Abstract:

The increase in processing power and the theoretical breakthroughs achieved in multibody systems dynamics have improved the usefulness of dynamic simulations to such an extent that the development of a whole range of applications has been triggered. Dynamic simulations are used for the analysis of mechanisms, virtual prototyping, simulators, computer animation, advanced control, etc. and are gaining in popularity. This thesis proposes a method for formulating the equations of motion of multibody systems with the purpose of further improving the efficiency of dynamic simulations. The proposed algorithm is recursive and is based on a set of Hamiltonian equations.

The simulation of multibody systems comprises two essential steps: formulating the equations of motion and solving the equations of motion. Most methods for formulating the equations of motion of multibody systems are based on accelerations: whether the Newton-Euler equations, the Lagrangian equations or the principle of virtual work or virtual power are used, these methods provide a set of second order differential equations and the simulation algorithms come down to calculating and integrating accelerations.

A set of Hamiltonian equations on the other hand does not contain accelerations, but is expressed in terms of canonical momenta and their time derivatives instead, resulting in twice as many first order differential equations. The motivation for using Hamiltonian equations can be found in the numerical integration of constrained multibody systems. Adding algebraic constraints to the differential equations results in a set of differential-algebraic equations with differential index 2, while acceleration-based algorithms typically have index 3. It is a well-established fact that index 3 DAEs are more difficult to solve than systems with a lower index.

The method proposed to obtain a Hamiltonian set of the equations of motion of a multibody system results in a recursive O(n) algorithm. It is based on the well-known articulated body method and introduces the concept of articulated momentum vectors. Closed-loop systems are handled by performing a coordinate reduction to obtain a set of independent coordinates. The resulting algorithm allows to compete with O(n) acceleration-based algorithms, while exploiting the benefits of the lower differential index. It even outperforms the comparable acceleration-based methods for formulating the equations of motion: counting the number of arithmetical operations needed to establish the equations of motion reveals that the proposed algorithm requires less computations than other acceleration based methods described in the literature.