New Factorizations and Fast Parallel Algorithms for Forward Dynamics Solution of Single Closed-Chain Robot Manipulators

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Abstract

The application of single open-chain manipulators for many typical tasks involves the interaction with the environment. This interaction constrains the motion of the End-Effector (EE), resulting in a single closed-chain system. From a topological point of view, such a system represents a rather simple example of closed chain mechanisms. However, from a computational point of view, its dynamics simulation (or forward dynamics solution) is significantly more demanding than that of a single open chain system. In addition to the solution for constraint force, it requires twice the solution of forward dynamics of the open-chain system as well as the computation of the inverse of the Operational Space Mass Matrix, Λ^{-1}, of the open-chain system.

In this paper new factorization techniques are developed which lead to the optimal sequential $O(N)$ algorithms and fast parallel $O(Log\,N)$ algorithms for dynamics simulation of single closed-chain robot manipulators. Starting with a recently developed [1] *Schur Complement* factorization of the inverse of the mass matrix ($\mathcal{M}^{-1}$) similar Schur Complement factorization of the inverse of the Operational Space Mass Matrix (Λ^{-1}) with simple physical interpretations is developed. A new $O(N)$ algorithm for the problem is then derived by a recursive implementation of these factorizations. It is shown that this $O(N)$ algorithm is *strictly parallel*, that is, it is slightly less efficient than other $O(N)$ algorithms for serial computation of problem. But, to our knowledge, it is the first known algorithm that can be parallelized and lead to a both time and processor-optimal parallel algorithms for the problem, i.e., parallel $O(Log\,N)$ algorithms with $O(N)$ processors. The parallel algorithms developed in this paper, in addition to their theoretical significance, are also practical from an implementation point of view due to their simple architectural requirements.

1. A. Fijany, I. Sharf, and G.M.T. D'Eleuterio,"Parallel $O(Log\,N)$ Algorithms for Computation of Manipulator Forward Dynamics," *IEEE Trans. Robotics & Automation*, Vol. 11(3), pp. 389-400, June 1995.

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