SINGLE-AXIS POINTING OF UNDERACTUATED SPACECRAFT WITH RESIDUAL ANGULAR MOMENTUM

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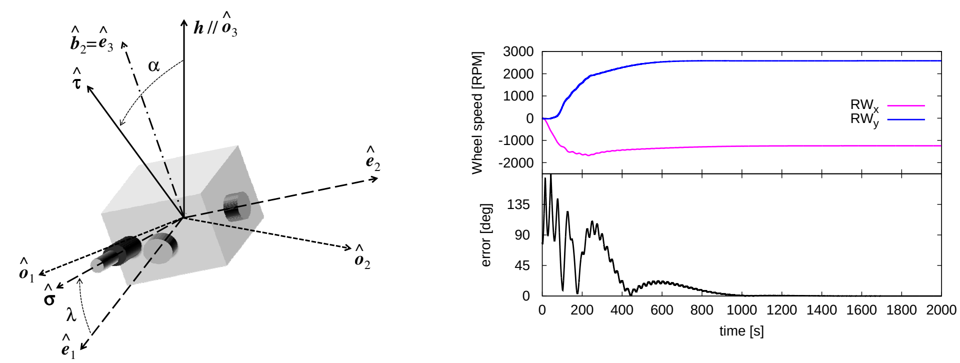
The paper deals with the single-axis pointing maneuver for an underactuated spacecraft equipped with only two reaction wheels (RW) in the presence of a (possibly large) non-zero residual angular momentum vector, $\mathbf{h}$. In this scenario, a body-fixed axis $\hat{\sigma}$, such as the line-of-sight of a sensor, a nozzle for orbit control or an antenna, needs to be aligned to a target direction $\hat{\tau}$, fixed in the inertial reference frame. This situation is representative of failure of a non-redundant control system, as low-budget space missions based on small-size low-cost spacecraft (nano-, pico-, and cube-sat families) usually are. Among the broad literature on attitude control of an underactuated spacecraft, spin-stabilization of symmetrical spacecraft has been considered first [1]. More recently, techniques for 3-axis partial attitude stabilization of either axis-symmetric or three-inertial satellites have been developed, [2, 3], where a principal axis of inertia is usually chosen as body-fixed axis to be pointed towards a prescribed inertially-fixed direction. In most cases, zero total angular momentum is assumed. This is a major assumption when dealing with momentum-exchange devices, as it allows all attitudes to be reachable when the spacecraft is at rest.

The present study aims at extending these results, removing the hypothesis of zero angular momentum, and also dealing with the case where an arbitrary body-fixed axis (that is, different from a principal axis of inertia) needs to be aligned with a fixed inertial direction. Under these circumstances, only a subset of attitudes is reachable, when the spacecraft is at rest. Feasibility of the pointing maneuver is assessed first, proving geometrically that the desired alignment of $\hat{\sigma}$ with $\hat{\tau}$ is possible only if the absolute value of the elevation α of the target direction $\hat{\tau}$ above the plane perpendicular to $\mathbf{h}$ is smaller than the angle λ between the underactuated direction $\mathbf{b}$ and $\hat{\sigma}$ [Fig. 1(a)]. A nonlinear controller to asymptotically stabilize the system about the chosen target attitude is designed by exploiting the cascade (triangular) nature of system dynamics and a 3-1-3 Euler-angle parametrization of spacecraft attitude. Magnitude of the total angular momentum can be large, but smaller than the angular momentum stored in a single reaction wheel at rate saturation. The effectiveness of the proposed control law is verified by means of numerical simulation. Several results are presented for both a 320 kg mini-satellite used as a reference spacecraft in [4] and a nano-satellite. As an example, the evolution of pointing error and RW speed during a maneuver are shown in [Fig. 1(b)].



(a) (b)

Figure 1. a) Geometry of the problem; b) Pointing error during an alignment maneuver.

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