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ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics - Part 1 (5)

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A NEW COMPUTER-ORIENTED APPROACH WITH EFFICIENT VARIABLES FOR MULTIBODY DYNAMICS WITH MOTION CONSTRAINTS

Abstract

A variety of engineering systems, such as manipulators, robots, large space structures, etc., can be modeled as multibody systems consisting of hinge-connected rigid and flexible bodies. The methods for formulating the dynamic equations of such systems fall into two main categories: the recursive and the direct formulations. The recursive formulations are computationally efficient since their computational cost varies linearly with n, where n is the number of system degrees of freedom. However, they can't provide the explicit description of the system, which leads to the difficulties for control system design because most of the time-domain techniques are based on state-space models. The direct formulations which involve the computation and inversion of the system mass matrix are suitable for controller design. Nevertheless, so much labor has to be performed to obtain the direct model, especially for a complex system containing flexible bodies. Moreover, introducing the Lagrange multipliers for constrained multibody systems causes the increase of the dimensionality and makes one runs into the difficulties of solving for and controlling the multipliers. For these reasons, it's desirable to obtain the explicit expressions that involve no unknown multipliers for dynamics of constrained multibody systems. This study seeks for efficient formulations of such mathematical model.

This paper presents a new formulation for automatic generation of the equations of motion for multibody systems. The formulation is base on Kane's equation. Each rigid or flexible body's contribution to the system's *generalized inertial force* is expressed in a similar manner; therefore, the method is amenable to computer solution. To improve the modeling efficiency, all the kinematic quantities' recursive relations are developed, including two newly defined quantities—*partial velocity matrix* and *partial angular velocity matrix*. Efficient motion variables describing the elastic motion and the hinge motion are adopted. The Efficient motion variables have been used in the recursive formulations; however, they haven't been employed to develop the approach capable of automatically generating the direct model in the open literature. The new form of Kane's equation developed recently for constrained systems is modified and incorporated to treat the motion constraints in multibody systems. The final mathematical model is of minimum dimension and involves no Lagrange multipliers, which makes it useful for control system studies.

The simulations of a space robot with one structural loop are compared between the proposed method and the recursive algorithm. The results validate the accuracy and efficiency of the proposed method.