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A Symplectic Integrator for Rigid Body Dynamics Based on Unit Quaternions

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A symplectic integrator based on the unit quaternions is presented for rigid body dynamics. The unit length constraint is enforced explicitly by means of an algebraic constraint. Correspondingly, the equations of motion assume the form of differential-algebraic equations. An identity transform between the time derivative of quaternions and angular velocity is introduced into the kinetic energy term. This proposed approach yields a non-singular mass matrix naturally, which is usually obtained for the quaternion representation of rigid body dynamics by introducing an artificial parameter of expanding the number of independent velocity parameters from the original three to four. Finally, based on the improved kinetic energy term and the discrete variational principle of the action function, a new symplectic scheme is proposed. Two numerical examples demonstrate the performance of the newly developed method. The numerical result shows that the new scheme avoids the significant period error of nutation for the special case of steady precession of a gyro top, which is a puzzling phenomenon in recent researches. In addition, it presents an impressive improvement of accuracy for the general case as well, compared with two classical quaternion-based structure-preserving algorithms.

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