Modeling of the Humanoid Robot Motion

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Abstract—***This paper will deal with the simulation and autonomous motion of humanoid robots. Studies in the area of humanoid robotics have recently made a remarkable progress. The modeling of the humanoid robot motion is analyzed. A kinematic scheme of a a 20-DOFs biped locomotion system is used in simulation. The simulation results in the Matlab /Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.***

Index Terms — *****Humanoid robots, biped locomotion, modeling, Lagrangian dynamics, kinematic scheme, simulation.*

1. *INTRODUCTION*

THIS paper will deal with the humanoid robot locomotion. The modeling of the the humanoid robot motion is analyzed. The problem of bipedal motion is a very complex task. Studies in the area of humanoid robotics have recently made a remarkable progress.

The considered humanoid locomotion in this paper has 20 DOFs (18 powered and 2 unpowered). The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method. The paper is organized as follows:

Section 1: Introduction.

The modeling of the humanoid robot motion is given in Section 2.

In Section 3 the simulation results of the humanoid robot motion are illustrated.

Finally, conclusions are given in Section 4.

2. *DYNAMIC MODELING OF THE HUMANOID ROBOT MOTION*

Biped locomotion is the a very complex process to modeling. The bipedal walking of the robot consists of several phases that are periodically repeated:

single-support phases and

double-support phases.

The robot’s body consists of a number of rigid segments interconnected with spherical or cylindrical joints. During the bipedal walking, some kinematic chains in their interaction with the unknown environment transform from open to closed type of kinematic chain.

The dynamic model of the locomotion mechanism of the robot in a vector form is:

$$\mathbf{H}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{h}(\mathbf{q},\dot{\mathbf{q}}) = \boldsymbol{\tau} + \mathbf{J}^T(\mathbf{q})\mathbf{F} \qquad (1)$$

where:

$\mathbf{H}(\mathbf{q})$ – is the inertia matrix of the mechanism,

$\mathbf{h}(\mathbf{q}, \dot{\mathbf{q}})$ – is the vector of centrifugal, Coriolis and gravitational moments,

$\mathbf{J}(\mathbf{q})$ – is the Jacobian matrix of the system,

$\mathbf{q}$ – is the vector of the internal coordinates,

$\mathbf{F}$ – is the vector of external forces and moments,

$\boldsymbol{\tau}$ – is the vector of the driving torques at the robot joints.

The dynamics of the locomotion mechanism can be expressed by the Lagrangian dynamics. Computed Torque Control method is applied for control of the humanoid robot motion.

The considered humanoid locomotion mechanism used in simulation in this paper has 20 DOFs: 18 powered and 2 unpowered DOFs. The kinematic scheme of a 20-DOFs biped locomotion system is presented in Fig. 1.

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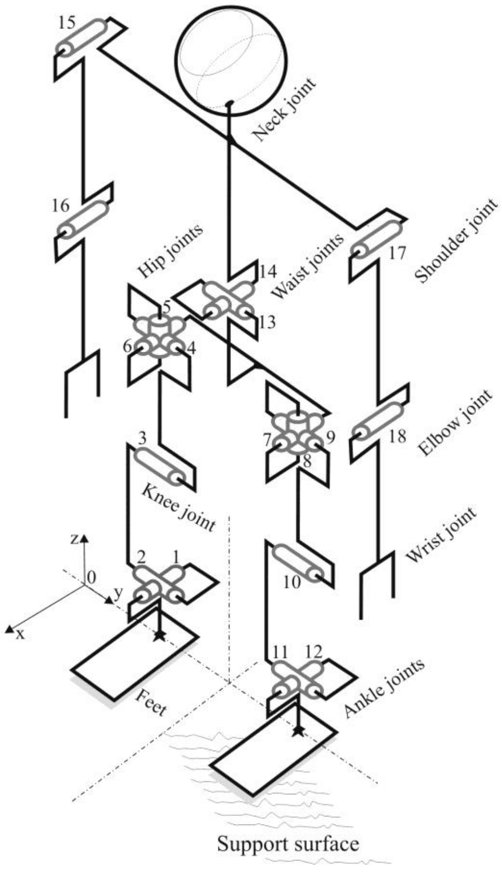

Fig. 1. Kinematic scheme of a 20-DOFs biped humanoid robot

The proposed scheme has:

- three active mechanical DOFs at each of the joints of the hip (6),
- two active mechanical DOFs at the ankle (4), waist (2), and
- one active mechanical DOF at the knee (2), shoulders (2), elbow (2).

