

**GAIT ANALYSIS OF WALKING ROBOT USING SIMULINK**N D V Satya Prasad^{1 a}, M N V Alekhya^{2, b}, Katam Sunny^{3, c}^{1, 2, 3}Department of Mechanical Engineering^{1, 3}ELURU COLLEGE OF ENGINEERING & TECHNOLOGY, ELURU²SIR C R REDDY COLLEGE OF ENGINEERING, ELURU

Abstract: As Humans are incredibly efficient at negotiating diverse terrain, and robots do not have that capacity yet, especially two-legged robots. However, science fiction has long promised two-legged, humanlike robots that can walk among us. There are a million different robots being built all over the world, but they all walk only on flat ground with stiff gaits. The gait cycle is a repetitive pattern involving steps and strides. A step is one single step; a stride is a whole gait cycle. The step time is the time from one foot hitting the floor to the other foot hitting the floor. The objective of this project was to geometrically model and create a walking robot that can walk on two feet and to imitate human motion and to take advantage of the benefits, such as flexibility in terms of accessible terrain. And this analysis is carried out in SIMULINK.

Keywords: Gait Analysis , SIMULINK, Biped- Robot, MATLAB

I. INTRODUCTION

^[1] In the last years there has been a growing interest in the area of legged robots. This increasing interest is justified by the fact that a legged robot is able to deal with very irregular terrain in which wheeled robots are unable to move. ^[2] Legged mechanisms make discrete terrain contacts and avoid undesirable footholds while wheeled mechanisms have rollers in continuous contact with the ground. ^[3] One of the main challenges in the design of human-like walking robots (useful for service or entertainment applications as well as the study of human locomotion) is to obtain dynamic locomotion, as opposed to the static form of locomotion demonstrated by most of the current prototypes. ^[4] One of the main challenges in the design of human-like walking robots (useful for service or entertainment applications as well as the study of human locomotion) is to obtain dynamic locomotion, as opposed to the static form of locomotion demonstrated by most of the current prototypes.

II. LITERATURE SURVEY

The work includes finalizing the hardware platform and developing suitable software needed to implement controllers that can make the robot walk. Furthermore a complete model is set up to be able to simulate the robot and design controllers for it ^[5]. Using the anthropometric data and preliminary data required for determination of torques, to actuate the considered prosthetic leg, generalized torque equations have been derived with the help of mathematical modeling through lagrangian equations using MATLAB/SIMULINK environment ^[6]. It should be made clear that the data obtained from this work are based on a simulation making use of computational tools. The simulation is based on a mathematical model that indicates a pendular change between potential energy and kinetic energy, resembling the action of an inverted pendulum ^[7]. The simulation is widely used in all fields of robotics from kinematics and dynamics to industrial applications. Actually, advanced robot systems require sophisticated simulation tools which can model accurately enough the physical world at a sufficient speed and allow the user interaction ^[8]. Finite elemental analysis showed the heel of the foot was under the most pressure, while the entirety of the frame was relatively unburdened. Moreover, center of mass analysis confirmed that the robot's center of mass shifted correctly over each foot while the other was lifted ^[9]. The biped model was chosen to be quite simple in order to make it possible to calculate the exact mathematical dynamic equations. The model can, however, describe the walking motion quite well and is therefore used as such or slightly modified also in many other researches ^[10].

III. Benefits of mobile robot simulators

Robot simulation tools are used to help in the development of algorithms for mobile robots.

- A. The development of algorithms for the robot without the presence of the actual Hardware
- B. A safe method of performing risky experiments
- C. No risk of damaging expensive robot hardware
- D. The simulation of complex system in unreasonable environments
- E. A reduction in the time taken to develop the algorithms for the robot
- F. Quality improvement for the code due to ease of testing and debugging
- G. Explicit view of the execution steps and logics of the algorithm

IV. Robot parameters

A. General parameters

Density = 1000 kg/m³
Foot density = 2000;
World damping = 0.25;

B. Inputs

Gait Period = 0.8;
Time = landscape (0, gait Period, 7);
Ankle motion = deg2rad ([-7.5 10 10 5 0 -10 -7.5]);
Knee motion = deg2rad ([10, -5, 2.5, -10, -10, 15, 10]);
Hip motion = deg2rad ([-10, -7.5, -15, 10, 15, 10, -10]);

