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Dynamic performance analysis of six-legged walking machines ☆

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Abstract

The aim of this article is to provide a systematic method to perform dynamic analysis in the task space for walking machine. The dynamic manipulability ellipsoid is introduced and the two quantitative indices of the walking machine's capability, in each configuration, of performing main-body accelerations along given task space directions are defined. The ellipsoids are derived on the basis of the mapping of the body accelerations onto the joint driving torques (including the selected generalized joints' driving torques and non-generalized joints' driving torques) via the proper dynamic coordination and optimal dynamic load distribution equations of the walking machine. The maximum joint torque limits are taken into account. In the final, a numerical example is given to indicate the use of the indices in the optimal designing of walking machine's mechanism parameters. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

Because a walking machine has good potential to be an effective and efficient transportation device on rough and/or soft terrain and the complex and challenging nature of the problem has been very attractive to many researchers, the development of walking or running machines has drawn significant attention in the field of robotics.

While the walking machine walks with static stability gaits (at least three legs are in the supporting phases at any moment), the supporting legs and the body form the configuration of closed multi-loop kinematic chains through the ground. This kinematic chain has the feature of redundant actuation (we call it the over-determinate inputs [1]). The closed chains tend to

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introduce additional dynamic coupling owing to the kinematic constraints between the cooperating mechanisms, and the redundant actuation offers an unlimited variety of control inputs that will effect any given system motion. These features also add a lot of difficulties to the analysis and design of walking machines.

The kinematics and dynamics of walking machines, including gaits, has been relatively well addressed. By virtue of the research on the dynamic manipulability ellipsoid of the multiple cooperating arms system, this paper will introduce the dynamic manipulability ellipsoid to walking machines, and the quantitative indices to describe the walking machine's capability, in each configuration, for performing main-body dynamics along given task space directions. We believe that these dynamic manipulability measures are of crucial important to the performance of task space analysis of walking machines. The present work is aimed at providing a systematic method for performing task space analysis of walking machines based on the definition of a suitable dynamic manipulability ellipsoid and the work of Huang and Zhao [1]; this is derived by expressing the joints' driving torques (including the generalized joints' driving torques and non-generalized joints' driving torques) of the walking machine as a function of the main-body acceleration by using the proper dynamic coordination and optimal dynamic load distribution equations of the walking machine. The proposed ellipsoid explicitly accounts for the joint maximum driving torques.

2. Dynamic modeling of walking machine

The diagram of a six-legged walking machine is shown in Fig. 1. The vehicle has six identical legs, with three powered degrees of freedom each. The contact region of each supporting leg with the ground can be assumed as a spherical joint, providing the foot force is in the friction cone. Thus, this walking machine's system has six-degrees of freedom. By using the kinematic influence coefficients method and virtual work principle [1–5], the dynamic model of the walking machine is in the following form:

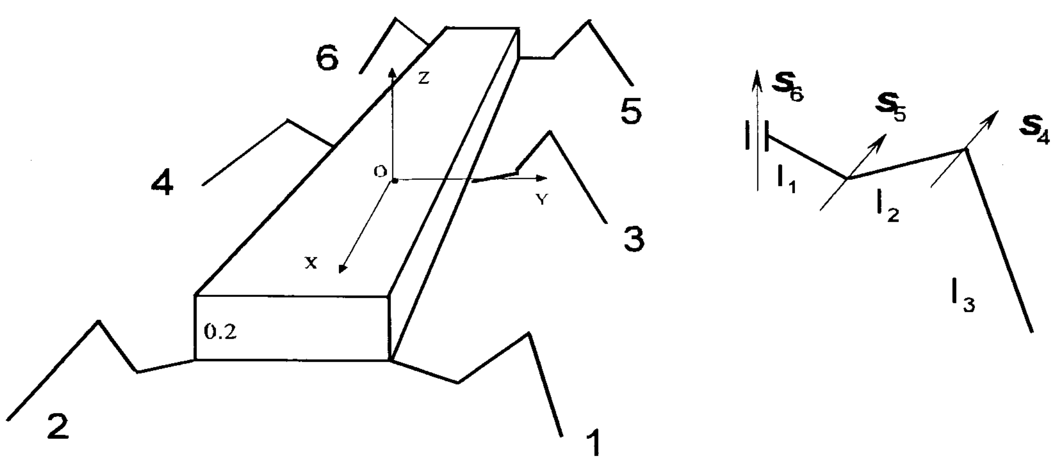

Fig. 1. Diagram of walking machine and its leg.