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Optimal control of constrained multi-rigid-body systems using recursive Hamiltonian formulation

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Abstract: The optimal control approach is exploited in many applications and, in general, aims at minimizing a certain performance index by satisfying one or several physical or artificial constraints imposed on the motion of a multibody system (MBS). The adjoint method is extensively used in this field in order to efficiently find the descent direction of the optimization procedure. On the other hand, there exists a large variety of recursive algorithms for efficient simulation of constrained multi-rigid-body dynamics. The purpose of this paper is twofold. In the first step, a recursive Hamiltonian based formulation for open-loop kinematic chains is demonstrated that generates the equations of motion in terms of joint coordinates and canonical momenta. In the second step, a novel recursive Hamiltonian-based algorithm for finding optimal control trajectories for holonomically constrained multi-rigid-body systems is proposed in the work. The differential-algebraic equations constituting equations of motion for MBS are solved numerically forward in time. The adjoint system of differential-algebraic equations is formulated in the same recursive manner. Systematic derivation of the adjoint equations is presented in the text and the recursive expressions are delivered. Explicit formulae for the calculation of a gradient of a performance measure are also included in the text. Sample planar test case is presented to demonstrate the validity of the proposed approach.
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