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# INVERSE DYNAMICS PARTICLE SWARM OPTIMIZATION APPLIED TO CONSTRAINED MINIMUM-TIME MANEUVERS USING REACTION WHEELS

**Abstract**

The paper deals with the problem of spacecraft time-optimal reorientation maneuvers by means of internal torques (using reaction wheels), with boundary and path constraints.

When searching for solutions to optimal attitude/control problems, spacecraft may be easily modeled as to be controlled by external torques, and much of the literature uses that model; however, when using actuators as reaction wheels, conservation of the total angular momentum must be taken into account and the wheel dynamics must be included.

The following constrained slew maneuver is considered: a spacecraft must perform a rest-to-rest slew maneuver where an optical sensor cannot be exposed to sources of bright light such as the Earth, the Sun and the Moon. The motion must be constrained to prevent the sensor axis from entering into established keep-out cones: such areas have central axes pointing to the bright-light sources and specified half-angles depending on the light magnitude, the distance from the satellite and the angular diameter of the source. In a given situation, the initial and final attitudes are known.

The minimum time solution with keep-out constraints and internal torques (using reaction wheels) is proposed using the Inverse Dynamics Particle Swarm Optimization technique. This technique may be applied to differential flat-systems where both the state and the control may be expressed as a closed-form algebraic function of the flat-outputs. Choosing the flat-outputs as the attitude parameters, the Particle Swarm Optimization makes the attitude and the kinematics evolve, leading to the successive attainment of the control without requiring numerical integration. This technique is referred to as Inverse Dynamics as opposed to the usual direct approach which consists in making the control evolve obtaining the attitude and the kinematics via numerical integration.

The angular displacement is described through the Modified Rodrigues Parameters and discretized through a user-defined number of control points. The B-spline interpolation is used to evaluate the kinematics. A dynamical refinement of the mesh points is introduced, leading to an important improvement of the results with respect to previous work. Numerical results will be presented evaluating the proposed technique over different scenarios. It is established that the computation of minimum time maneuvers with the proposed technique leads to near optimal solutions, which fully satisfy all the boundary and path constraints. The rapid convergence along with the ability to perform in a variety of difficult scenarios characterizes the proposed technique as a feasible future on-board path-planner.