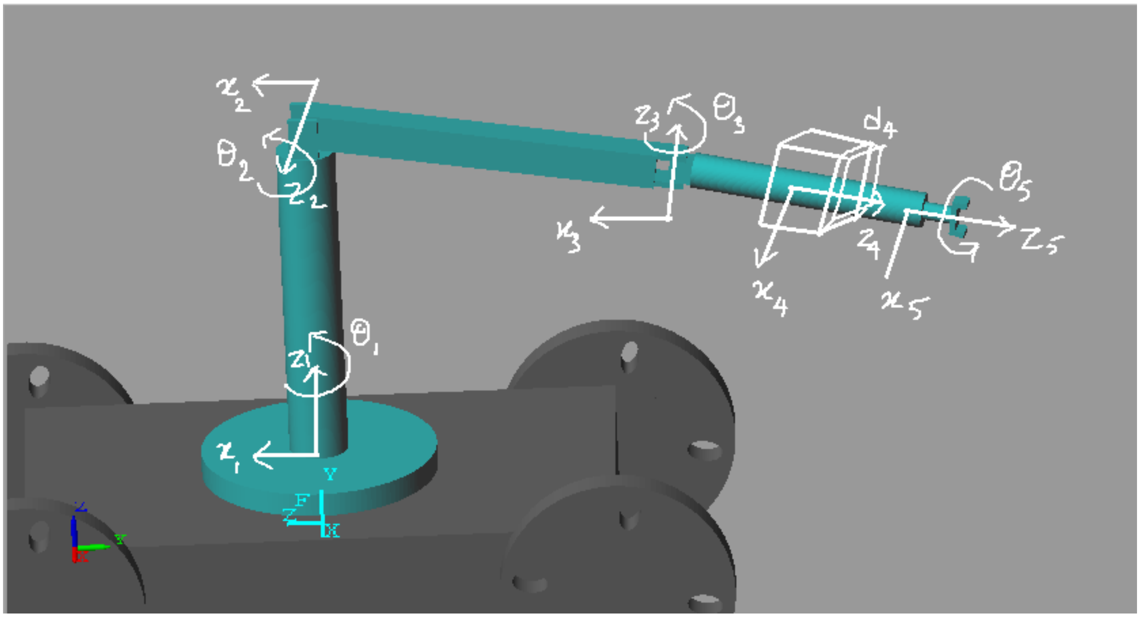

Figure 2.2: Simmechanic Model with DH parameter

2.3 Inverse Kinematics

The optimization technique is used to determine the inverse kinematics of the manipulator. While deriving the Inverse kinematics the gripper is not considered.

Consider the following equations, where X, Y are the desired end effector positions and L_i is the length of the link.

$$X = \Sigma_{i=0}^{3} cos(\theta_i) L_i \tag{2.1}$$

$$Y = \Sigma_{i=0}^{3} sine(\theta_i) L_i \tag{2.2}$$

Each joint angle has certain constraints which should be taken care in optimization.

$$20 < \theta_1 < 145 \tag{2.3}$$

$$-135 < \theta_2 - \theta_1 < 0 \tag{2.4}$$

$$-45 < \theta_3 - \theta_2 < 15 \tag{2.5}$$

With equations 2.1 and 2.2 one can form an objective function for the optimization.

$$Obj = X - \Sigma_{i=0}^{3} cos(\theta_i) L_i + Y - \Sigma_{i=0}^{3} sine(\theta_i) L_i \tag{2.6}$$

Above non linear objective function with constraints can be optimized using fmincon function in Matlab. The Matlab code used to optimize the above objective function is attached in the Appendix A of this report.

2.4 Simmechanics Simulation

Forward Kinematics and Inverse Kinematics are simulated for wide range of data and tested for different configurations. As Manipulator is the part of the robotic vehicle, it is simulated along with the simulation of the vehicle.

Figure 2.3 shows the simulink block diagram, where one may observe that the gripper is connected to the manipulator through cylindrical joint which accounts for both prismatic and revolute joint. Figure 2.4 and Figure 2.5 show the Gripper model and simmechanics block diagram. Gripper has two prismatic joints to hold a object such as fruit. The simulation of gripper is performed by providing motion input to prismatic joint.

