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Opinion

Designing a Low-Cost Space Simulator

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OPINION

Future commercial and military spacecraft are expected to achieve new levels of autonomy and pointing precision, thanks to improved on-board computing speed and memory capacity. These on-board capabilities are critical for the difficult tasks of envisioned future space missions, such as extremely large base interferometry, space optical telescope deployment, formation flying, and autonomous spacecraft docking and maintenance. Numerous spacecraft control systems have been developed in recent years to handle the difficult attitude tracking, stability, and disturbance rejection needs of these missions.

Experimental confirmation of existing theoretical conclusions is a significant component that has generally been lacking in the field of satellite attitude control development. Before any innovative control rules can be included into future-generation spacecraft, they must first be tested experimentally. The most challenging aspect of establishing spaceship control rules is that ground-based tests must be carried out in a 1-g environment, but the real spacecraft will operate in a 0-g environment. With the recent expansion of the commercial and military satellite industries, there is a greater need for rapid prototyping and testing of the most promising attitude control algorithms proposed in the literature. Several nongovernmental organisations and academic institutions have lately begun the creation and building of realistic simulators that will be used to train the next generation of spacecraft dynamics and control engineers. To replicate a torque-free environment, the platform must be precisely balanced. When the platform's centre of rotation aligns with its centre of gravity, perfect balance is achieved. To do this, an identification method was created to estimate the moment of inertia matrix and the platform's centre of gravity. This technique may also be used to calculate the inertia matrix, which can then be utilised in attitude tracking and indirect adaptive control systems. The GIT spacecraft simulator's "bus" is a disk-shaped metal platform with a diameter of 60.96 cm (1.90 cm) and is supported by a hemispherical air bearing. The platform holds all of the spacecraft's different components (i.e., sensors, actuators, control computer). The air bearing is powered by compressed air from an external source, which is routed via an air filter. The air filter eliminates moisture, oil, and other pollutants while also regulating the air pressure (approximately 170-270 KPa depending on the typical load). Under the platform are three wheels that may be operated in momentum or reaction wheel (RW) mode. Each wheel is connected to a dc motor and amplifier. Angular position feedback is provided via encoders mounted on dc motors. Six 12-volt batteries are linked in series pairwise to produce 24 V at a time for the complete system.

The spacecraft simulator's primary aim is to test various feedbacks attitude control rules. Measurements for the Eulerian angles and angular speeds are necessary to implement the different controllers. Crossbow, Inc.'s dynamic measurement unit (DMU-AHRS) was chosen as the attitude sensor unit. The Eulerian angles, angular rates, and linear acceleration are all provided by the DMU-AHRS. It can measure roll and pitch angles of 90 degrees, as well as heading angles of 180 degrees. In the Eulerian angle measurement signal, the root mean square (RMS) noise level is 0.1°. The angular rate range is 150 degrees per second, and the RMS noise level is 0.05 degrees per second.

The accelerometer has a range of 2 g and an RMS noise of 0.002 g. In our situation, the accelerometer outputs were not utilised. The analogue transmission has higher sampling rates, but the RS-232 connection transmits digital data straight without adding noise. The signals from the digital output were chosen for convenience after considering the criteria for noise-free operation. Separate software programmes were created for the CMP5e on-board computer and the remote PC computer. The latter is used to send start/stop orders as well as commands for health monitoring, data processing, and graphing after an experiment. The control toolbar, monitor view, message view, and other GUIs are implemented on the remote PC via separate view-based graphical user interface (GUI) software. The applications on the distant PC and the on-board computer communicate via four types of custom-developed packets: data, message, file, and command packets, over the wireless RS-232 serial connection. The static motor gain may be determined using the motor specs, D/A converter settings, and motor amplifier gain. The motor transfer function was identified using a least-squares fit. At 0.48 Nm/V, the motor's gain is about 0.48 Nm/V. At zero frequency, the frequency drops, while at higher frequencies, the frequency increases.

The motor bandwidth is fairly large, as illustrated in this picture and the advantage does not vary significantly up to about ten rad/s. This frequency is high enough as compared to the rigid-body reaction of a spacecraft. The Georgia Institute of Technology

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School of Aerospace Engineering has planned and built a spaceship simulator facility. The simulator will primarily be used to teach undergraduate students about spacecraft attitude dynamics and control. Several technical problems were faced throughout its creation, including the selection of motors, wheel size, and sensor range and resolution.