Learning Energy Efficient Walking with Ballistic Walking

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1. Introduction

Comparing with human walking, bipedal walking of a robot is rather rigid. It is mainly because currently realized robot walking does not utilize natural dynamics while human walking does. We suppose that, for realizing energy efficient walking, it is necessary to have a control phase in which no torque is applied to a robot, which is called "ballistic walking". Ballistic walking is supposed to be a human walking model suggested by Mochon and McMahon [1]. They got the idea from the observation of human data, in which the muscles of the swing leg are activated only at the beginning and the end of the swing phase.

In this paper, to utilize dynamics of a robot, we let the hip joint free in the middle of the swing phase, and uses torque control instead of a PD controller in the beginning of the swing phase. Moreover, the learning module is added to the state machine controller so that the minimum energy walking can be realized.

2. Ballistic walking controller with a learning module

We propose a layered controller as shown in Fig.1. The lower layer controller has a state machine for each leg. The state machine consists of four states: First, constant torque is applied to hip and knee joints of the swing leg. Second, no torque is applied so that the swing leg can move in a ballistic manner. Third, a PD controller is used so that the certain posture can be realized at the heel contact, which enables a biped robot to walk stably. Finally, as the support leg, hip and knee joints are servoed to go back and the torque to support upper leg is applied. With this lower layer controller, parameters that enable robot to walk as energy efficiently as human walking can be searched by the upper layer controller without paying any attention to fall down.

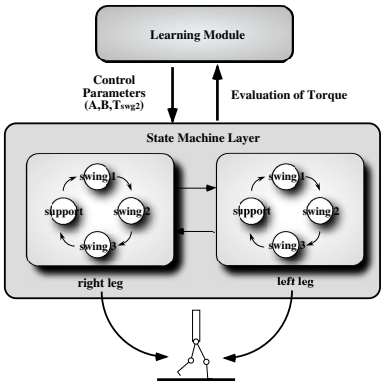
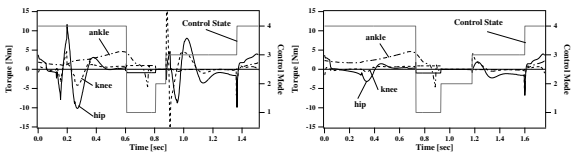


Fig. 1: Ballistic walking with learning module

3. Simulation results

We applied the proposed controller to a two-dimensional humanoid model. Fig. 2 shows the time-courses of output torque in each joint before and after learning. These graphs show the maximum torque are successfully reduced about 1/10 in the hip and knee joints after learning.



(a) before learning (b) after learning

Fig. 2: Simulation results

References

[1] Mochon, S. and McMahon, T.A., 1980, "Ballistic walking", *J. Biomech.*, 13, pp. 49-57.