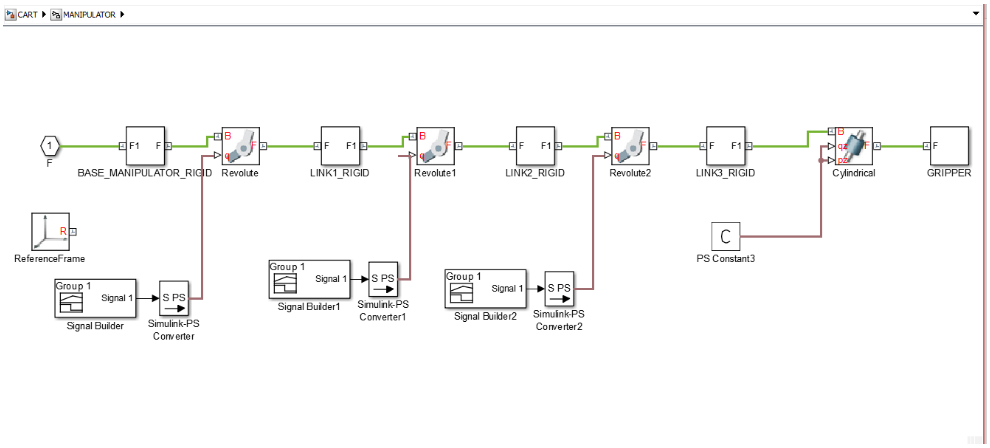

Figure 2.3: Manipulator Simmechanic Block Diagram

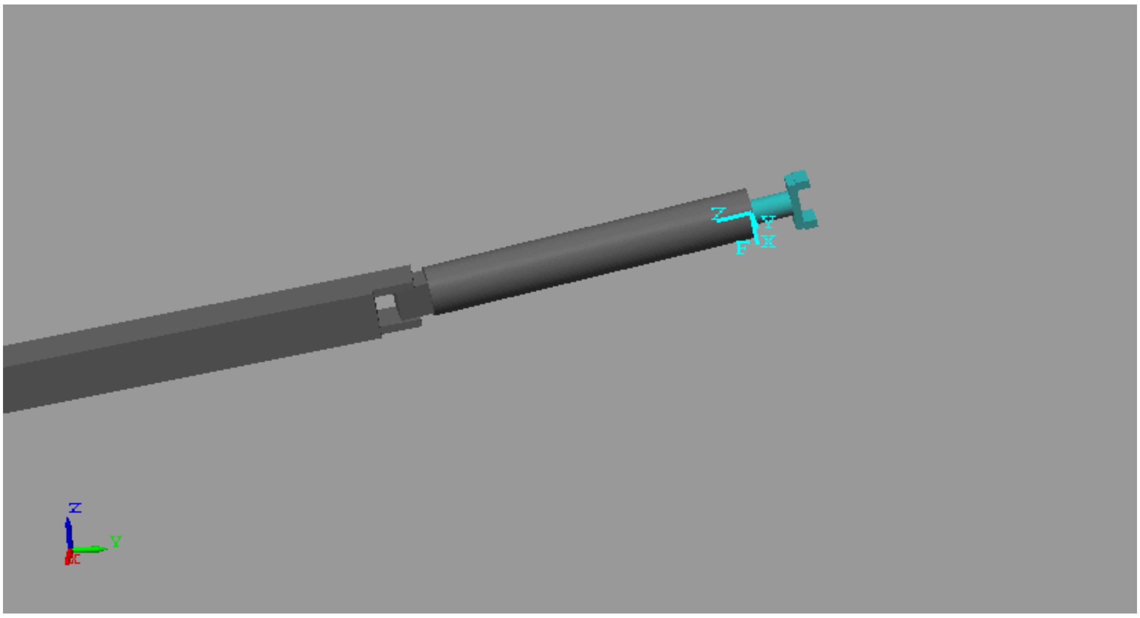

Figure 2.4: Gripper Simmechanic Model

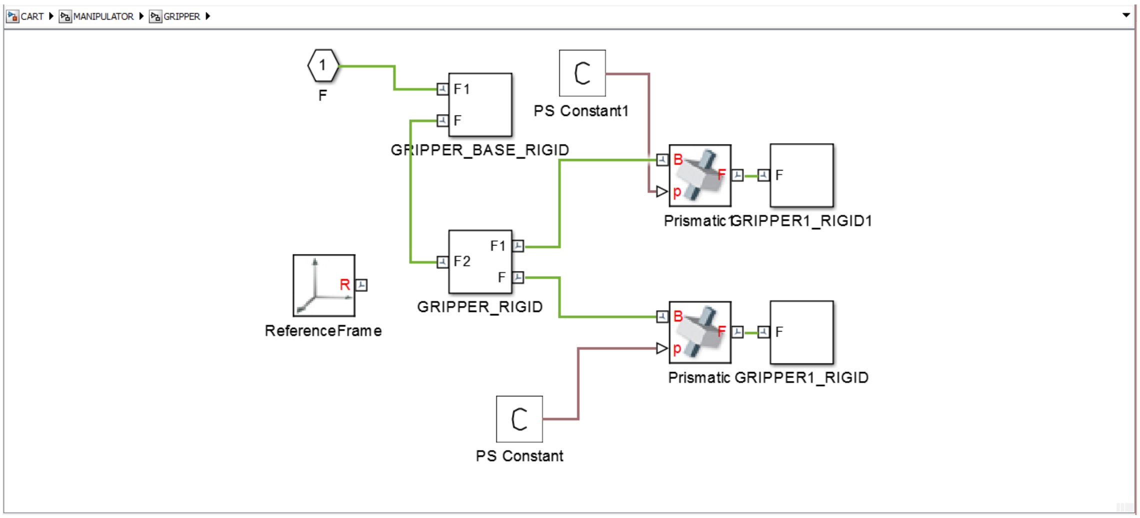

Figure 2.5: Gripper Simmechanic Block Diagram

Chapter 3

4 Wheel 3 DOF Robotic Vehicle

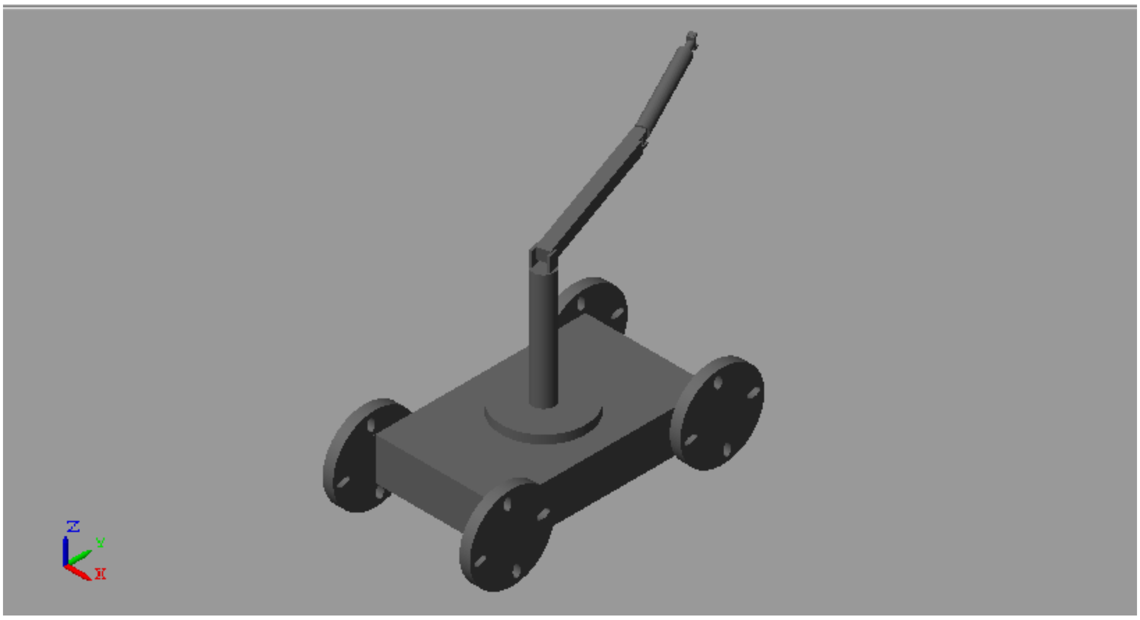

Figure 3.1: Simmechanic Model

3.1 Introduction

The 4 wheel robotic vehicle has 3 degree of freedom i.e. x axis, y axis and yaw (rotation along z axis). In the following sections, Forward kinematics is shown in the form of DH parameters. Apart from the DH parameters, position and heading estimation is shown for demonstration of forward kinematics.

