Compliance Control for Jointed-Leg Type Quadruped Robot

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Abstract. Due to the irregularity of ground, a walking robot suffers from the mechanical shock and slippage, which cause the instability of walking. A jointed-leg type walking robot is more vulnerable to those problems than the pantograph type because of its heavy leg. In order to secure the walking stability for a jointed-leg type quadruped robot, a balancing algorithm consisting of the leg compliance control and the body posture control is implemented in this paper.

Keywords: Jointed-leg type quadruped robot, Wave gait, Compliance control, Walking stability.

1 Introduction

The conventional wave gait for quadruped walking has strict assumption that the center of gravity (c.g) is not affected by leg motion and the walking surface is flat in order to maintain the walking stability[4]. But these assumptions cannot be hardly satisfied in the most practical cases. For example, the c.g location of the jointed-leg type quadruped robot is fluctuated according to the leg motion since the weight of a leg of the jointed-leg type robot is so heavy in contrast with that of the pantograph type. Moreover, if the walking ground is irregular and rough, or the foot trajectory control is not accurate, the swinging leg may land earlier or later than the planned time. This may violate the synchronized land and lift of foots required in the wave gait, and cause the landing shock and bounce on the foot, and the incomplete supporting state.

These problems can be solved by the compliance control for the support legs which adapts the vertical length of a leg to come up with the desired reaction force. The leg compliance control for the hexapod or pantograph type quadruped robots have been already implemented and reported by Klein and Yoneda, respectively [1][2][3]. But similar studies have been very few reported in case of the jointed-leg type quadruped robots. It's reason is that the most of the quadruped robots developed until now are the pantograph type whose legs can be designed to have light weight, so that the c.g fluctuation by the leg motion and the landing shock by the inaccurate trajectory control can be greatly reduced. In contrast with it, the jointed-leg type robot is generally more disadvantageous in respect to the leg design and gait control. And it needs compact, light and high torque joint drive, which is usually difficult to fulfill [6]. Nevertheless, the jointed-leg type robot is of great meaning in research and development, because its model represents the dynamic and powerful sort of

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locomotion such as those of horse, cow, cat and so on [7]. In this paper, it will be shown how the walking stability of a jointed-leg type quadruped robot over an irregular terrain can be improved by the leg compliance control, where the leg weight has significant influences on the walking stability.

2 The Leg Compliance Control

Fig. 2 shows the compliance model of a quadruped robot on the irregular ground. The irregularity may exist on the walking ground or may be virtually caused by the inaccurate foot trajectory control.

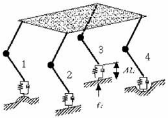

Fig. 1. Model of the leg compliance

The compliance equation for each leg is as follows;

$$k_a \Delta \ddot{l}_i + k_v \Delta \dot{l}_i + k_p \Delta l_i = f_{di} - f_i , \quad k_a , k_v , k_p > 0 \tag{1}$$

where the subscript i denotes the leg index from 1 to 4, Δl_i is the change in the leg length due to its compliance, f_i is the vertical reaction force measured at the ankle joints, and f_{di} is the reference force for the compliance control. Kinematics control for each leg adjusts the leg length resulting from (1). In order to derive the reference force f_{di} which acts on each foot in case of walking on the flat and horizontal ground, the quadruped robot is mathematically described by a lumped mass model shown in Fig. 2 [5]. It is assumed in this paper that the gait pattern follows the conventional wave gait, which makes the mathematical model for f_{di} simple and calculable in real time.

At the c.g location, $\mathbf{P_{cg}}=(x_{cg} , y_{cg})$, of the whole lumped mass robot model, the moment equilibrium condition given in (2) should be satisfied;

$$m_b(\mathbf{P_b} - \mathbf{P_{cg}}) + \sum_{i \in LEG} \sum_{j \in LINK} m_{ij}(\mathbf{P_{ij}} - \mathbf{P_{cg}}) = 0 \tag{2}$$

where $\mathbf{P_b} = (x_b , y_b)$ is the mass center of the body, m_b is mass of the body, $\mathbf{P_{ij}} = (x_{ij} , y_{ij})$ is the mass center of the j^{th} link of the i^{th} leg and m_{ij} is the mass of the ij link. By the c.g location, it is meant the projection of the actual c.g on the x-y ground plane here.

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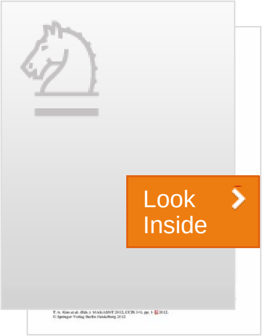

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