Kinematic and dynamic parameters of the humanoid robot are presented in [2].

3. *SIMULATION RESULTS OF THE HUMANOID ROBOT MOTION*

Simulation of the humanoid robot motion was performed using Matlab/Simulink and Robotics toolbox for Matlab/Simulink. The results of the simulation are shown in Fig. 2-14**.**

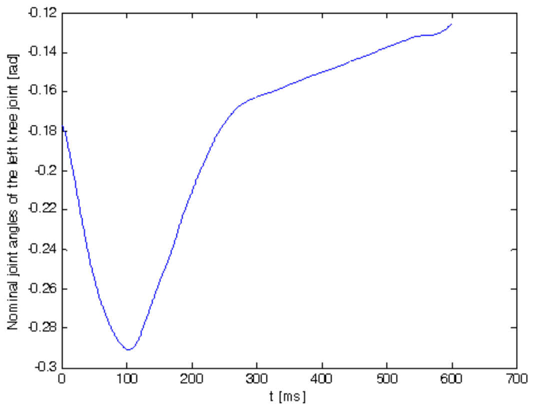

Fig. 2. Nominal joint angles of the left knee joint

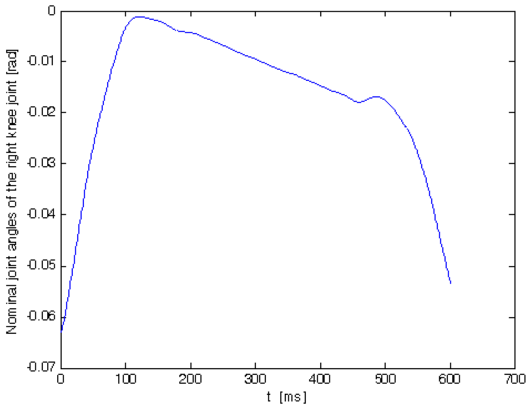

Fig. 3. Nominal joint angles of the right knee joint

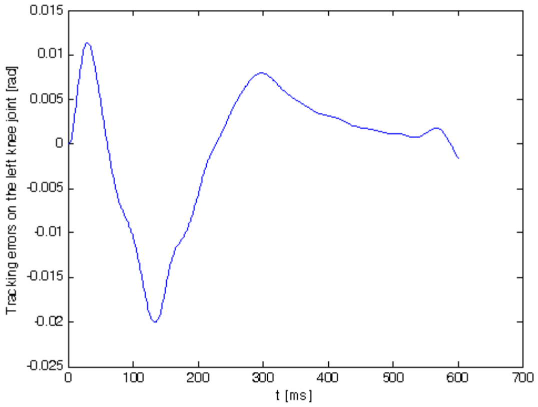

Fig. 4. Tracking errors on the left knee joint

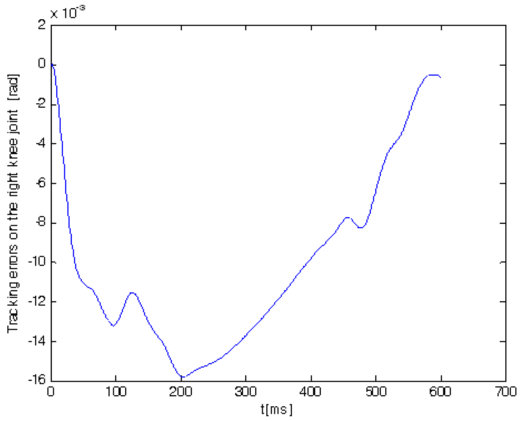

Fig. 5. Tracking errors on the right knee joint

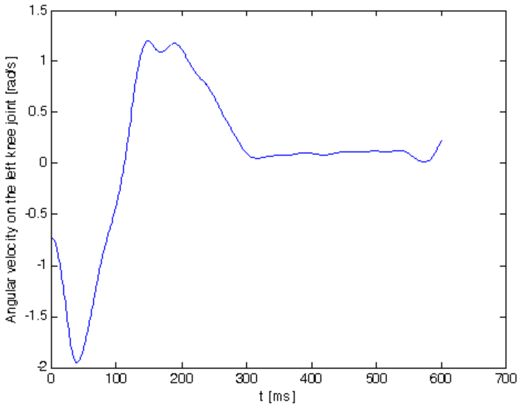

Fig. 6. Angular velocity of the left knee joint

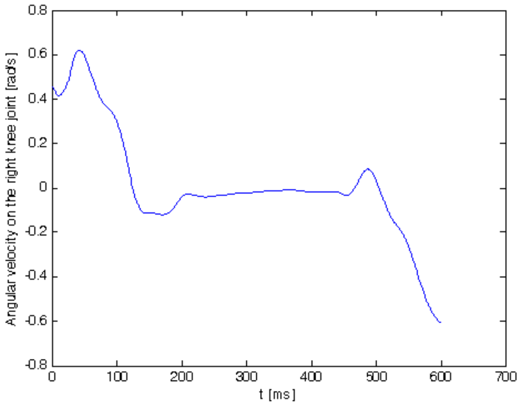

Fig. 7. Angular velocity of the right knee joint

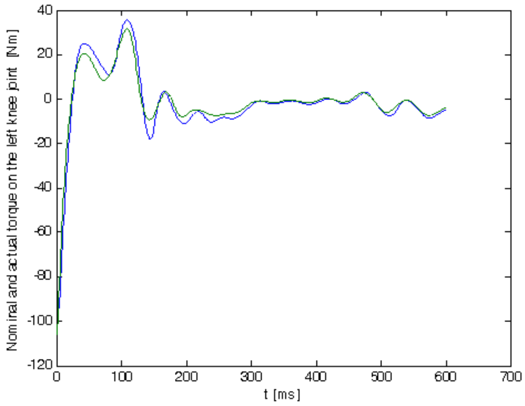

Fig. 8. Nominal and actual torque of the left knee joint

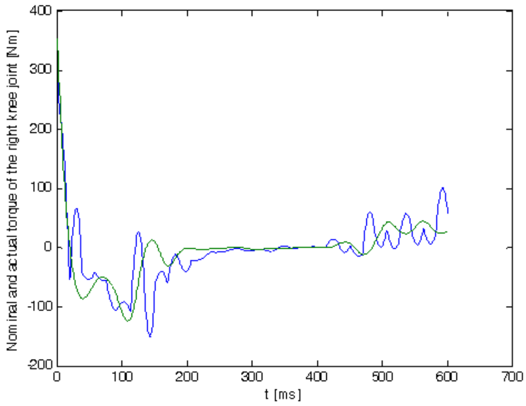

Fig. 9. Nominal and actual torque of the right knee

joint

