Autonomous Vehicle Simulation (AVS) Laboratory,
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Basilisk Technical Memorandum

MOMENTUM MANAGEMENT

Rev	Change Description	By	Date
1.0	Reaction wheel momentum management via magnetic torque rods.	H. Macanas	2021/07/03

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1 Introduction

This document presents the underlying mathematics utilized in the development of the reaction wheel momentum management and torque rod dipole command generation algorithms. It's important to point out that these algorithms are developed with the target of dumping the net momentum of the reaction wheels. This does not necessarily mean driving the individual reaction wheel speeds to zero since the wheels can be spun up in their null space, if it exists, and still have a net momentum of zero. Additionally, saturating the dipole commands described in the mathematics below may result in an imperfect projection of the desired torque to be produced by the rods into the plane orthogonal to the local magnetic field, though it has been observed in simulation that this is not an issue.

2 Reaction Wheel Momentum Management Mathematics

2.1 Wheel Momentum to Torque

Assume the spacecraft contains N_{RW} RWs. The net RW angular momentum is given by

$$ {}^{B}\boldsymbol{h}_{wheels} = \sum_{i=1}^{N_{\text{RW}}} \hat{\boldsymbol{g}}_{s_i} J_{s_i} \Omega_i \tag{1} $$

where $\hat{\boldsymbol{g}}_{s_i}$ is the RW spin axis in the Body frame B, J_{s_i} is the spin axis RW inertia and Ω_i is the RW speed rate about this axis. The desired torque to be produced by the torque rods to drive the wheel momentum to zero is then given by the proportional control law

$$ {}^{B}\boldsymbol{\tau}_{desired} = -K_p * {}^{B}\boldsymbol{h}_{wheels} \tag{2} $$

where K_p is the proportional feedback gain with units of $1/s$.

2.2 Torque to Dipole

The desired body frame dipole to be produced by the torque rods is given by

$$ {}^{B}\boldsymbol{\mu}_{desired} = \frac{1}{|\boldsymbol{b}|^2} {}^{B}\boldsymbol{b} \times {}^{B}\boldsymbol{\tau}_{desired} = [Gt]\boldsymbol{\mu}_{cmd} \tag{3} $$

where $\boldsymbol{b}$ is the local magnetic field vector and $[Gt]$ is a $3 \times N_{\text{MTB}}$ matrix that transforms the individual rod dipoles to the Body frame.

2.3 Dipole Mapping and Saturation

The individual rod dipoles are then given by

$$\boldsymbol{\mu}_{cmd} = [Gt]^{\dagger\, B}\boldsymbol{\mu}_{desired} \tag{4}$$

where the † symbol denotes the psuedoinverse. The dipole commands may need to be saturated at this point. The saturated commands are referred to as $\boldsymbol{\mu}_{saturated}$ from here on out in this document.

2.4 Feed Forward Torque

The expected torque produced by the torque rods is given by

$${}^{B}\boldsymbol{\tau}_{rods} = [Gt]\boldsymbol{\mu}_{saturated} \times {}^{B}\boldsymbol{b} \tag{5}$$

and the feed forward command used to dump the momentum of the reaction wheels is simply the negation of the expected torque produced by the rods.

$${}^{B}\boldsymbol{\tau}_{ff} = -\,{}^{B}\boldsymbol{\tau}_{rods} \tag{6}$$