Introduction

• University at Buffalo Nanosatellite Lab is part of Air Force Research Labs (AFRL) and NASA cubesat programs

• Glint Analyzing Data Observation Satellite (GLADOS) is an Space Situational Awareness mission that seeks to gather glint data on space debris

Test Setup and Outline

• Tracking objects in GEO from LEO requires fine attitude control
  • Reaction wheels provide this control
  • Seek to characterize the torque of GLADOS’s Maryland Aerospace (MAI) 101 reaction wheels to validate torque resolution requirements
  • Particularly interested in low torques for tracking maneuvers

Test Setup

• Command a torque to reaction wheels
• Utilize Pixy Camera to track position of colored mark with respect to time
• Use Arduino Uno and laptop to capture x and y position data of marker in Pixy camera frame

Table 1: Test Outline

<table>
<thead>
<tr>
<th>Step #</th>
<th>Step Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Place MAI 101 reaction wheels on spin table and command torque to the wheels</td>
</tr>
<tr>
<td>2</td>
<td>Use a Pixy Camera to track the angular position of the table with respect to time</td>
</tr>
<tr>
<td>3</td>
<td>Use the position data ($\theta_0$) to obtain angular acceleration ($\alpha_0$) of the table</td>
</tr>
<tr>
<td>4</td>
<td>Use acceleration along with inertia to obtain torque output by the wheels ($T_{SW}$)</td>
</tr>
<tr>
<td>5</td>
<td>Compare measured torque to commanded torque to obtain torque accuracy ($\frac{T_{SW}}{T_{CM}}$)</td>
</tr>
</tbody>
</table>

Methodology

1. Calibration

• To obtain angular position data, relative center of x and y coordinates must be found
• Marker is tracked through a full rotation so maximum and minimum coordinates are obtained

2. Inertia Determination

• Formula to obtain torque is $T_{CM} = I_\alpha_{max}$ therefore inertia must be determined

3. Torque Verification

• Torque commanded to wheels, and angular position data of marker obtained
• Assuming constant acceleration, $\alpha = \frac{1}{2} \omega t^2 + \omega_0 t$
• Table at rest, $\omega_0 = 0$
• Coefficient of squared term in polynomial fit is used to calculate angular acceleration

Example Trial

• Torque of 0.635 mN·m commanded to wheels and angular position data obtained

Results

• For purposes of presentation, $R^2$ from curve fit (Excel generated) will be used to assess accuracy of test setup
• Indicates on scale from 0 to 1 how well angular position data can be fit to second order curve to determine angular acceleration

Table 2: Torque Trial Results

<table>
<thead>
<tr>
<th>Trial</th>
<th>$\alpha$ commanded (rad/s^2)</th>
<th>$\alpha$ measured (rad/s^2)</th>
<th>$%$ difference</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.191</td>
<td>0.169</td>
<td>88.7</td>
<td>0.999</td>
</tr>
<tr>
<td>2</td>
<td>0.254</td>
<td>0.254</td>
<td>79.3</td>
<td>0.999</td>
</tr>
<tr>
<td>3</td>
<td>0.358</td>
<td>0.36</td>
<td>113.5</td>
<td>0.972</td>
</tr>
<tr>
<td>4</td>
<td>0.381</td>
<td>0.384</td>
<td>99.6</td>
<td>0.985</td>
</tr>
<tr>
<td>5</td>
<td>0.445</td>
<td>0.454</td>
<td>101.3</td>
<td>0.985</td>
</tr>
<tr>
<td>6</td>
<td>0.506</td>
<td>0.517</td>
<td>101.7</td>
<td>0.984</td>
</tr>
<tr>
<td>7</td>
<td>0.572</td>
<td>0.522</td>
<td>91.4</td>
<td>0.994</td>
</tr>
</tbody>
</table>

• $R^2$ values are high even for trials in which torque percentage is low
• Indicates setup can accurately obtain angular acceleration

Conclusions

• Current methods require expensive force tables or extensive motor characterization and data acquisition. This method requires minimal hardware development [2,4]
• Minimal software development
• Potential for increase in data fidelity over wheel-speed testing
  • Tachometry methods require detailed knowledge of wheels’ inertia, error-prone assumptions, or measurements that are difficult with packaging [5]
  • Spin table setup affords easier inertia characterization when calculating torque
• Cost is high priority for Cubesat programs and all Aerospace industry partners

Future Improvements

• Improve frictionless assumption
• Experimental method of inertia determination
• Precise timestamping of commands
• Characterize error inherent in Pixy

References