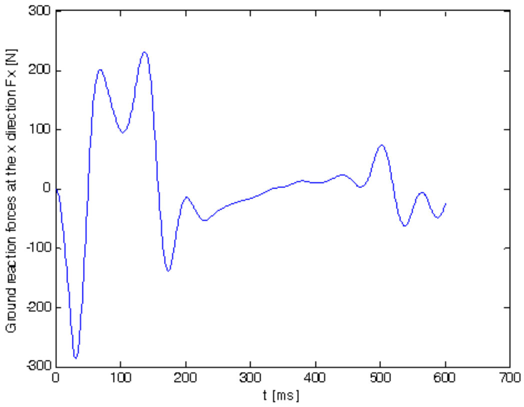

Fig. 10. Ground reaction forces at the x direction

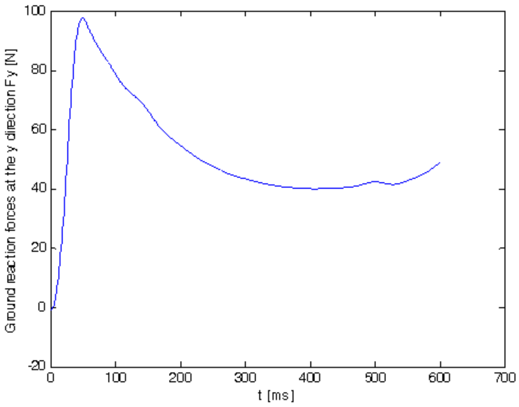

Fig. 11. Ground reaction forces at the y direction

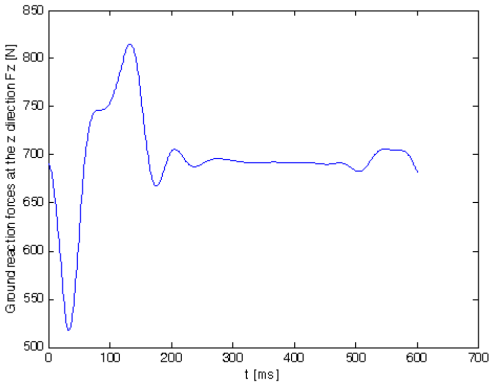

Fig. 12. Ground reaction forces at the z direction

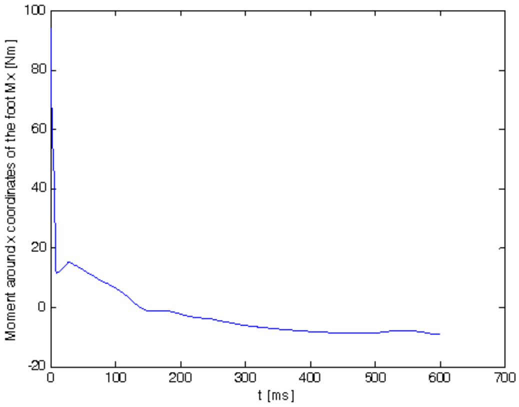

Fig. 13. Moment around x coordinates of the foot

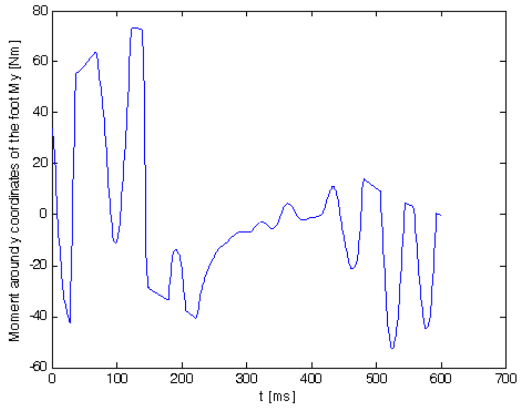

Fig. 14. Moment around y coordinates of the foot

The human body for its complex motion uses synergy of more than 600 muscles. It has more then 300 DOFs [6].

Some of these particular motions are essential for the human activities while the others give it a full mobility.

In this article, a 20 DOFs biped locomotion mechanism of the anthropomorphic structure (Fig. 1) will be considered as an appropriate model of biped locomotion mechanism.

The proposed strategy of biped robot autonomous locomotion is evaluated through the corresponding simulation experiments.

The simulation platform is Matlab/Simulink toolbox dedicated for advanced modeling and simulation of biped robots of anthropomorphic structure. The software uses Robotics toolbox for Matlab [24] to calculate basic model functions of the simple kinematical chains. This toolbox provides many functions that are useful in robotics including such things as kinematics, dynamics and trajectory generation. The Robotics toolbox is useful for simulation. Using Simulink input/output interface it is possible to store simulation results in the corresponding data-files.

The simulation results in the Matlab/Simulink and Robotics toolbox for Matlab/Simulink environment show the effectiveness and the validity of the proposed method.

4. CONCLUSION

This paper will deal with the modeling and simulation of the autonomous motion of humanoid robots.

A kinematic scheme of a a 20-DOFs biped locomotion mechanism of the anthropomorphic structure is used.

The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.

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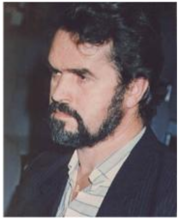
Biography



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