“Order-(n+m)” Direct Differentiation Determination of Design Sensitivity for Constrained Multibody Dynamic Systems

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Abstract

With the complexity and large dimensionality of many modern multibody dynamic applications, the efficiency of the sensitivity evaluation methods used can greatly impact the overall computation cost, and as such can greatly limit the usefulness of the sensitivity information. Most current direct differentiation approaches suffer from prohibitive computational cost, which may be as great as $O(n^4+n^2m^2+nm^3)$ (for system with n generalized coordinates, and m algebraic constraints). This paper presents a concise and computationally efficient sensitivity analysis scheme to facilitate such sensitivity calculations. A unique feature of this scheme is its use of recursive procedures to directly embed the algebraic constraint relations, in forming and simultaneously solving a minimal set of equations. This results in far fewer operations than more traditional, or so called $O(n)$, counterparts . The algorithm determines the derivatives of generalized accelerations in $O(n+m)$ operations overall. The resulting equations are “exact” to integration accuracy, and enforce constraints exactly at both the velocity and acceleration levels.

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