論文の内容の要旨

論文題目

Computational Study on Dynamics of Large DOF Multibody Systems with Underactuated Base and its Application to Mass-Property Identification of Humans and Humanoids

（非駆動ベースをもつ大自由度多体系のダイナミックスに関する計算論的研究とその人間およびヒューマノイドの質量特性の同定への応用）

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This dissertation studies the dynamics of large DOF multi-body systems with the base not permanently fixed to the inertia frame, or more specifically legged systems such as humanoid robots and humans. The issue is approached in terms of the identification theory developed in the field of robotics. Especially, the under-actuated base characterizing the dynamics of legged systems is focused, and the essential linear form of the physical consistency conditions of multi-body mechanics is also discussed. Based on the study, the practicable method to identify the inertial parameters of each body segment of humanoids and humans is presented.

In this dissertation, the useful mechanical features to analyze the dynamics of legged system are provided as follows:

(1) If each rigid body making up the whole system is considered as a discrete collection of an infinite number of point masses, the non-linear physical consistency conditions of inertial parameters are equivalent to the linear ones of each point mass. Especially if approximated by a finite number of points, the approximated physical consistency can be treated as sufficient conditions for the original one.

(2) The set of inertial parameters appeared in the equation of motion of the

under-actuated base is equivalent to the one in the whole body equations. Especially, when no external force acts on the system, all the parameters in the set except the total mass is generally identifiable only from the observation of the free-flying motion.

The proposed methods to analyze the dynamics of legged systems are as follows:
(A) The inverse kinematics method based on finite distribution model of feature points and their high-order moments is proposed. The whole body pose can be generated from a set of 3D markers or pixels of 2D images without labeling each feature point. Some generated poses and motions of a human model are shown.
(B) The method to identify inertial parameters based on the dynamics of the under-actuated base is proposed. In the method, the joint torques need not to be measured and the joint frictions not to be considered. The implementation techniques for the three types of external force measurement and their valid results are presented.
(C) The method to identify physically consistent parameters based on finite distribution model of point masses is proposed. It can also estimate all the standard inertial parameters in combination with a priori parameters extracted from the geometric model or the statistical information. The identified results of a humanoid robot are shown.
(D) Based on (B) and (C), the implementation method for real-time identification is presented. The method is applied for the identification of human mass properties.
By visualizing the identified results during the measurement, the human subject can intuitively generate the persistent exciting trajectories.