The vehicle includes 5 link Manipulator. And, it is 500cm long, 200 cm wide, and 50 cm high.

3.2 Forward Kinematics

3.2.1 DH Parameter

Table 3.1: DH parameter for 4 Wheel 3 DOF vehicle.

Frame	$\theta(deg)$	d(cm)	a(cm)	$\alpha(deg)$
1	-90^o	0	250	0
2	θ_1^*	100	0	-90^o
3	-90^o	0	250	0
4	θ_2^*	100	0	-90^o
5	θ_3^*	100	0	$+90^o$
6	θ_4^*	100	0	$+90^o$

There are 4 kinematic chains defined for each wheel: 0->1->2 , 0->3->4 , 0->1->5, and 0->2->6. One can write Jacobians and transformation Matrix as shown in the text, but it would be cumbersome to show all transformation matrices in the report.

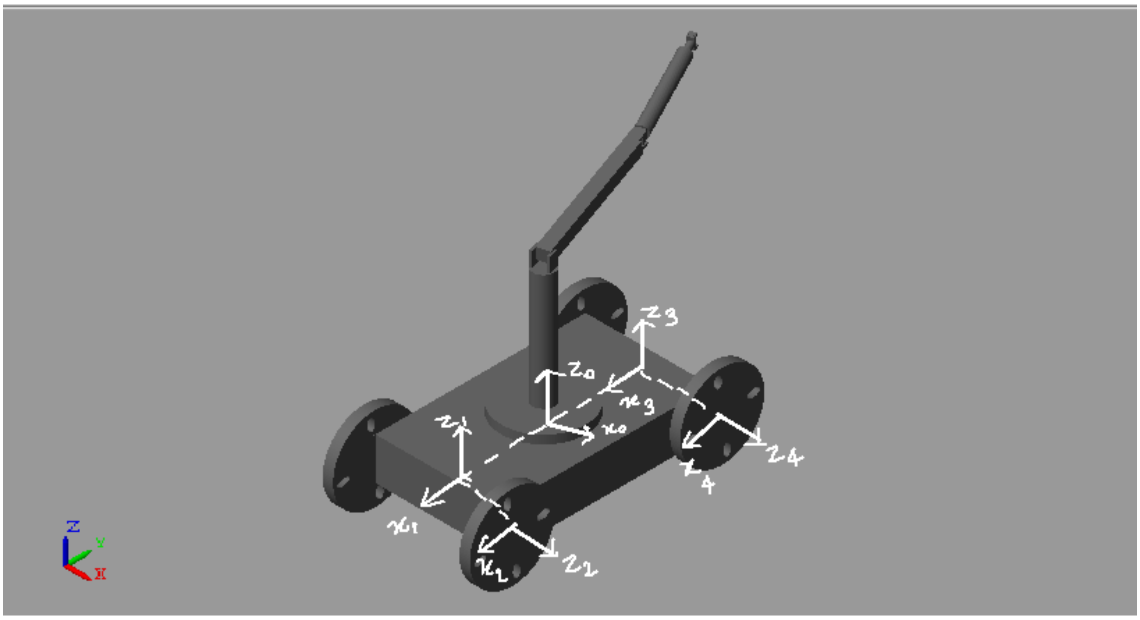

Figure 3.2: Simmechanic Model with DH parameter

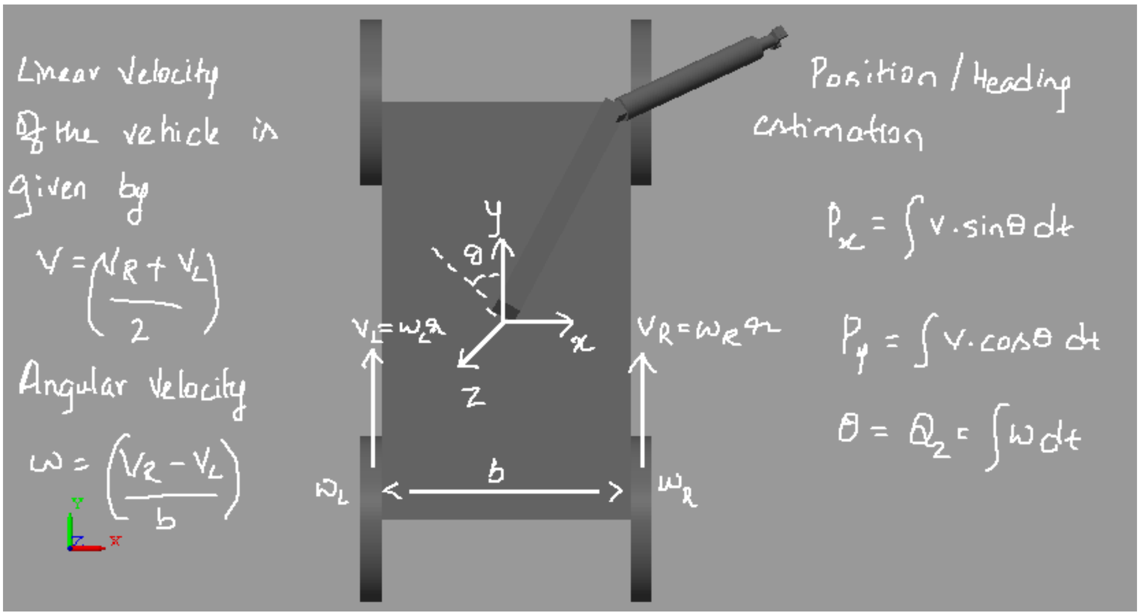

Figure 3.3: Position and Heading Estimation equations

3.2.2 Position and Heading Estimation

It is clear from the Figure 3.3, the linear velocity and angular velocity of the vehicle are used to find the Position and Heading values: P_x, P_y and Q_z. The simulink implementation of the kinematics equations are shown in the Figure 3.4. For simulation, ω_R and ω_L are measured from Rear wheels of the vehicle using sensor and same is fed to the Kinematic subsystem as the input for the estimation.

