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MINIMUM-ERROR SINGLE-AXIS POINTING FOR AN UNDERACTUATED SPACECRAFT IN THE PRESENCE OF A RESIDUAL ANGULAR MOMENTUM

Abstract

In recent years there has been an increasing interest for tackling the problem of attitude control when the spacecraft is in underactuated conditions, that is, only two control torque components are available. This condition is representative of a failed attitude control system, when only two attitude effectors remain active, or an attitude control system based on the use of magnetic coils only is considered.

When the problem of aiming a body-fixed axis (e.g. a sensor boresight or a nozzle) towards a prescribed direction in the orbit or in the inertial frame by means of a set of two reaction wheels is considered, the feasibility of the maneuver was demonstrated for an arbitrary direction only when the overall angular momentum of the spacecraft (platform and spinwheels) is zero. Conversely, only some inertial directions can be reached by the body-fixed axis, with zero residual angular speed for the spacecraft platform, when a residual angular momentum is present. The possibility of performing the maneuver, when feasible, was demonstrated in a recent paper.

The present paper aims at investigating pointing strategies when the prescribed pointing cannot be reached exactly with zero residual angular rate. Three scenarios are considered. The minimum pointing error in the framework of admissible directions with zero residual angular speed is identified first. In the most general case, such a strategy may results into unacceptably large pointing errors, so that in the second scenario, conditions for exact pointing with non-zero residual angular rate are searched.

Since exact pointing requires that the residual angular rate is constrained around the body-fixed axis to be pointed, a wheel angular rate command is derived which enforces this condition. However, when wheel saturation limits are exceeded, this spin condition is not achievable anymore. Moreover, when the residual angular momentum is high, this strategy may result into a significant angular rate around the pointed axis, which may compromise sensor operations. Therefore, a third scenario is envisaged, which is represented by the analysis of a tradeoff between pointing accuracy and residual angular rate around the pointed axis and in the transverse direction.

For the three considered situations, a control law for wheel command torques is proposed, which drives the spacecraft towards the desired pointing condition. The control approach is demonstrated by means of numerical simulation. Pointing performance in terms of pointing error and residual angular rate are determined in a representative operative scenario of a small-scale spacecraft.