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MODELLING AND CONTROL OF HUMANOID ROBOT

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Abstract — *legged robots have a number of advantages compared with their wheeled counterparts, i.e. navigate rough terrain and deal with obstacles. The study of leg dynamics is also applicable to prosthetic design and human gait research. The Humanoid robot has complicated analysis due to so many degrees of freedom. So in this work, Analysis of leg of the humanoid robot has been considered. Each leg has of four degrees of freedom. So the total degree of freedom of biped excluding upper part is eight.*
The SYMBOL Shakti software has been used to develop the dynamic model of the biped robot and studied about the foot mechanism also discussing about bond graph model of leg mechanism.

Keywords- Biped robot*; leg kinematic; leg dynamic; trajectory of the joint; bond graph model of leg mechanism.*

I. INTRODUCTION

For a biped robot to be able to walk in various ground conditions, such as on level ground, over rough terrain, and in obstacle- filled environments, the robot must be capable of various types of foot motion. For example, a biped robot should be able to lift its feet high enough to negotiate obstacles, or have support feet with suitable angles to match the roughness of the terrain.
Through this work, Study of biped leg has been done i.e. degree of freedom, stability, speed control etc. Model of leg will be analyzed with help of Bond graph. Before knowing about both legs, 2 DOFs serial robot has been studied and describing the kinematic analysis of robot leg.

1.1 Study about leg of Humanoid robot

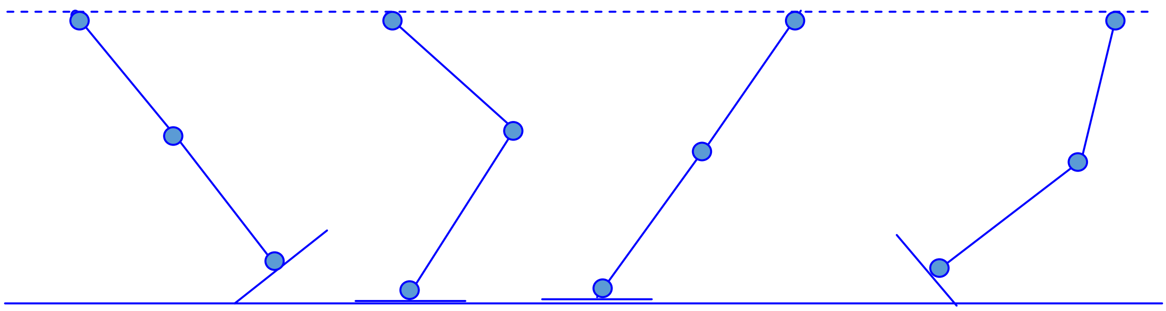

Figure 1 Leg of Humanoid Robot

Biped robots have higher mobility than conventional wheeled robots, especially when moving on rough terrain, steep stairs, and in environments with obstacles. Many related issues such as stability criterion, actual robot design and application and dynamic analysis have been studied.

During locomotion, a legged robot plans both its path as well as gait (sequence of leg movement) simultaneous. Each leg has 4- degree of freedom i.e. hip joint (forward-backward), a splay joint (side-way rotation), a knee joint and an ankle joint (that lifts / lowers the foot).

1.2 Walking cycle

Here an anthropomorphic biped robot has been considered. Each leg consists of a thigh, a shin, and a foot, and has four degrees of freedom (DOF): two DOF in the hip joint, one in the knee joint, and one in the ankle joint.

Biped walking is a periodic phenomenon. A complete walking cycle is composed of two phases: a double-support phase and a single-support phase. During the double-support phase, both feet are in contact with the ground. This phase begins with the heel of the forward foot touching the ground, and ends with the toe of the rear foot leaving the ground. During the single-support phase, while one foot is stationary on the ground, the other foot swings from the rear to the front.

