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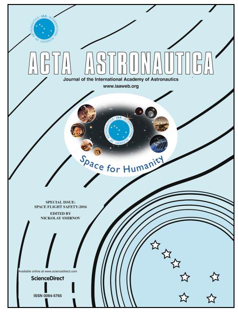

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TORQUE DISTRIBUTION ALGORITHM FOR EFFECTIVE USE OF REACTION WHEEL TORQUES AND ANGULAR MOMENTUMS

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Abstract

In attitude control of spacecraft using more than three reaction wheels, the distribution of the attitude control torque to the wheels is not unique because of the redundancy. There are several wheel torque distribution algorithms which optimize the wheel torques or other factors. In particular, the optimal torque distribution algorithm is acknowledged as algorithm which minimizes the maximum wheel torque. This algorithm is advantageous to make maximum use of the wheel torques, because each wheel torque must be lower than the wheel torque capability and torque is the primary driver in many cases. However, as a result of minimizing the maximum wheel torque, the distribution of the wheel angular momentums is not calculated by a similar formula for the wheel torques distribution. In other words, the wheel angular momentums cannot be derived from the current attitude angular momentum. When certain wheel reaches maximum angular momentum earlier than the other wheels, this prohibits maximum use of the other wheels' capability. Therefore, minimizing the maximum wheel torque is not always effective when other constraint such as angular momentum matters.

Recently, it has become more important that both wheel torques and angular momentums are used more effectively in order to improve the performance of the spacecraft agility, such as the high angular acceleration and rate, by using minimum spacecraft resources (i.e. minimum number of wheels which satisfies certain agility requirements). In this paper, shown is the wheel torque distribution algorithm which is effective in terms of both the wheel torques and angular momentums as much as possible. In the proposed algorithm, the wheel torques/angular momentums distributed from the current attitude torque/angular momentum can be optimal for particular direction like the spacecraft X/Y/Z axis. In addition, it is shown by numerical simulation that the proposed algorithm improves the usage of attitude control angular momentum by up to 60 percent compared to the optimal torque distribution algorithm.

Keywords: (Torque Distribution, Wheel Angular Momentum, Wheel Torque, Minimum Spacecraft Resources)

Nomenclature

$A_{w\to 3}$: Transform matrix (wheels to X/Y/Z axis)
$A_{3\to w}$: Transform matrix (X/Y/Z axis to wheels)
$\mathbf{e}_x$: X axis unit vector $\left(=[1\quad 0\quad 0]^T\right)$
$\mathbf{e}_y$: Y axis unit vector $\left(=[0\quad 1\quad 0]^T\right)$
$\mathbf{e}_z$: Z axis unit vector $\left(=[0\quad 0\quad 1]^T\right)$
$f_*(\boldsymbol{\tau}, A_{w\to 3})$: Arbitrary function which transforms $\boldsymbol{\tau}$ and $A_{w\to 3}$ into $\boldsymbol{\tau}_w$ ($*$ is arbitrary symbol.)
$\mathbf{h}$: X/Y/Z axis angular momentum (3×1)
$\mathbf{h}_w$: Wheel angular momentums $(N\times 1)$
I_m : $m\times m$ unit matrix
N : Number of wheels $(N>3)$
t : Time
$\boldsymbol{\tau}$: X/Y/Z axis torque (3×1)
$\boldsymbol{\tau}_w$: Wheel torques $(N\times 1)$
τ_{wi} : Wheel #i torque

1. Introduction

For the attitude control of spacecraft using more than three reaction wheels (RW's), some wheel torque distribution algorithms have been studied. Because of the redundancy (a number of RW's is larger than three), the wheel torque distribution algorithm is not unique. Therefore, several wheel torque distribution algorithms have been used, and some algorithms are optimized in terms of the wheel torques or the other factors [1, 2, 3 ,5].

In some algorithms, the wheel torque distribution is given by multiplying a constant matrix (distribution matrix) to the control torque (X/Y/Z axis torque). The pseudo inverse matrix of $A_{w\to 3}$ (transform matrix from wheel torques to X/Y/Z torque) is usually used for obtaining the distribution matrix [1, 5]. This method, which is called the pseudo inverse distribution algorithm in this paper, is optimized in terms of the norm of wheel torques. Because the magnitudes of the distributed wheel torques vary, when one of the wheels reaches maximum torque earlier than the other wheels, this limits maximum use of the other wheels' torque capacity.