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Quaternion based free-floating space manipulator dynamics modeling using the dynamically equivalent manipulator approach

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Abstract: The paper presents a dynamics modeling method dedicated to free-floating spacecraft, e.g. manipulators, based on a modified Dynamically Equivalent Manipulator (DEM) method. DEM enables dynamics modeling of space manipulators (SM) via their suitable substitution by ground fixed manipulator models. The resulting SM dynamics is equivalent to the ground one. This provides attractive modeling and control design tools. It enables carrying tests and experiments for SM in earth labs multiple times what contributes to mission cost and failure reductions. Originally, DEM is developed in Euler angles. The paper contribution is the modification of DEM to present SM dynamics in quaternions. The Euler angles description is not suitable for dynamics and control of SM and other spacecraft, e.g. for large reorientation and attitude description. Quaternions do not share Euler angles' drawbacks and they are computationally more efficient. However, their implementation reveals challenges due to nonlinear relations for SM angular velocities and a constraint equation they add to SM dynamics. The motivation for DEM modification is to make dynamics models suitable for description of arbitrary SM maneuvers and missions like debris removal, servicing, space mining and on-orbit docking and assemblies. It may also support SM attitude controller designs. Derivation of Lagrange based dynamics in quaternions can be found in some works but it is limited to ground fixed manipulators with position constraints only. The development of DEM in quaternions is illustrated by an example of SM attitude dynamics.

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