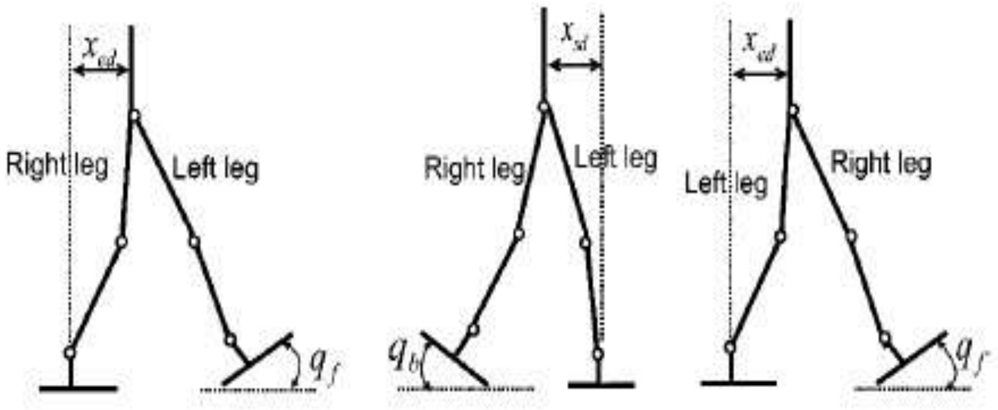

Figure 2 Walking Cycle [9]

Here double-support phase has been shown in the above walking cycle. In order to maintain its stability, the robot's center of gravity, in the case of static stability or the ZMP in the case of dynamic stability, must be transferred from the rear foot to the front foot during the short double-support phase.

1.3 Model of the Biped robot

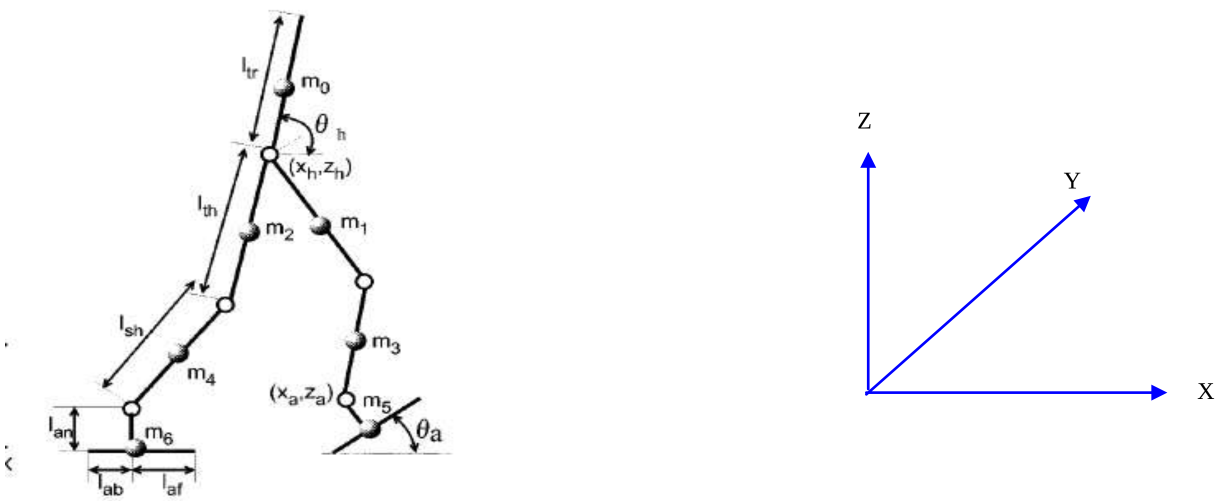

Figure 3 Model of the Biped robot [9]

The trajectories of the hip and foot can be only studied on the sagittal plane.

For a sagittal plane, each foot trajectory can be denoted by a vector $X_a = [\ x_a(t),\ z_a(t),\ \theta_a(t)\ ]^T$, Where ($x_a(t)$, $z_a(t)$) is coordinate of the ankle position, and $\theta_a(t)$ denote the angle of the foot. The hip trajectory can be denoted by a vector $X_h = [\ x_h(t),\ z_h(t),\ \theta_h(t)\ ]$ T, Where ($x_h(t)$, $z_h(t)$) is coordinate of the hip position and $\theta_h(t)$ denote the angle of the hip.