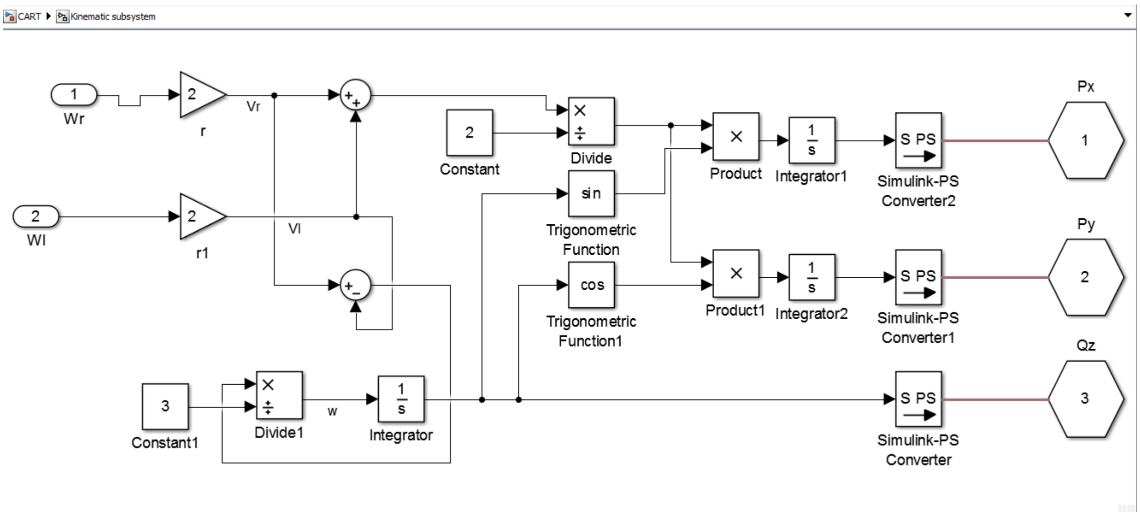

Figure 3.4: Kinematics Subsystem Block Diagram

3.3 Simmechanics Simulation

Simulation of the vehicle is performed with different values of ω_R and ω_L values. When angular velocities of both rear wheel are same, then the vehicle moves in either x direction or y direction. On the other hand, if the ω values are different, the vehicle moves based on the angular acceleration(caused from the differential velocities) direction.

Figure 3.5 shows the screenshot taken during simulation. And, Figure 3.6 shows the simulink block diagram.

