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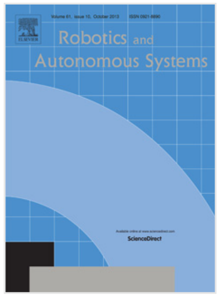
Xiang Luo, Liqin Zhu, Lei Xia



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Principle and method of speed control for dynamic walking biped robots

Xiang Luo*
School of Mechanical Engineering, Southeast University,
Nanjing, 211189, China
luox@seu.edu.cn

Liqin Zhu
School of Mechanical Engineering, Southeast University,
Nanjing, 211189, China

Lei Xia
School of Mechanical Engineering, Southeast University,
Nanjing, 211189, China

Abstract
In this paper, the method of speed control for 3D biped robots is addressed. First, the primary principle of speed control by regulation of input energy is studied, the feature of which is to regulate the speed and the step length synchronically. The method of *Poincaré* mapping is used to prove the stability of speed control in the common range. Second, a method of speed control for an 18 DOFs bipedal 3D robot, which is characterized by the two-point-foot, is proposed. The method is developed on the base of the 3D walking pattern proposed previously, with the new function of speed regulation being added in. The simulations show that the performances of regular walking, acceleration, and deceleration are effective and stable, and therefore verify the feasibility of the proposed method. Furthermore, some walking features, such as the walking efficiency and lateral control, are demonstrated.

Keywords: biped robot; 3D biped walking; dynamic walking; speed control.

1. Introduction

Recently, rapid and brilliant progress has been made on the research of biped robots. A number of robots, such as ASIMO [1], have been endowed with the capability of agile walking, running and simple manipulations. Up to date, the most common principle of walking control is through tracking of reference trajectories. The reference trajectories can be prescribed by analogy with biological systems or passive biped systems [2-4]. In recent decades, the trajectory of zero moment point (ZMP) is applied in the generation of reference trajectory [5-9]. ZMP is defined as the point on the ground about which the sum of all the moments of the active forces equals zero. If the ZMP is within the convex hull of all contact points between the feet and the ground, the biped robot is possible to walk. Basically, these researchers firstly design a desired ZMP trajectory, and then derive the torso motion required to achieve the desired ZMP trajectory. However, the ZMP trajectory is dependent on the motion of the center of mass (COM) of robot. The acceleration of COM may need to be large if the trajectory of ZMP is not appropriately designed. It follows that the energy consumption increases, and the control for task execution of the upper limbs becomes difficult.

Another way of generation of reference trajectory is optimization. Roussel et al. [10] proposed a method for energy optimal gait without any constraint. To decrease the computing cost, they used piecewise constant inputs instead of the continuous input, and simplified the biped robot to a four-link planar model. Bessonnet et al. [11] presented a spline-based parametric optimization technique, and applied it on a seven-link planar biped robot. Using spline approximations, the problem of gait optimization is casted into a constrained non-linear optimization problem of mathematical programming, which is solved using a computing code implementing an SQP algorithm. Also by optimization method, Tlalolini et al. [12] found that a foot-rotation is useful to reduce the energy cost. However, huge cost of computing stands in the way of the on-line application of gait optimization. Up to date, appropriately reduction of the dimension of the search space merely decreases the computing consumption to the level of off-line calculation.

*Corresponding author. Tel.:+86-25-52090501-8527. Cell Phone: +86-13605172739