II. WORKDONE

This chapter includes model of the leg of the robot and velocity equation of joint movement and also the joint control of the biped robot. The trajectory of the joint is also presented. All of this has been done on the bond graph using SYMBOL Shakti.

2.1 Degree of freedom

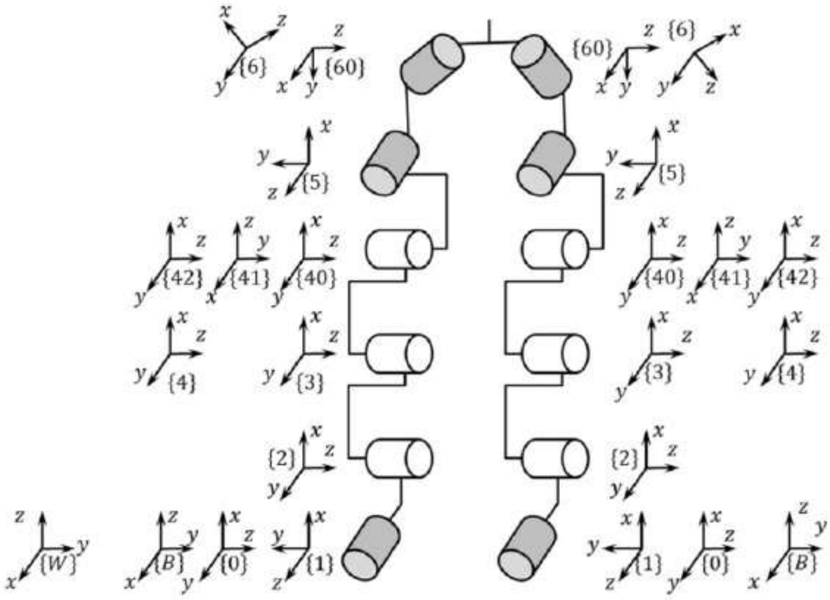

Figure 4 Skeleton of the leg of the humanoid robot [5]

In the above figure, there are six degree of freedom in each leg. They include ankle roll, ankle pitch, knee pitch, hip pitch, hip roll, and hip yawpitch.

Ankle pitch, knee pitch and hip pitch joints are employed for the movement of the robot in the X-direction of the sagittal plane, and thus larger operational area.

Both Ankle roll and Hip roll joints are mainly utilized for movement in the y-direction of frontal plane. The Hip Yawpitch joint has a combinational movement both in the sagittal and transverse planes, since it is mounted $45°$ with respect to the y and z axes.

