Minimum Input Walking Gait of Four-DOF Biped Model Solved by Optimal Trajectory Planning Method

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There has long been an interest in understanding human walking locomotion, not only from a desire to build biped mechanisms to perform dangerous tasks instead of humans, but also to improve prosthetic devices for amputees. In recent years, many studies have been published about biped walking systems, either from the viewpoint of constructing human-like biped walking mechanism by joint torque control, or aims to discover walking characteristic by measuring the human motions during locomotion. Mita and Yamaguchi et al. [1], Furusho and Masubuchi [2,3], Kato et al. [4] developed various kinds of biped mechanisms by using model-following control methods to simulate and realize biped locomotion. Vladimir [5] wrote a book describing the methods, technical devices, and procedures used when measuring both pathological and/or healthy human locomotion.

However, most of the researchers did not considered the energy efficiency problem of the walking locomotion, with a notable exception of Silva and Machado [6], Ono and Liu [7]. Silva and Machado characterized the biped motion by a set of locomotion variables, and established the correlation among these locomotion variables and the energy performance. Ono and Liu built a 3-degree-of-freedom (DOF) walking model that composed of a knee-less stance leg and a 2-DOF swing leg. Divided one swing phase into two sections: controlled swing motion of 2-DOF swing leg with straight stance leg and free motion of straight swing leg with straight stance one. And they obtained an energy efficient gait with minimum input torque of the controlled section by using optimal trajectory planning method.

Experimental studies of human locomotion [8] support the hypothesis that the choice of a gait pattern is influenced by energy considerations. That is, the human body will integrate the motions of the various segments and control the activity of the muscles so that the metabolic energy required for a given distance walked is minimized.

Bearing these in mind, an optimal trajectory planning study on a 4-DOF planar biped walking mechanism is performed. The biped locomotion mechanism that has thighs, shanks and small feet was modeled as a four-degree-of-freedom (DOF) link system composed of a two-DOF stance leg and a two-DOF swing leg that connected directly at the hip joint. By using the function approximation method and nonlinear programming method, the minimum input walking gaits under full-actuated condition that similar to those of the human walking was obtained. Also, the validity of this method is confirmed by forward dynamic simulation.

References

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