C. Contact/friction parameters

contact_stiffness = 2500;
contact_damping = 100;
mu_k = 0.6;
mu_s = 0.8;
mu_vth = 0.1;
height_plane = 0.025;
plane_x = 25;
plane_y = 3;
contact_point_radius = 1e-4;
Foot parameters
foot_x = 8;
foot_y = 6;
foot_z = 1;
foot_offset = [-1 0 0];

D. Leg parameters

leg_radius = 0.75;
lower_leg_length = 10;
upper_leg_length = 10;

E. % Torso parameters

torso_y = 10;
torso_x = 5;
torso_z = 8;
torso_offset_z = -2;
torso_offset_x = -0.5;
init_height = foot_z + lower_leg_length + upper_leg_length + torso_z/2 + torso_offset_z + height_plane/2;

F. Joint parameters

joint_damping = 1;
joint_stiffness = 1;
motion_time_constant = 0.01; %0.025;

G. Joint controller parameters

hip_servo_kp = 60;
hip_servo_ki = 10;
hip_servo_kd = 20;
knee_servo_kp = 60;
knee_servo_ki = 5;
knee_servo_kd = 10;
ankle_servo_kp = 20;
ankle_servo_ki = 4;

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ankle_servo_kd = 8;
deriv_filter_coeff = 100;
max_torque      = 20;
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H. Electric motor parameters

```
motor_resistance = 1;
motor_constant = 0.02;
motor_inertia    = 0;
motor_damping    = 0;
motor_inductance = 1.2e-6;
gear_ratio       = 50.
```

V. MODELLING OF A ROBOT

Simulink is a block diagram environment for multi domain simulation and Model-Based Design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB®, enabling you to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis. Model-Based Design is a process that enables fast and cost-effective development of dynamic systems, including control systems, signal processing, and communications systems. In Model-Based Design, a system model is at the centre of the development process, from requirements development through design, implementation, and testing. The model is an executable specification that you continually refine throughout the development process. After model development, simulation shows whether the model works correctly.

