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Application of Evolutionary Algorithms for Humanoid Robot Motion Planning

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ABSTRACT

In this article, the authors present a new method for humanoid robot motion planning, satisfying multiple objectives. In this method, the multiple objectives humanoid robot motion is formulated as a multiobjective optimization problem, considering each objective as a separate fitness function. Three different objectives are considered: (1) minimum energy consumption; (2) stability; and (3) walking speed. The advantage of the proposed method is that, in a single run of multiobjective evolution, generated humanoid robot motions satisfy each objective separately or multiple objectives simultaneously. Therefore, the humanoid robot can switch between different gaits based on environmental conditions. The results show that humanoid robot gaits generated by multiobjective evolution are similar to that of humans. To further verify the performance of optimal motions, they are transferred to the "Bonten-Maru" humanoid robot.

Keywords: *Artificial Intelligence, Evolutionary Algorithm, Humanoid Robot, Motion Planning, Multiobjective Evolution*

1. INTRODUCTION

The problem of gait planning for humanoid robots is fundamentally different from the path planning for traditional fixed-base manipulator arms due to the inherent characteristics of legged locomotion. Up to now several approaches have been proposed to address this problem. The majority of humanoid robot control policies are built around the notion of controlling the Zero Moment Point (ZMP). The ZMP trajectory is pre-described and the humanoid robot motion is generated such as the real ZMP trajectory follows the prescribed one (Vokobratovic & Borovac, 2004; Vokobratovic et al., 1990). There are also other methods, which considered natural optimal performance, like energy consumption, to generate humanoid robot motion (Chanon et al., 1996; Roussel et al., 1998). In our previous works, we considered energy consumption and torque change as criteria for humanoid robot gait generation (Capi et al., 2001, 2003). In another approach (Capi & Yokota, 2007), we applied multiobjective evolution to evolve the humanoid robot gait that satisfied two conflicting objectives. In all previous works, the main

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objective was to generate an optimal stable human like walking motion.

However, humans and humanoid robots must generally carefully adapt their gaits depending on environment conditions: whether the ground is even or uneven, slippery or sticky, soft or hard, horizontal or with a slope (Kagami et al., 2003; Kuffner, 2000). As the environment changes, the humanoid robot has to switch to the appropriate gait that satisfy a specific objective or different objectives, simultaneously. For example, in slippery or uneven environments the robot has to increase the stability by restricting the ZMP in a narrow region. In even terrains it will be advantage if the robot walk fast or operates for a long time by reducing the energy consumption. In addition, there are situations where multiple objectives have to be satisfied. In order to cope with a wide range of environments in real time, various types of sensors will be necessary.

This article presents a novel approach for multiple objectives humanoid robot gait generation based on multiobjective evolutionary algorithms (MOEAs) (Coello et al., 2002; Deb, 2001; Fonseca & Fleming, 1995; Weile, 1996). The basic idea is to consider each objective as separate fitness function of MOEA. Three different objectives are considered in the current work: minimizing the energy consumption by reducing the joint torque; increasing the stability by restricting the ZMP in narrow region; and increasing the walking speed by reducing the step time. The nondominated sorting genetic algorithm (NSGAII) (Deb et al., 2002) is used to generate the Pareto set of humanoid robot gaits that tradeoff between different objectives. An advantage of the proposed algorithm is that in a single run of MOEA are generated humanoid robot gaits that satisfy each objective separately or multiple objectives simultaneously. Another advantage of applying MOEA is the easy with which the number of objectives may be increased. In real time situations the humanoid robot can utilize different sensors and switch to the appropriate gait based on the environment conditions.

In order to further investigate the performance of humanoid robot motions generated by MOEA they have been implemented on “Bonten-Maru” humanoid robot. Despite some restriction due to the hardware specifications, the robot motion satisfied the objectives.

The outline of this chapter is as follows. In Section 2, the humanoid robot model, motion objectives and optimized variables are discussed. The multiobjective evolution algorithm is presented in Section 3. Section 4 presents series of experiments carried by simulation and with real robot system. Finally, we conclude and discuss some future work in Section 5.

2. HUMANOID ROBOT MOTION OBJECTIVES

2.1 Biped Robot Model

During motion, the arms of the humanoid robot will be fixed on the chest. Therefore, it can be considered as a five-link biped robot in the sagittal plane, as shown in Figure 1. The motion of the biped robot is considered to be composed from a single support phase and an instantaneous double support phase. The friction force between the robot’s feet and the ground is considered to be great enough to prevent sliding. During the single support phase, the ZMP must be within the sole length, so the contact between the foot and the ground will remain. In our work, we calculate the ZMP by considering the link mass concentrated at one point. To have a stable periodic walking motion, when the swing foot touches the ground, the ZMP must jump in its sole. This is realized by accelerating the body link. To have an easier relative motion of the body, the coordinate system from the ankle joint of the supporting leg is moved transitionally to the waist of the robot ($O_1X_1Z_1$). Referring to the new coordinate system, the ZMP position is written as follows:

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