

N90-22990

An Order (n) Algorithm for the Dynamics Simulation of Robotic Systems

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Abstract

The ability to simulate and analyze the dynamics of complicated multibody systems has been of great benefit to engineers for the past decade. Applications have included robotics, land vehicles, and spacecraft. However, many of the commercially available software have been computationally intensive and are costly and time-consuming for analyzing large systems. Fortunately, recent developments in Order (n) algorithms and parallel processing for multibody dynamics simulation have drastically reduced the computer time needed to simulate systems involving many bodies.

This paper presents the formulation of an Order (n) algorithm for DISCOS (Dynamics Interaction Simulation of Controls and Structures), which is an industry-standard software package for simulation and analysis of flexible multibody systems. For systems involving many bodies, the new Order (n) version of DISCOS is much faster than the current version. Results of the experimental validation of the dynamics software are also presented. The experiment is carried out on a seven-joint robot arm at NASA's Goddard Space Flight Center.

The algorithm used in the current version of DISCOS requires the inverse of a matrix whose dimension is equal to the number of constraints in the system. Generally, the number of constraints in a system is roughly proportional to the number of bodies in the system, and matrix inversion requires $O(p^3)$ operations, where p is the dimension of the matrix. The current version of DISCOS is therefore considered an Order (n^3) algorithm. In contrast, the Order (n) algorithm requires inversion of matrices which are small, and the number of matrices to be inverted increases only linearly with the number of bodies.

The newly-developed Order (n) DISCOS is currently capable of handling chain and tree topologies as well as multiple closed loops. Continuing development will extend the capability of the software to deal with typical robotics applications such as put-and-place, multi-arm hand-off and surface sliding.