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ATTITUDE DETERMINATION USING A SYSTEM OF SENSORS AND UKF FOR A SOLAR SAILING NANOSATELLITE

Abstract

CSAT is a team of undergraduate students from College of Engineering Pune working on a solar sailing nano-satellite "COEPSAT-2". The team seeks to achieve optimal increase in the satellite's semi-major axis by controlling the orientation of its solar sail. For this, the satellite must have a highly accurate control system, and in turn, an accurate attitude determination system. This paper presents techniques adopted in the attitude determination system of the satellite for achieving this goal. The system consists of a 3-axis magnetometer and a sun sensor for determining attitude, and a 3-axis gyroscope for angular velocity. The system's software component employs the TRIAD algorithm in conjugation with a Kalman Filter. For cost efficiency, and to account for the presence of the solar sail, we have designed an in-house sun sensor which uses multiple planar photodiodes with trans-impedance amplifiers and ADCs. In the paper, we describe the design of the sun sensor circuitry along with the placement of photodiodes on the satellite body. Additionally, we present the noise analysis of our sensors. While the Kalman filter negates sensor noise, it is unable to nullify the effect of the earth's albedo radiations. We thus incorporate a model of albedo radiations, and modify the inputs to TRIAD to obtain an error-free quaternion, which is then passed to the kalman filter. Owing to our requirement for accuracy, the presence of errors in sensor readings, and the fact that sun sensor readings will not be available in the eclipse region of the satellite's orbit, our system uses an Unscented Kalman Filter for attitude estimation. The filter state consists of the 4 component quaternion and 3 axis angular velocity. The filter uses Runge-Kutta 4 as a propagator in its prediction step. We describe the design and implementation of the filter, and the techniques that we used for tuning filter parameters. We also describe the mechanism by means of which we handle the

absence of sun sensor readings during a part of the orbit. Finally, we present simulation results which indicate the filter's stability and indicate its convergence to accurate values. The in-house simulation that we have built for validating our determination algorithm is modular and is designed for being directly portable to the satellite's onboard computer. In summary, the paper describes a low-cost, modular and accurate attitude determination system built specifically for use in a solar sailing nanosatellite.