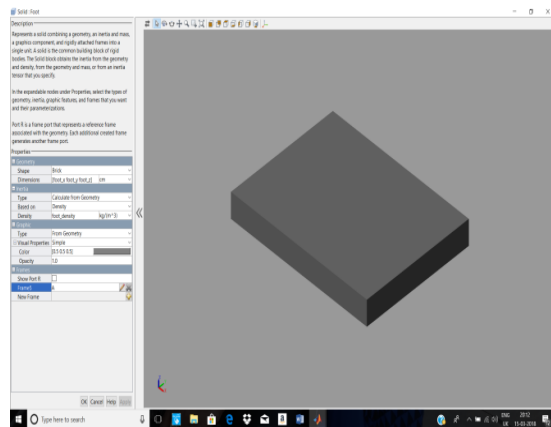


Fig1. Foot

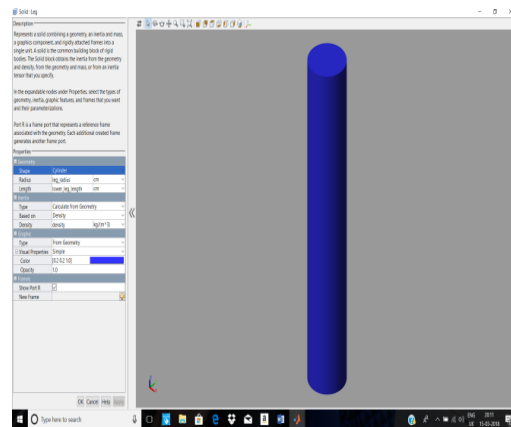


Fig2. Lower leg

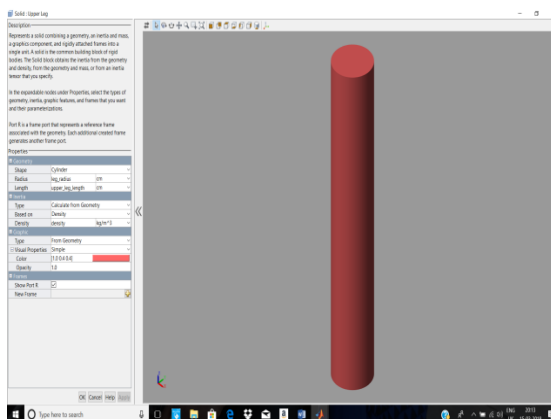


Fig3.Upper Leg

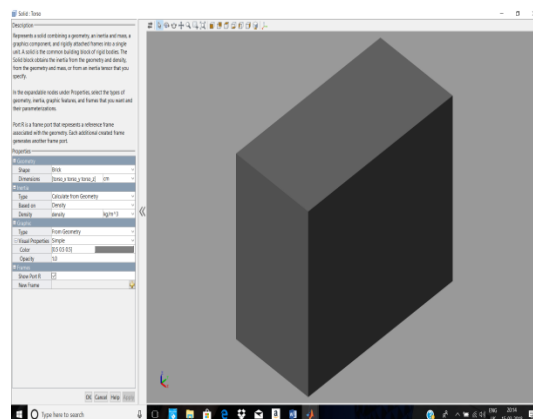


Fig4.Torso

When software and hardware implementation requirements are included with the model, such as fixed-point and timing behaviour, you can generate code for embedded deployment and create test benches for system verification, saving time and avoiding manually coded errors.

VI.COMPONENT-BASED MODELING.

Use Simulink Projects to organize large modeling projects by finding required files, managing and sharing files and settings, and using source control.