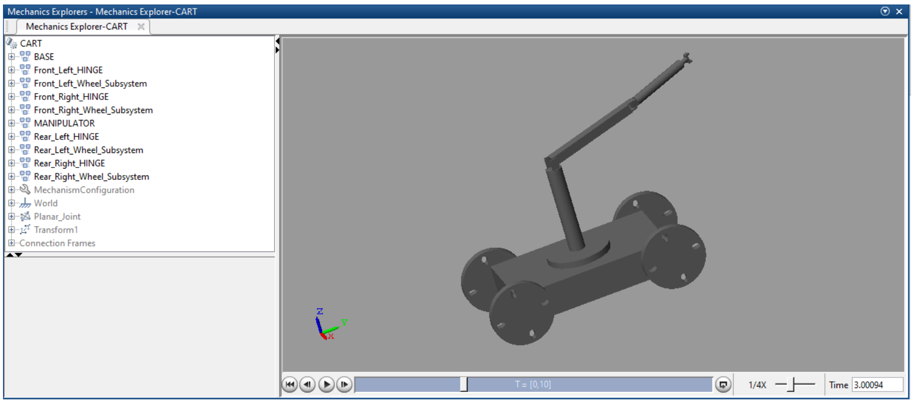

Figure 3.5: Manipulator Simmechanic Block Diagram

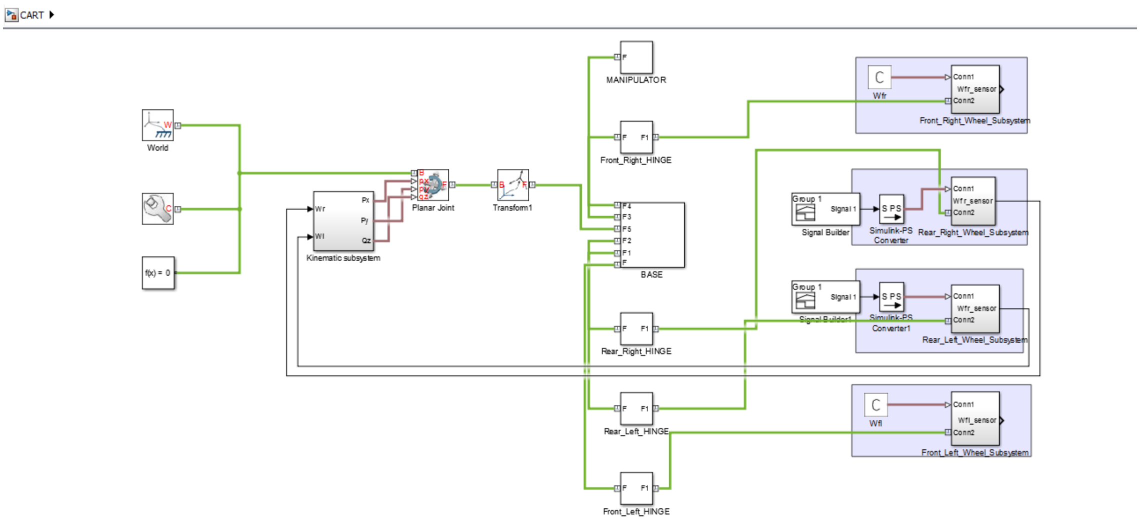

Figure 3.6: Manipulator Simmechanic Block Diagram

Chapter 4

6 Wheel 6 DOF Robotic Vehicle

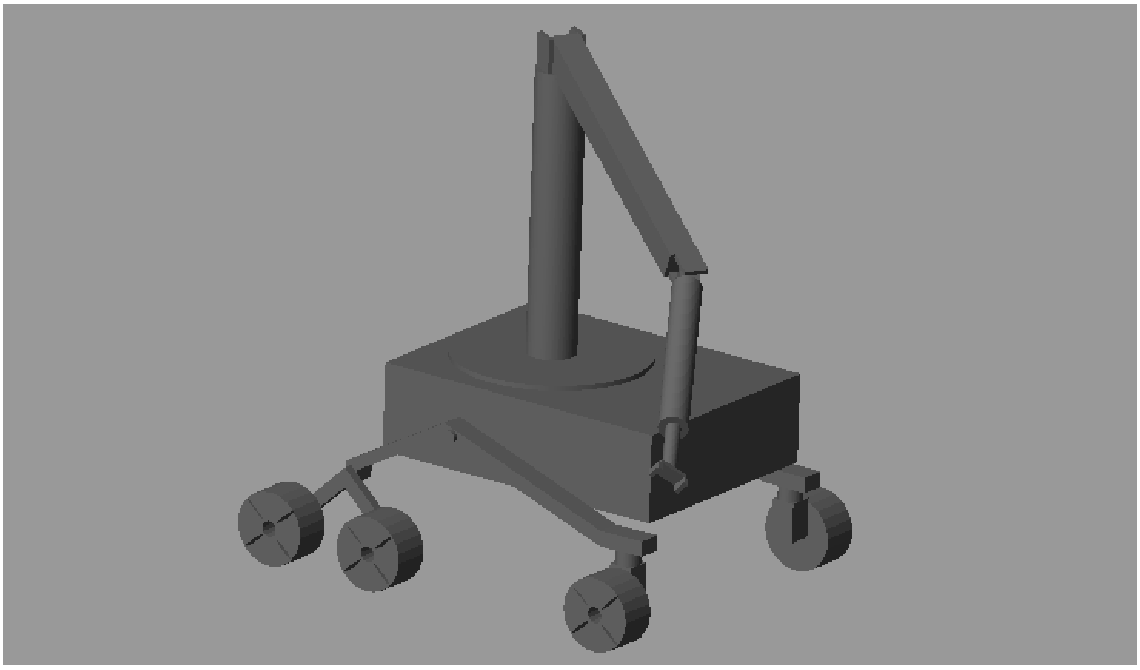

Figure 4.1: Simmechanic Model

4.1 Introduction

The high mobility vehicle demonstrated in this chapter has 6 wheel and 6 Degree of Freedom. This vehicle was inspired by the Rocky 7 Mars Rover design [1] which was designed by Nasa's Jet Propulsion Laboratory for Mars Mission. The vehicle is very robust for rough terrain, which is actually required in steep agricultural farmlands.The vehicle includes 1:5 scale model of 5 link Manipulator. And, it is 64cm long, 48 cm wide, and 32 cm high.

In the following sections, the brief introduction to Rocker -Bogie Mechanism is given, which is followed by Forward Kinematics and Simmechanic Simulation.

4.2 Rocker-Bogie Mechanism

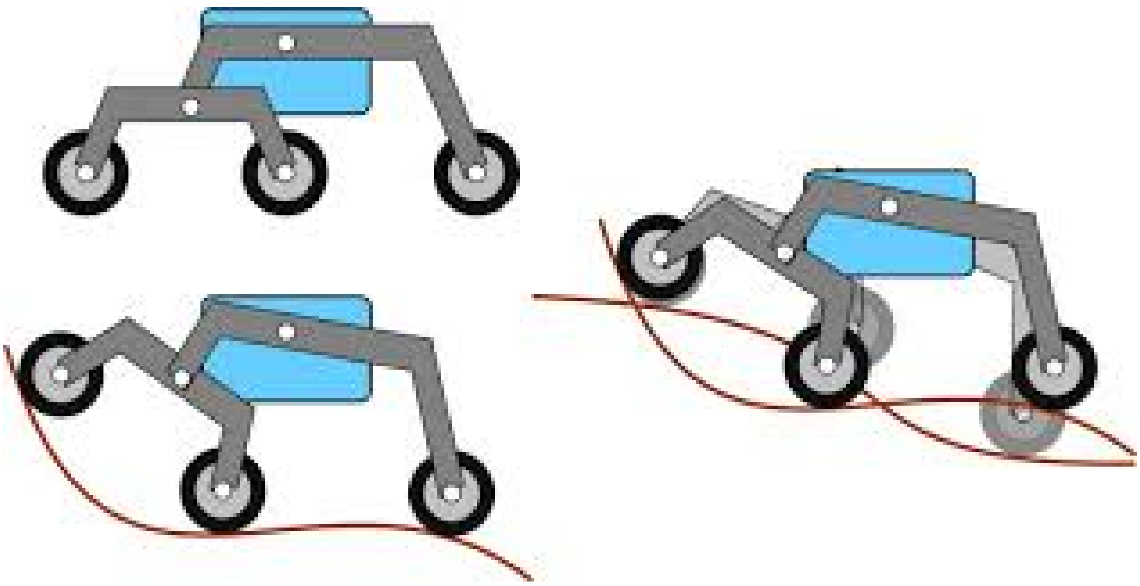

Figure 4.2: Rocker-Bogie Mechanism [2]

The rocker-bogie design has no springs or stub axles for each wheel, allowing the rover to climb over obstacles, such as rocks, that are up to twice the wheel's diameter in size while keeping all six wheels on the ground.The term "rocker" comes from the rocking aspect of the larger links on each side of the suspension system. These rockers are connected to each other and the vehicle chassis through a differential. The term "bogie" refers to the links that have a drive wheel at each end[3].