2.2 Bond graph model and joint control of two d. o. f. links:

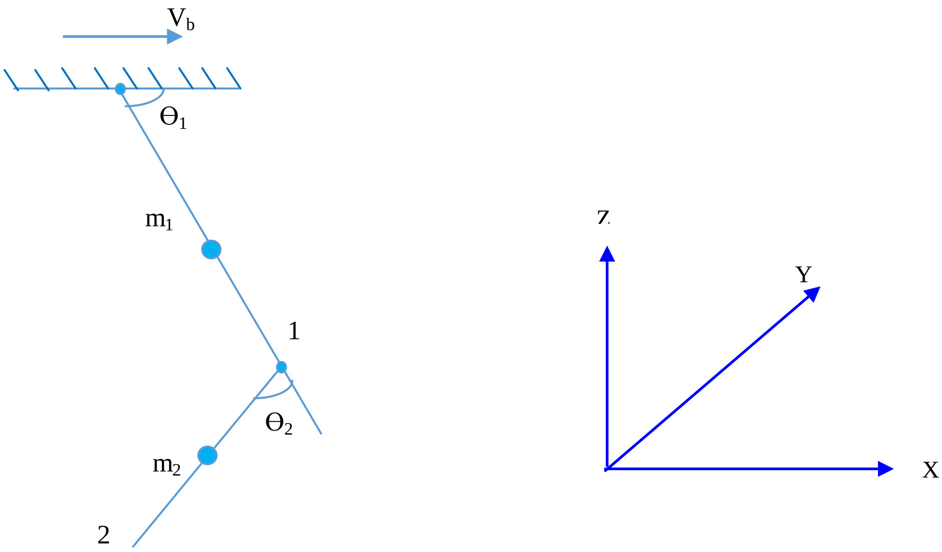

Figure 5 Robot leg

Bond graphs are mainly used in modelling different mechatronic/electrical/hydraulically systems because this component part of the system is the most difficult to simulate.

The control system is applied to a walking robot leg that has 2 degrees of freedom with rotating joints.

Equation of position at point 1:

$$x1 = l1 * cos\theta 1 + X_b$$

$$y1 = l1 * sin\theta 1$$

Equation of position at point 2:

$$x2 = l1 * cos\theta 1 + l2 * \cos(\theta 1 + \theta 2) + X_b$$

$$y2 = l1 * sin\theta 1 + l2 * \sin(\theta 1 + \theta 2)$$

Equation of position at C.O.M. of link 1:

$$xc1 = 0.5 * l1 * cos\theta 1 + X_b$$

$$yc1 = 0.5 * l1 * sin\theta 1$$

Equation of position at C.O.M. of link 2:

$$xc2 = l1 * cos\theta 1 + 0.5 * l2 * \cos(\theta 1 + \theta 1) + X_b$$

$$yc2 = l1 * sin\theta 1 + 0.5 * l2 * \sin(\theta 1 + \theta 2)$$

After differentiating, we get the equation of velocity:

Equation of velocity at point 1:

$$\dot{x}1 = -l1 * sin\theta 1 * \dot{\theta}1 + V_b$$

$$\dot{y}1 = l1 * cos\theta 1 * \dot{\theta}1$$

Equation of velocity at point 2:

$$\dot{x}2 = -l1 * sin\theta 1 * \dot{\theta}1 - l2 * \sin(\theta 1 + \theta 2) * (\dot{\theta}1 + \dot{\theta}2) + V_b$$

$$\dot{y}2 = l1 * cos\theta 1 * \dot{\theta}1 + l2 * \cos(\theta 1 + \theta 2) * (\dot{\theta}1 + \dot{\theta}2)$$

Equation of velocity at C.O.M. of link 1:

$$xc1 = -0.5 * l1 * sin\theta 1 * \dot{\theta}1 + V_b$$

$$\dot{y}c1 = 0.5 * l1 * cos\theta 1 * \dot{\theta}1$$

Equation of velocity at C.O.M. of link 2:

$$\dot{x}c2 = -l1 * sin\theta 1 * \dot{\theta}1 - 0.5 * l2 * \sin(\theta 1 + \theta 2) * (\dot{\theta}1 + \dot{\theta}2) + V_b$$

$$\dot{y}c2 = l1 * cos\theta 1 * \dot{\theta}1 + 0.5 * l2 * \cos(\theta 1 + \theta 2) * (\dot{\theta}1 + \dot{\theta}2)$$

m_1	0.4 kg
m_2	0.3 kg
L_1	0.5 m
L_2	0.5 m

Where m_1 = Mass of the link 1
m_2 = Mass of the link 2
L_1 = Length of the link 1
L_2 = Length of link 2
X_b = Position of the reference along x-direction at point 0

To control the movement at the joint 0 and 1, the PID controller has been added in the bond graph of model. In the PID controller there are three types of control is added. First, proportional constant which is denoted by K_p , second proportional-integral control constant which is denoted by $K_{I,}$ third proportional-integral-derivative control which is denoted by $K_{D.}$

This type of controller has been applied for the trajectory control of the joint.

By this, the biped of the robot can be controlled.