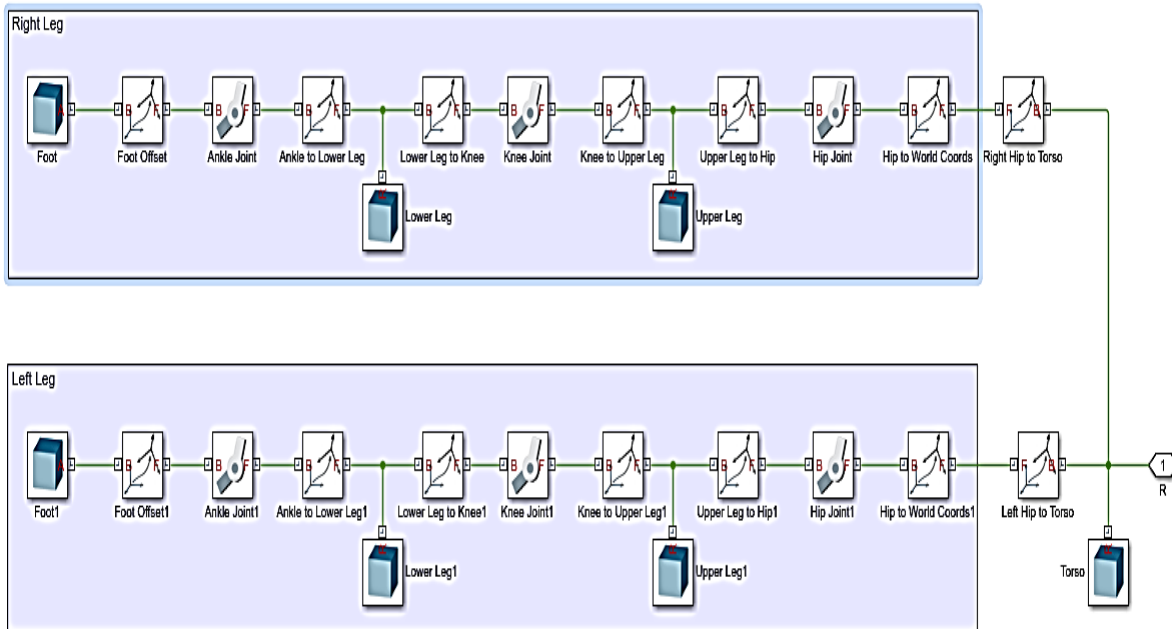


Fig5. Modeling of right and left legs with inserting ankle, knee and hip joints

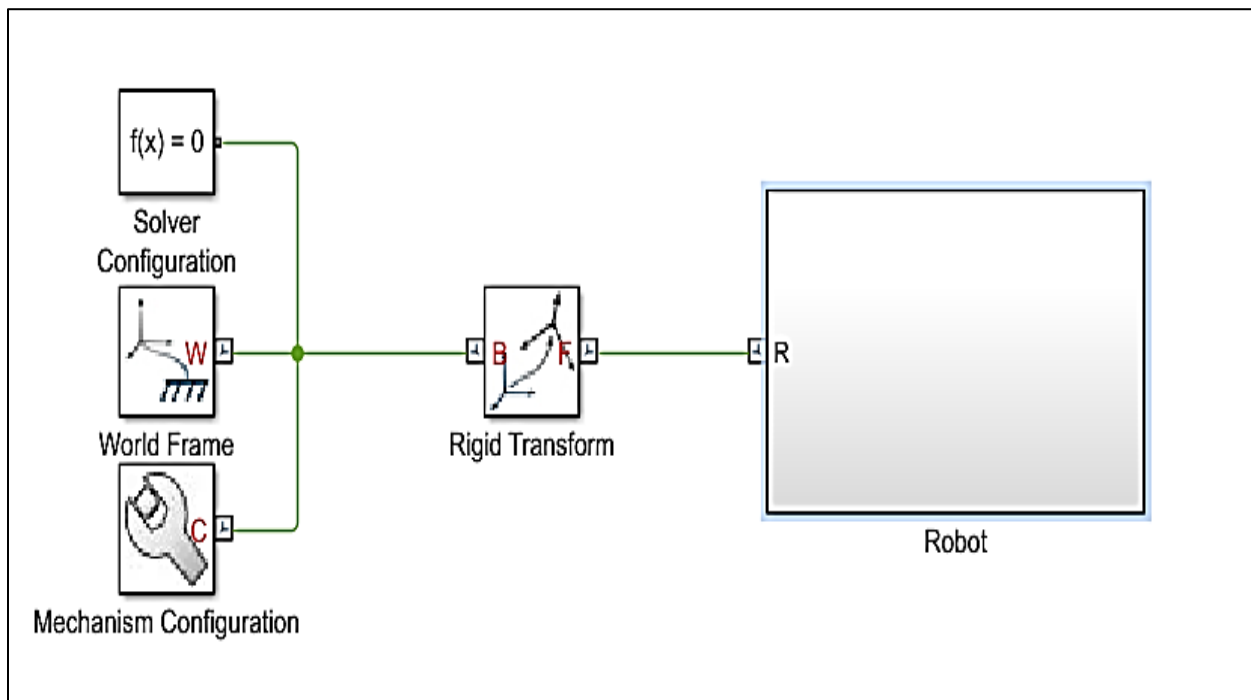


Fig6. Basic Modeling of circuit diagram in Simulink environment