4.3 Forward Kinematics

4.3.1 DH Parameter

In Table 4.1, DH parameter of all the kinematic chains are mentioned. Wheel 2, wheel 4 and wheel 6 are on the other side of the vehicle. In each kinematic chain, the number of links ranges from 3 to 5 i.e. 0->1->2->8->10.

Table 4.1: DH parameter for 6 Wheel 6 DOF vehicle.

Frame	$\theta(deg)$	d(cm)	a(cm)	$\alpha(deg)$
1	0	0		-90^o
2	$\theta^*_{\beta 1}$	24	-16	0
3	$\theta^*_{\beta 2}$	-24	-16	180^o
4	$\theta^*_{\psi 1}$	-16	32	90^o
5	$\theta^*_{\psi 2}$	-16	32	90^o
6	$\theta^*_{\theta 1}$	-7.5	0	-90^o
7	$\theta^*_{\theta 2}$	-7.5	0	-90^o
8	$\theta^*_{\rho 1}$	0	-12	0
9	$\theta^*_{\rho 2}$	0	-12	0
10	$\theta^*_{\theta 3}$	0	6	0
11	$\theta^*_{\theta 4}$	0	6	0
12	$\theta^*_{\theta 5}$	0	-6	0
13	$\theta^*_{\theta 6}$	0	-6	0