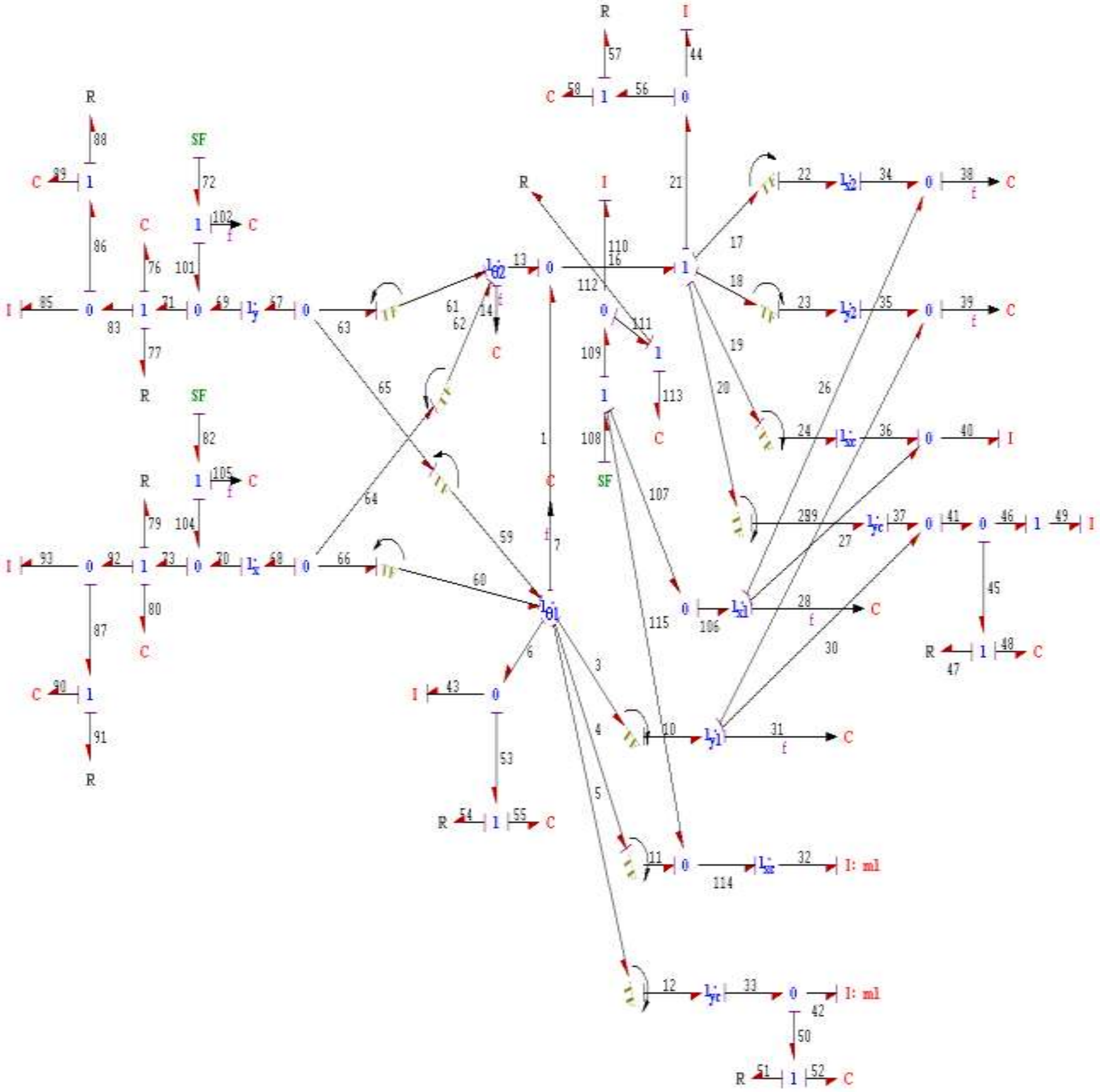

Figure 6 Bond graph of two degree of freedom

III. CONCLUSION

This chapter concludes the joint control of the biped robot by using the model of the leg of the robot and velocity equation of joint movement as well as trajectory of the joint. All of this has been done on the bond graph using SYMBOL Shakti.

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