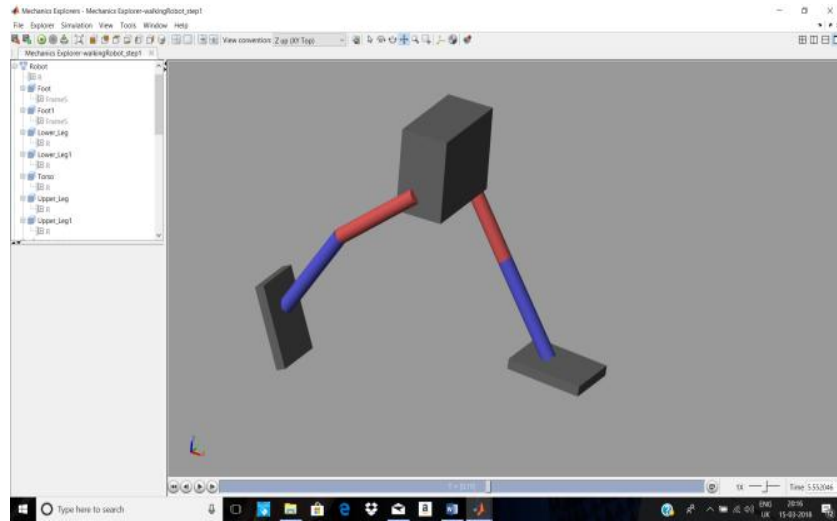


Fig7.Completed model of robot in Simulink environment

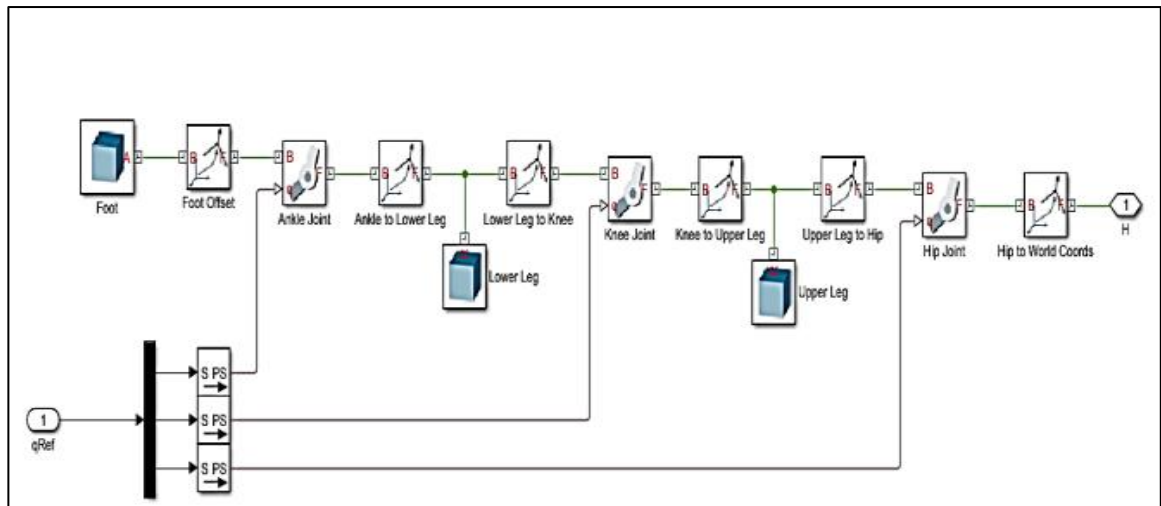
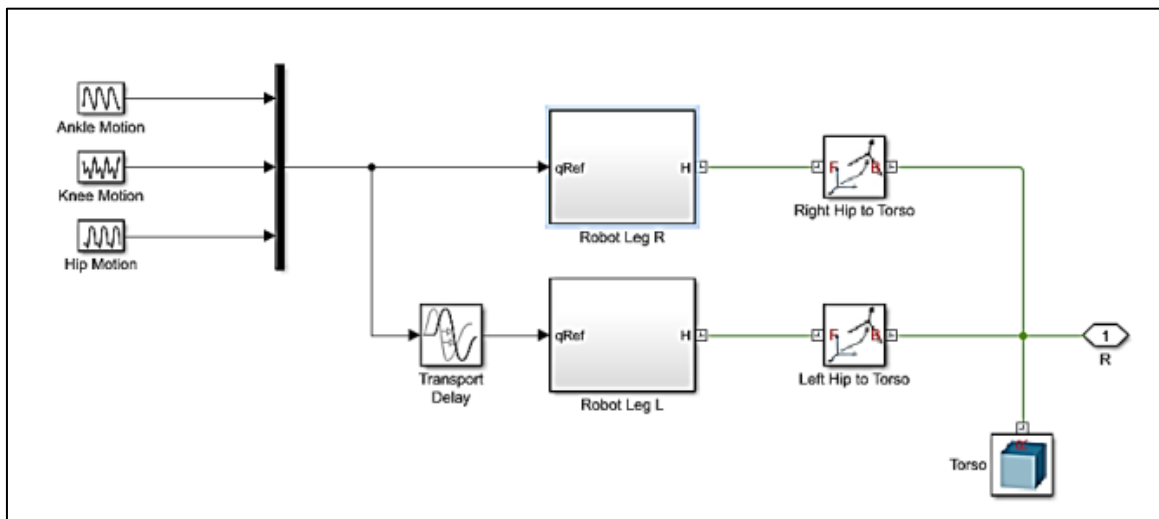


