Impedance Control for Body Motion of Quadruped Robot

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Abstract. One of the basic assumptions in the conventional wave gait for a walking robot is that the weight of a leg should be negligible compared to that of body, so that the total gravity center of the robot is always kept inside of the support polygon, not affected by a motion of a leg. In case that a leg is relatively heavy, however, while the gravity center of the body is kept inside of the support polygon, the total gravity center can be out of the support polygon due to moving leg, which causes instability in walking. In this paper, an impedance control for body motion is proposed to make the total gravity center of a quadruped robot track the pre-designed trajectory for the gravity center of the body, so that the walking stability is secured even in case that the weight of a leg has serious influence on the total gravity center of the robot.

Keywords: Quadruped robot, Wave gait, Impedance control, Gravity center.

1 Introduction

The most frequently used gait pattern for a quadruped robot is so called the wave gait, which defines the sequence and phase of the leg- transfer so that the gravity center of the robot always lies inside of the support polygon consisting of each support leg's tip position[1]. One of the basic assumptions in the wave gait is that the weight of a leg should be negligible compared to that of body, so that the total gravity center of the quadruped robot is not affected by a motion of a leg. In extreme case of zero leg-weight, the total gravity center coincides exactly with the gravity center of the body, regardless of moving leg.

Hereafter, it is denoted as an ideal robot for the case of the zero leg-weight, and a real robot for the other case. Roughly speaking, the pantograph type of walking robot can be classified into the ideal robot since all actuators are integrated into the body and the driving mechanism of a leg is simple and light compared to the body [2]. On the contrary, the jointed-leg type of walking robot can be called as a real robot since each joint actuator is located directly at each joint, thereby a leg becomes relatively heavy. As a consequence, the total gravity center of the robot has fluctuation by the motion of a leg and the conventional wave gait considering only the body gravity center cannot be successfully applicable. In order to secure the walking stability for the real robot, it is necessary to compensate the fluctuation in the total gravity center.

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A compulsive body sway was proposed to drive the total gravity center of a walking robot into the support polygon [3][4] and an independent trunk mechanism was used to compensate the fluctuation in the total gravity center[5]. The first method has problems in determination of the sway direction and magnitude at each walking situation, and in the latter, together with an extra cost for an additional controller, the total weight of robot increases due to the trunk.

For a walking robot, the effect of the weighty leg on the total gravity center is reflected in the foot reaction force of each support leg. Thus, if the real robot is driven for the measured foot force to follow the desired foot force of the ideal robot, it is possible to realize the pre-designed stable walking for an ideal robot. Since the force-moment equation for a walking robot represents the relationship between the total gravity center and the foot force of each support leg, the body motion can be drawn for the foot force of the real robot to follow that of the ideal robot. The main aim of this paper is to propose an impedance control for the body motion of the jointed-leg type of quadruped robot.

2 Effects of the Weighty Leg on the Total Gravity Center of a Walking Robot

In order to inspect the effects of the weighty leg on the total gravity center of a quadruped robot, each link element of the robot is modeled as a point mass as shown in Fig. 1.

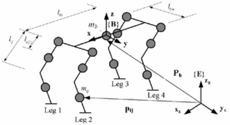

Fig. 1. The point mass model for a quadruped robot

Then, the position of the total gravity center $\mathbf{p_{cg}} = (x_{cg}, y_{cg})$ of the robot satisfies the following (1)

$$m_b(\mathbf{p_b} - \mathbf{p_{cg}}) + \sum_{i \in LEG} \sum_{j \in LINK} m_{ij}(\mathbf{p}_{ij} - \mathbf{p_{cg}}) = \mathbf{0} \qquad (1)$$

where m_b and m_{ij} denote the body mass and the j^{th} link mass of the i^{th} leg respectively. The vectors, $\mathbf{p_b}$ and $\mathbf{p}_{ij}$, represent the positions of m_b and m_{ij} with respect to the earth-fixed reference coordinate frame, $\mathbf{E}$, and LEG and $LINK$ are the sets of all legs and all links of a leg respectively. Note that the body gravity center,

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