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AN EXPONENTIALLY FAST ATTITUDE TRACKING CONTROLLER ON THE ROTATION GROUP

Abstract

In this paper a continuous attitude tracking control law is derived directly on the rotation group SO(3). Deriving controls directly on the rotation group avoids the unwinding problem associated with quaternions and lends itself to accurate and efficient numerical integrators that exploit the group structure. Furthermore, it is shown that this control law reduces the closed-loop attitude dynamics to a linear oscillator description of the eigen-axis error. The main practical benefit of this is that the gains can be easily tuned to drive this eigen-axis error to zero exponentially fast and with a damped response without oscillations. This tuning method is obtained without using any approximation and is therefore applicable to achieving a critically damped response for large slew maneuvers. The approach uses geodesic metrics on the rotation group and the angular velocity tracking errors to construct a geometric Lyapunov function. The time-derivative of this Lyapunov function is control dependent and a continuous control is selected to guarantee asymptotic stability of the reference motion. Furthermore, the closed-loop system, with this rotation-matrix based feedback control applied, is converted to its quaternion form and further reduced to an eigen-axis error description of the dynamics. This reduction reveals a simple method for tuning the control which involves only one parameter and that can be selected to obtain the fastest convergence to the reference motion. In addition a related rotation-matrix based control is presented that requires no knowledge of the inertia matrix and can therefore be useful for the attitude stabilization of spacecraft where the inertia is uncertain. This control is derived using an energy based Lyapunov function on SO(3) rather than the previous geometrically defined one. The proposed controls are applied in simulation to the attitude control of a small spacecraft and show a settling time performance enhancement, for given actuator constraints, over other rotation-matrix based feedback controllers in the literature.