Autonomous Vehicle Simulation (AVS) Laboratory, University of Colorado

Basilisk Technical Memorandum
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REACTION WHEEL MOTOR TORQUE

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Status: Tested
Scope/Contents
This module takes a desired torque vector and maps it to available reaction wheel torques.

Rev:	Change Description	By
v1.0	Initial Document	J. Martin

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1 Model Description

The module takes a torque vector in the body frame [3 x 1] and maps the vector onto the available control axes, $\{\hat{c}\}$, [n x (3x1)], and then projects the mapped torque onto the available reaction wheel axes, $\{\hat{g_{s_j}}\}$ [m x (3x1)]. The module accounts for the availability of the reaction wheels in the case that not all wheels are functioning appropriately or need independent analysis.

1.1 Torque Mapping

The rwMotorTorque module is provided a desired torque in the body frame $^{\mathcal{B}}L_r$ which first needs to be mapped onto the n control axes $\{\hat{c}\}$ using the mapping matrix $[CB]$ (dimensions $n \times 3$).

$$^{\mathcal{C}}L_r = [CB]^{\mathcal{B}}L_r \tag{1}$$

The module then determines the DCM between the control axes and the wheel axes, which requires the module to first identify which of the RW are available to generate the g_s vectrix [m x (3x1)] . From the $^{\mathcal{B}}g_s$ vectrix, we can compute the mapping matrix [n x m] between the control axes and the wheel axes.

$$[CG_{ij}] = \{\hat{c}_i\} * \{\hat{g_{s_j}}\} \tag{2}$$

This formulation allows for us to map torques onto an overdetermined system using a least squares optimization.

$$^{\mathcal{G}}L_r = [CG]^T \left([CG][CG]^T\right)^{-1} * {}^{\mathcal{C}}L_r \tag{3}$$

1.2 RW Availability

If the input message name `rwAvailInMsgName` is defined, then the RW availability message is read in. The torque mapping is only performed if the individual RW availability setting is `AVAILABLE`. If it is `UNAVAILABLE` then the output torque is set to zero.

2 Model Functions

The code performs the following functions:

- **Accepts**: `RWArrayConfigFswMsg`, `CmdTorqueBodyIntMsg`, and (optional) `RWAvailabilityFswMsg`.

- **Maps torque vector onto reaction wheels**: Takes a desired body-frame torque from `CmdTorqueBodyIntMsg` and maps it onto the RW axes.

- **Removes torque from unavailable reaction wheels**: The module observes the availability of the RWs and maps the torques to only available reaction wheels.

3 Model Assumptions and Limitations

This code makes the following assumptions:

- There must be equal or more wheels then control axes for successful mapping. If not, no torque is applied.

4 Test Description and Success Criteria

The unit test checks for proper functionality of the module for various numbers of control axes and reaction wheel configurations, both within and outside expected bounds. The two test cases run include:

1. Standard 3-axis control basis, with four available reaction wheels.

2. 2-axis control basis (dropped axis), with four available reaction wheels.

5 Test Parameters

The unit test verify that the module's output reaction control torques match expectation.

Table 2: Error tolerance for each test.

Output Value Tested	Tolerated Error
`rwMotorTorques`	1e-08

6 Test Results

The unit test results are shown in Table 3. All tests should be passing.

Table 3: Test results

Num Axes	Num RW	Pass/Fail
3	4	Failed
2	4	PASSED

7 User Guide

Input required:

- `rwMotorTorqueConfigData.controlAxes_B`: Set the control axes into a single array.

- `rwMotorTorqueConfigData.numControlAxes`: Assigns the number of control axes.

- `rwMotorTorqueConfigData.numAvailRW`: Number of available reaction wheels.

- `rwMotorTorqueConfigData.rwConfigFswMsg`: Message with information on RW configuration data.

- `rwMotorTorqueConfigData.GsMatrix_B`: Axes of the RWs.

- `rwMotorTorqueConfigData.CGs`: The RW axes in the control axis frame.

- `rwMotorTorqueConfigData.outputDataName`: Name for the `RWArrayTorqueIntMsg` which contains RW torque information.

- `rwMotorTorqueConfigData.inputVehControlName`: Name for the `CmdTorqueBodyIntMsg` which contains the original required torque vector .

- `rwMotorTorqueConfigData.rwParamsInMsgName`: Name for the `RWArrayConfigFswMsg` which contains information on RW spin axes, inertias, and motor torque limits.

- `rwMotorTorqueConfigData.rwAvailInMsgName`: Name for the `RWAvailabilityFwsMsg` which contains information on which RW can be used to apply the desired torque.

- `rwMotorTorqueConfigData.rwMotorTorques`: Name for the `RWArrayTorqueIntMsg` which stores the RW motor torques.