Fig8.Simulink converter to physics(s-ps) is added to foot

Fig9. Ankle, Knee, Hip motions are added to robot legs



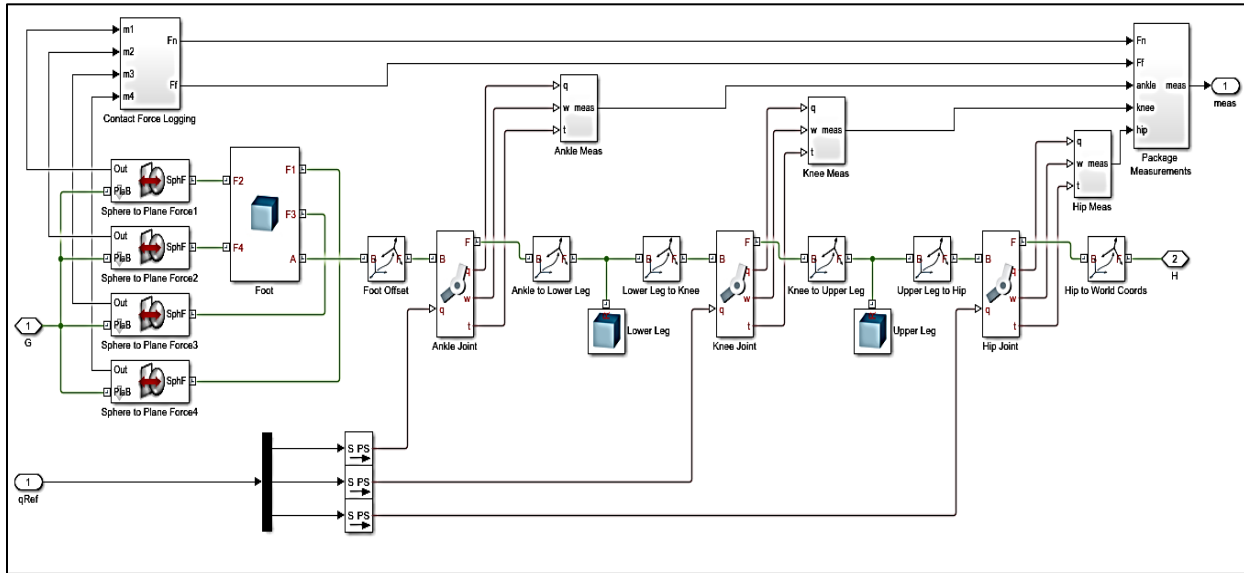
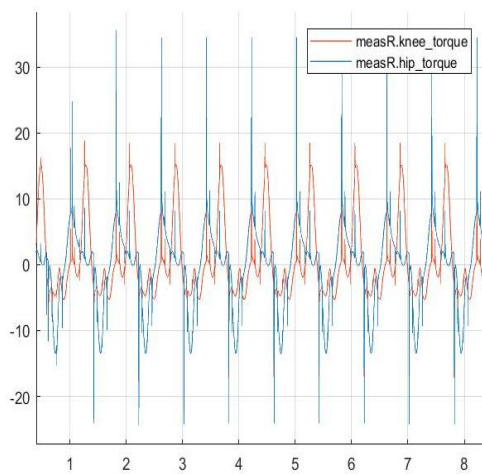
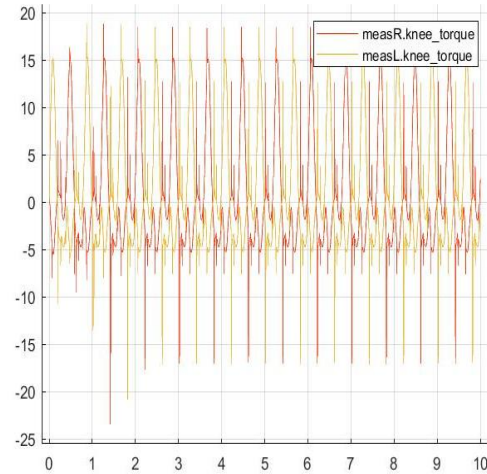