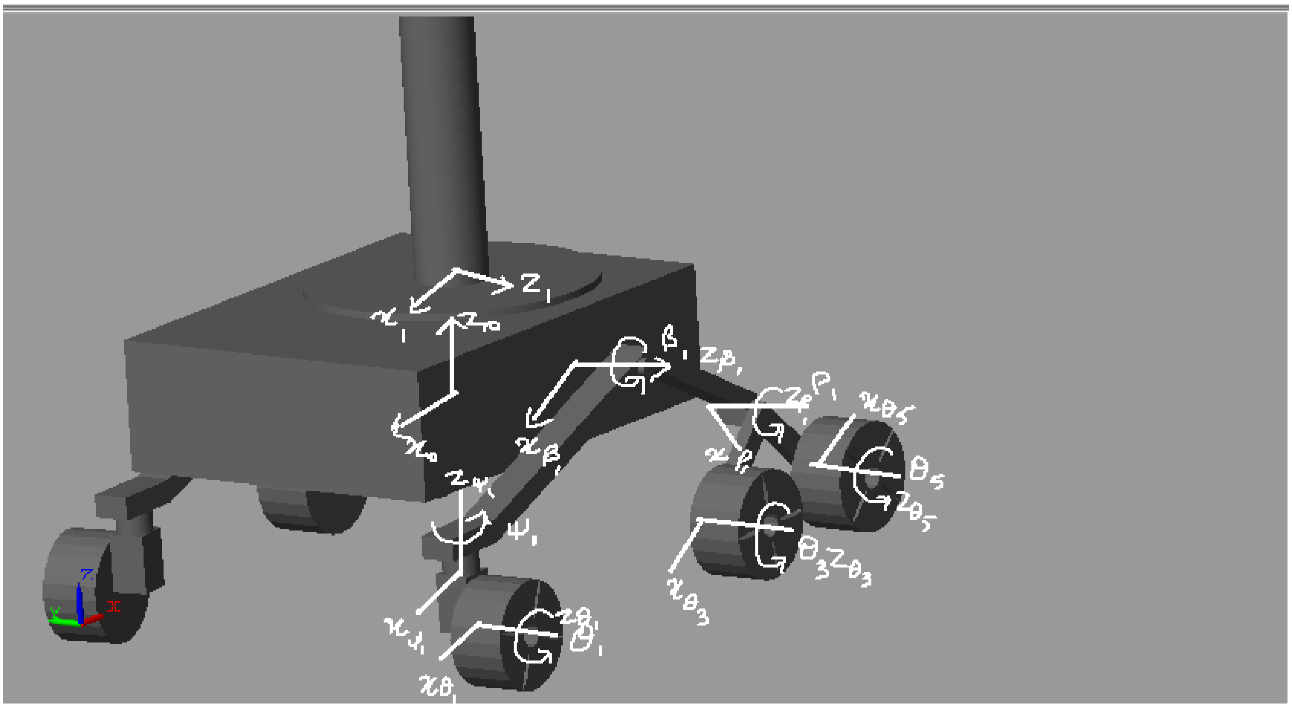

Figure 4.3: Rover Model with DH parameter

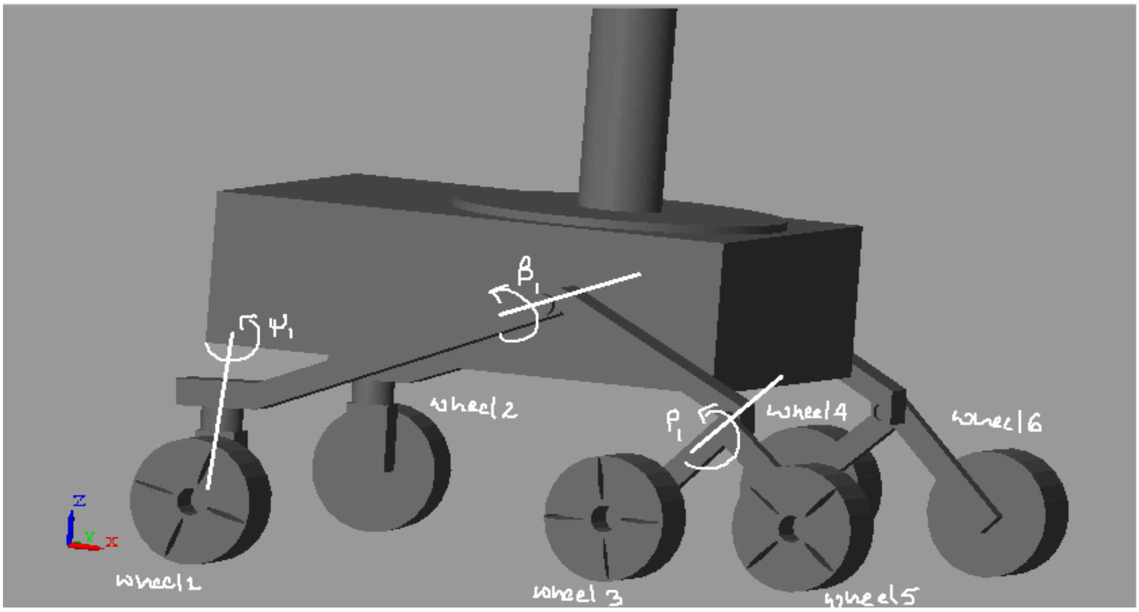

Figure 4.4: Rover Model Side view

4.4 Simmechanics Simulation

It is very complex to demonstrate and visualize the full working of the model without the 3D terrain environment. Hence, in the simulation part each revolute joint is provided with signals to simulate the real world scenario.

From Figure 4.6 it is evident that each rocker configuration are made as subsystems i.e. Right wheel and Left wheel subsystem, which are shown in Figure 4.7 and 4.8 respectively. Signal builder is used to actuate all the revolute joint.

Kinematic Subsystem designed for 4 wheel 3 DOF vehicle is reused in the simulation. The vehicle is tested for different angular velocities and checked for the direction of the motion

