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A NOVEL HIGH-PERFORMANCE NANOSATELLITE ATTITUDE AND RATE SENSOR

Abstract

With the maturity of the CubeSat industry and advancements in commercial off-the-shelf components, CubeSat-based projects have become an attractive option for advanced outer space missions. This increase in mission complexity has given rise to the necessity of a new generation of accurate attitude determination subsystems.

The development and testing of low-cost, attitude determination sensors, however, come with an array of difficulties. Low-cost sensor technologies sacrifice overall sensitivity for simpler design and calibration methods, whilst more accurate sensors are difficult to test. An example of such a sensor used for fine pointing is a star tracker. Star trackers offer high accuracy attitude determination but can only be tested under specific atmospheric conditions. Traditional star trackers also have high power requirements and can only function at low slew rates. Therefore, to ensure full system observability, extra sensors are required. This increases mission complexity and cost, whilst decreasing useable real estate for the main mission payload.

The purpose of this work, therefore, entails the design and development of an augmented stellar sensor. This sensor delivers accurate attitude and rate estimates at a fast update frequency, whilst conforming to the small satellite power and size requirements. The sensor uses inertial rate sensor data, with error compensation performed by use of matched vector measurements obtained from a star sensor. Sensor measurements are combined in an Extended Kalman filter, providing both high rate attitude propagation and bias drift compensation. The sensor features a robust tracking mode as well as a stellar gyro algorithm to deliver accurate low-rate rate estimates independent of host dynamics.

To prove overall system functionality, the sensor has undergone extensive tests in an in-house developed star emulation environment. During these tests it was exposed to conditions typically experienced by satellites throughout their mission lifetimes. These conditions range from tumbling, to fine pointing. To ensure a consistent sensor response, the effect of false identities in the field of view were investigated as well as sensor performance whilst measurement updates were unavailable. As a final proof of concept, actual night-time tests were performed to serve as both a comparison for the emulation environment results, and a demonstration of actual sensor functionality.

Initial testing show that this sensor offers a robust response regardless of satellite spin rate and orientation whilst simultaneously adhering to CubeSat standards. Results show that the average 3σ rate accuracies were 0.01 deg/s whilst the 3σ orientation accuracy was around 0.016 deg.