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Implementation of Position-based Walking to Torque-controlled Humanoid

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Abstract: Torque controlled humanoid robots have been actively developed for better interactivity with human and environment through compliant motion. In this paper, a walking control framework is proposed for a torque-controlled humanoid robot by utilizing position-based walking algorithms with feed-forward torque control. The proposed walking control framework consists of a feed-forward term of gravity compensation with contact redistribution, and walking control with an IK-based position controller. The IK-based position control uses a disturbance observer-based compliant controller and the swing foot orientation controller for more stable contact. The performance of the proposed walking controller is demonstrated through real robot experiments on our humanoid robot TOCABI.

Keywords: Humanoid, Walking, Torque control, Stable contact, Compliant control, Orientation control

1. INTRODUCTION

While position-based walking has been successfully developed[1], torque-controlled robots are recently investigated due to the capability of creating compliance that is important for many applications such as walking on uneven terrains, interacting with human, and dealing with disturbances. In this paper, the control framework of position-based walking to torque-controlled humanoid is introduced. The main purpose is to be able to utilize the previously developed position-based walking algorithm on a torque controlled robot, and exploit the torque control capability. The proposed control framework have the features of both position-controlled and torque-controlled robots.

The first component of the proposed walking control framework is gravity compensation using feed-forward torque command. To overcome the discontinuity of gravity compensation when contact states are changed, contact distribution is implemented during the contact transition[2]. Joint position tracking is used to implement the walking motion of following COM trajectory. The second component is a low level joint controller to track the desired joint trajectory which computed by inverse kinematics. However, simple low level joint controller cannot guarantee stable contact between foot and ground. Therefore, the DOB based compliant controller [3] and a PD controller for the swing foot orientation are additionally implemented. The proposed walking controller is demonstrated by the real robot experiment using a torque-controlled humanoid robot, called TOCABI.

2. PROPOSED CONTROLLER

In this section, the proposed control framework for implementing position-based walking to torque-controlled humanoid robot will be explained. The proposed walking control framework for humanoid is as shown in Fig. 1. The proposed walking control framework integrates gravity compensation, contact redistribution algorithm and DOB based estimator to achieve compliant motion of humanoid. Especially, to enhance the walking stability, swing foot orientation control algorithm is implemented for more stable contact between foot and ground.

2.1 Gravity compensation and Contact redistribution

Gravity compensation is implemented to resist joint torque caused by the weight of the link. Whenever humanoid contact state changes, the size of the contact jacobian changes depending on the contact point. Because of the change in contact Jacobian, gravity compensation torque will abruptly change and this will cause instability of humanoid. To overcome this problem, the contact redistribution algorithm using contact null-space is implemented when the contact state of the humanoid changes [2].

2.2 Disturbance observer for compliant humanoid

When the swing foot touches the ground, the ground impact force would destabilize the humanoid. To overcome this problem and accomplish more stable contact between the swing foot and the ground, Disturbance caused by external forces can be observed by DOB implemented at each leg joint and this estimated disturbance is positively feedback to create compliant motion [3].

2.3 Swing foot orientation control

During the swing phase, the swing foot orientation error occurs due to the reasons such as joint elasticity and modelling error. Because of the swing foot orientation error, unstable edge contact occurs during the swing foot contact with the ground. When the humanoid robot touches the ground with the edge of the swing foot, it may not be enough to maintain the balance of the robot only with the compliant control algorithm. Especially, the roll/pitch angle of the swing foot has a great effect on the ground contact. In order to accomplish a stable contact between the swing foot and the ground, the swing foot should be controlled parallel to the ground. To ensure that the roll/pitch angle of swing foot is parallel to