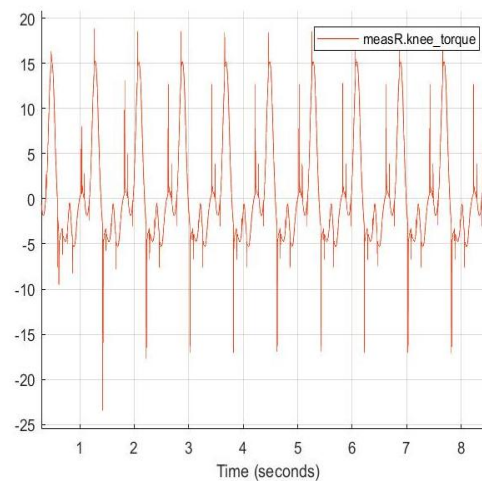
fig12. Circuit diagram for Robot leg in Simulink Environment



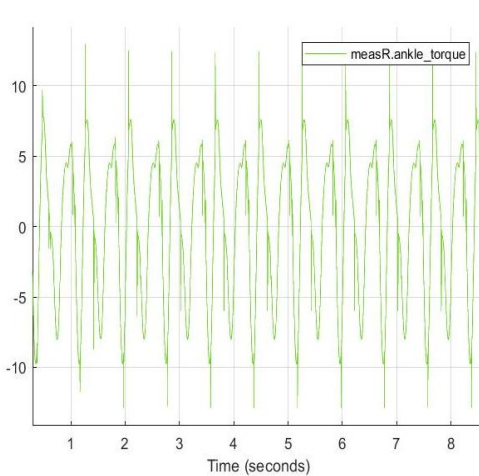
Right knee vs Right hip torque



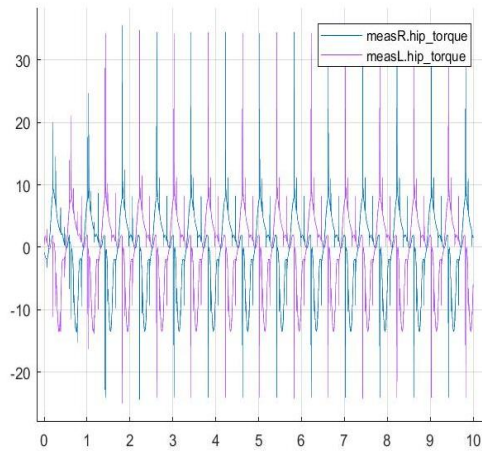
Right knee vs left knee torque



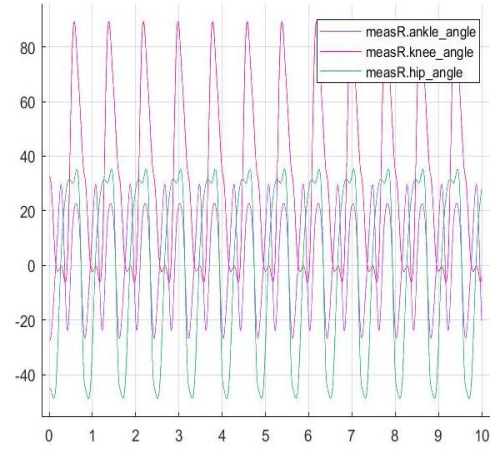
Right knee torque w.r.to time



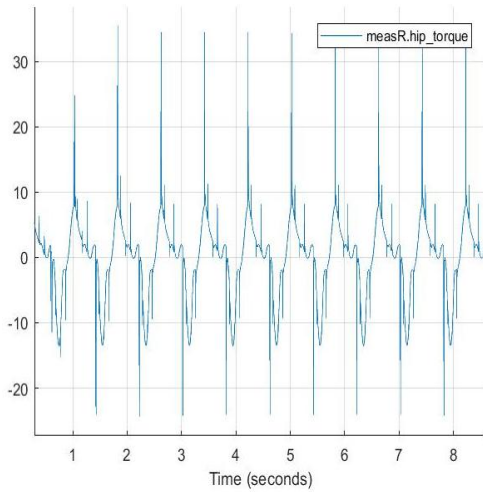
Right ankle torque w.r.to time



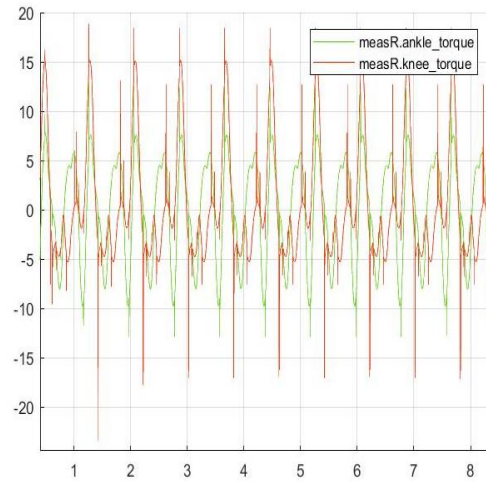
Right hip vs left hip torque



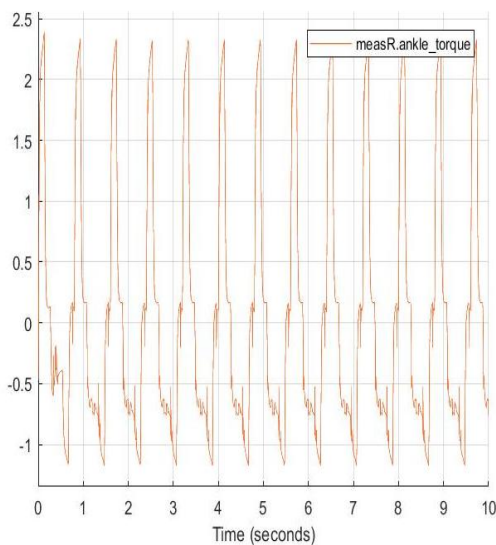
Right ankle vs right knee vs right hip angle



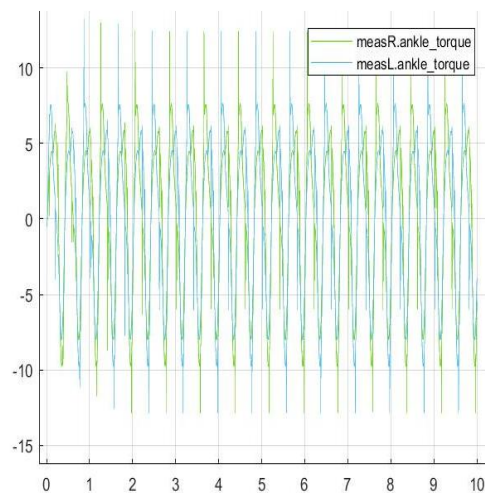
Right hip torque



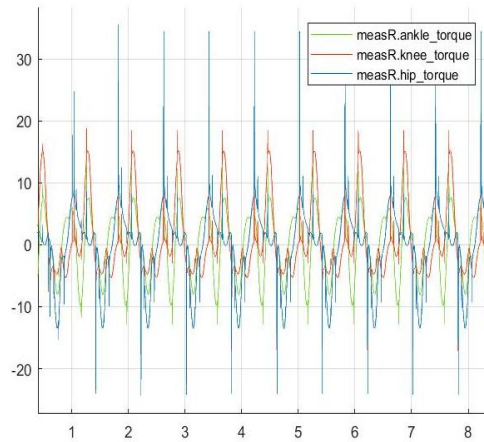
Right ankle vs right knee torque



Right ankle torque



Right ankle vs left ankle torque



Right ankle vs right knee vs right hip torque

VIII. CONCLUSION

Here we created a robot walker system and modeled the mechanics of robot. This means building a 3D model and as well as making robot foot contact for walking in a stable manner on the ground. In addition, here we have analyzed normal, friction forces along with torques for each joint i.e. ankle, knee, and hip joints and compared the results of right leg joints to left leg joints.

These results helped for controlling individual joints to move in a straight and without any aggressive or unrealistic motions and also without falling .And these results are plotted in graphs.

Overall, a simulation environment is constructed for the biped locomotion in 3D space of humanoid robots with a proposed control strategy. In this thesis, the devised simulation environment covers an important portion for a comprehensive simulation tool for humanoid robots. Since the integration of detailed models, which are not covered in this thesis study into the simulation environment, is possible, a complete simulation tool for various studies related with humanoid robots can be formed. In addition, the help of task-oriented user can test defined MATLAB functions different control strategies by necessary rearrangements for a more general simulation structure.

IX. REFERENCES

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