Passive Dynamic Walking : Design of Internal Parameters

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Abstract

This paper presents the design of a passive biped walking robot based on limit cycle analysis. By using numerical analysis and experiment, we identify better design criterion for biped walking robot. In designing robot parameters we apply global search method to find limit cycles for given robot parameters and ground angle. Internal parameter variation changes limit cycle behavior, total energy, strides, etc and the characteristics of walking is analyzed by simulation and experiments.

1 Introduction

In robotic field, there are many robots which can walk very well. To improve the walking performance, some optimality concept should be introduced in the design stage of the walking robot. Then, what is the more efficient design for walk, for example, to resemble human walking, because human walking pattern is optimalized by nature and training. There were trials for giving criterion for robot design through passive biped walker [4], [2], etc., but not for human-like type walker, a walker with knee for general walking speed. Only there was a research for straight legged walker and tuning result for minimal energy consuming kneed walker, which is not proper in normal walking speed. In this paper, we address some aspects of design for kneed walker using 2-D graphical representation for limit cycle. We also describe some other properties of kneed passive walker.

2 Passive Walker with Knee

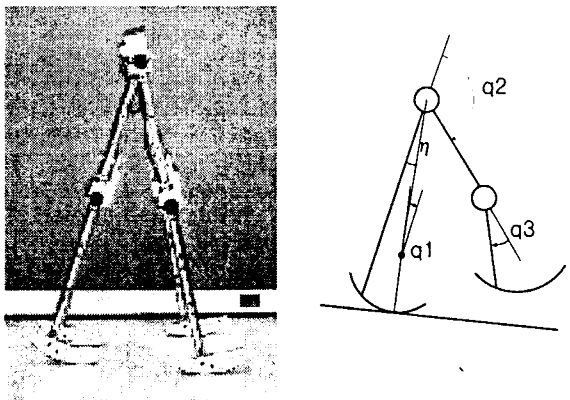
In this paper, we used kneed type passive walker for analysis[5] as shown in Fig.1. In simulation, we used classical dynamics in [6], [1], with inelastic assumption of environment. The designed walker is shown in Fig.1 where we can adjust mechanical parameters arbitrarily.

3 Dynamics Formulation

In dynamics formulation, we used Lagrangian formulation. In the following sections, we introduce knee impact and heel impact formulation.

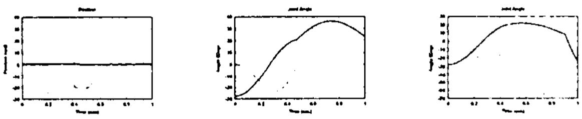
3.1 Knee Impact

Besides angular momentum conservation law which comes from inelastic assumption, knee impact simulation was made in more realistic way. Previous way of simulation can not explain suction damping character(Fig.2(b)), but this is included in this simulator. Before inelastic knee-impact calculation, damper model of short period was applied and outcome of this joint value was used to calculate in inelastic calculation.



(a) Passive walker   (b) Modeling of robot

Fig. 1: Model used in this paper



(a) Experimental Data   (b) Case when modeled for suction   (c) Case when not modeled for suction

Fig. 2: Comparison of experimental data and simulation

3.2 Heel Impact

3.2.1 First Step of Impact Formulation - Lagrangian Method

From [1], we can calculate post-angular velocities of generalized coordinates. Basic equations is as follows.

$$\sum_{j=1}^{n} m_{ij}\Delta\dot{q}_j = \hat{Q}_i \ (i = 1, 2, \ldots, n). \tag{1}$$

Here we have n algebraic equations from which to solve for n $\Delta\dot{q}$'s. Using matrix notation, we can write it as

$$\Delta\dot{q} = m^{-1}\hat{Q}. \tag{2}$$