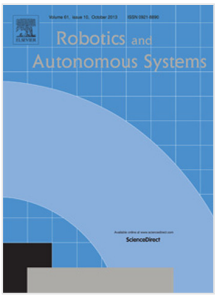

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Bipedal Walking with Dynamic Balance that Involves Three-Dimensional Upper Body Motion

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Abstract

This paper presents a method of designing a more human-like walking pattern for a bipedal humanoid robot. Motivated by biomechanical studies on human walking, we model the walking pattern with continuous and differentiable mathematical functions. For dynamic balance of the robot, we design a pattern generator based on the ZMP (Zero-Moment Point) criterion. In comparison to the conventional bent-knee walking pattern, the proposed walking pattern involves three-dimensional motion of the upper body. With the proposed walking pattern the robot can walk with almost stretched knees at low and medium walking speeds. This paper also presents a body posture control method. The controller is based on sensory feedback and modifies the reference walking pattern in real time in order to stabilize the robot.

We have implemented the proposed walking pattern and control method on the humanoid robot NAO. Walking experiments have verified that the proposed scheme improves the dynamic balance of the robot. Besides, we have investigated the energy consumption at the knee joint actuators and the overall energy consumption at all the joints of both legs, by using NAO that fulfills the conventional walking pattern and the proposed walking pattern respectively. Experiments have proved that (i) knee-stretched motion can improve the walking efficiency of a humanoid robot; and (ii) the proposed walking pattern is more efficient.

Keywords: biped humanoid robot, walking pattern generation, 3D waist