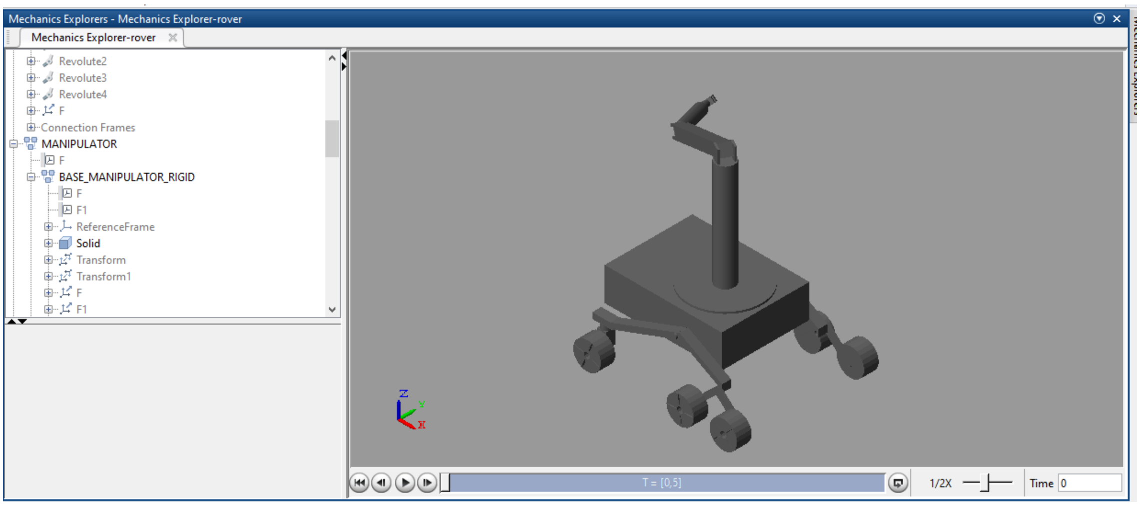

Figure 4.5: Rover Simulation Model

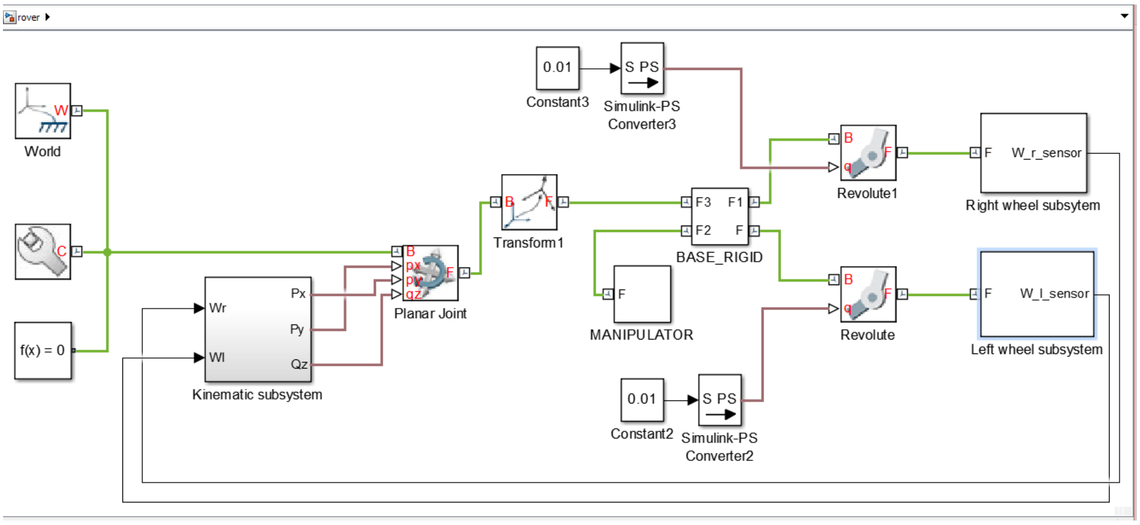

Figure 4.6: Rover Simulation Block Diagram

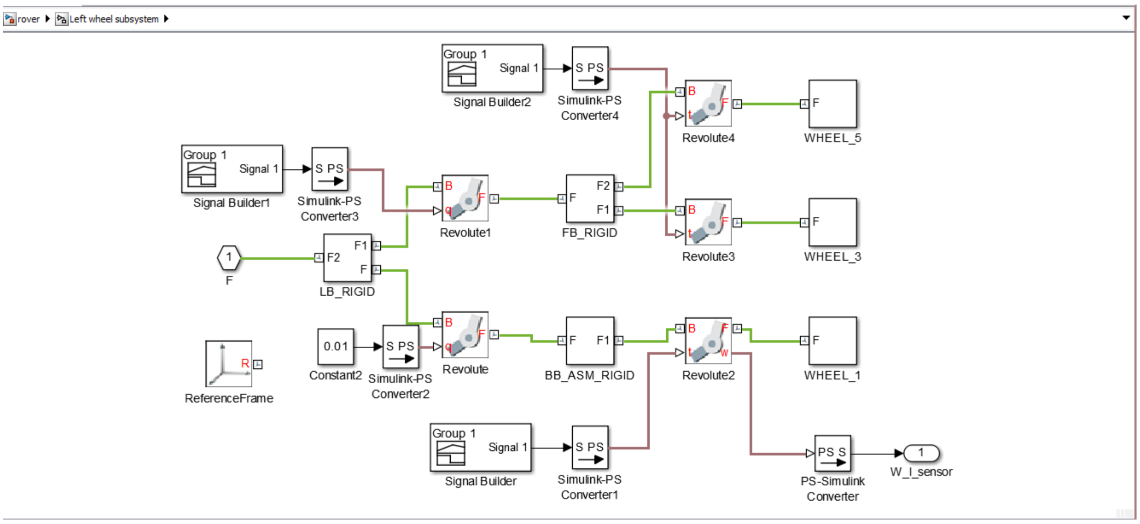

Figure 4.7: Rover Left Wheel Subsystem Block Diagram

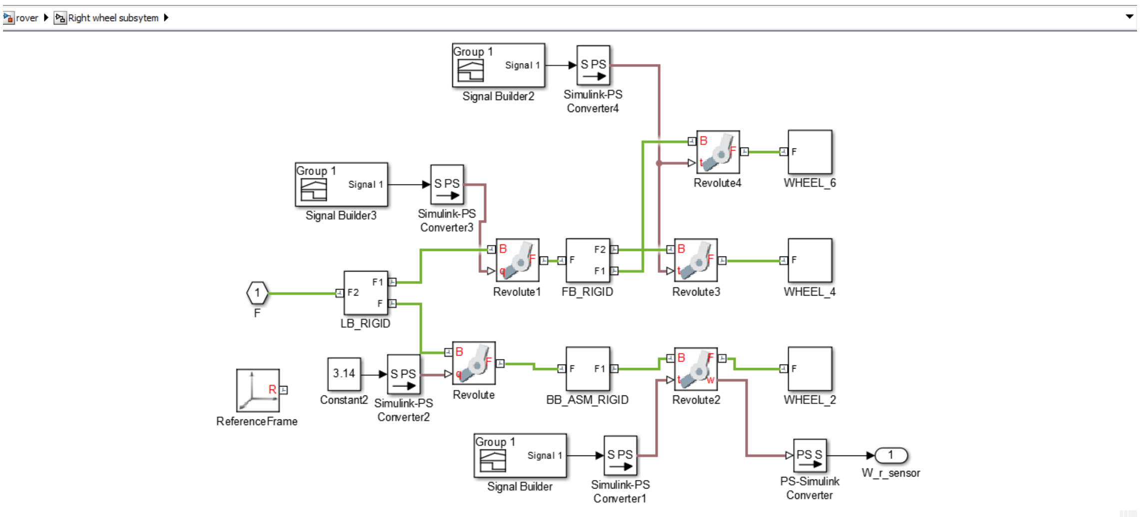

Figure 4.8: Rover Right Wheel Subsystem Block Diagram

Chapter 5

Conclusion and Future Work

5.1 Conclusion

The two robotic vehicles with the manipulator are simulated for wide range of data and simulation is captured in the form of video. The project is completed according to the schedule provided in the Gantt chart.

5.2 Future Work

With the help of Simulink 3D Matlab package, rough farmland environment can be simulated and configuration space and workspace of a robot can be defined. And also, one can implement path planning and trajectory planning algorithms for a specific terrain environment.

There are many open source robotics simulation software such as Gazebo, Moveit (Motion Planning) which are used in industries. CAD model can be directly imported into the open source softwares. The source code used for simulation can be directly emulated on a real hardware.

Chapter 6

References

[1] Tarokh, M.; McDermott, G.; Hayati, S.; Hung, J., "Kinematic modeling of a high mobility Mars rover," in Robotics and Automation, 1999. Proceedings. 1999 IEEE International Conference on , vol.2, no., pp.992-998 vol.2, 1999
[2] WVU Lunabotics Rocker-Bogie System (csee.wvu.edu)
[3] https://en.wikipedia.org/wiki/Rocker-bogie
[4] http://robohub.org/are-agricultural-robots-ready-27-companies-profiled
[5] https://www-robotics.jpl.nasa.gov/

Appendix A

Inverse Kinematics Matlab Code

```
l1 = 3 % length of link 1
l2 = 3 % length of link 2
l3 = 2 % length of link 3
 X = 4  % length of X Coordinate
 Y = 6  % length of Y Coordinate
 % Nonlinear constraints
[c, ceq] = confun(theta)
c = [theta(1)-(3*pi/4);
        theta(1) - theta(2) - (3*pi/4);
        theta(2) - theta(3)-(pi/4)];
ceq = [];
%Initial Position
x0 = [-1,2,0.5];
%Object Function
f = objfun(theta)
f = ((X-(cos(theta(1))*l1)- (cos(theta(2))*l2)-(cos(theta(3))*l3))+(Y-(sin(thet
options = optimoptions(@fmincon,'Algorithm','sqp');
%Optimization
[theta, fval] = fmincon(@objfun,x0,[],[],[],[],[],[],@confun,options);
theta1 = theta(1)
theta2 = theta(2)
theta3 = theta(3)
```