THE EXTENDED H_∞ FILTER FOR CALIBRATION AND ATTITUDE DETERMINATION USING REAL DATA OF CBERS-2 SATELLITE

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ABSTRACT

This work describes the attitude determination and the gyros drift estimation using the Extended H_∞ Filter and the Extended Kalman Filter for nonlinear systems. Such filter uses the Taylor series to approximate the non-linearity of the known dynamics and assumes that the noise sources have approximately known statistical properties. The application uses measurement data of a real satellite CBERS-2 (China Brazil Earth Resources Satellite 2) which has polar sun-synchronous orbit with an altitude of 778km, crossing Equator at 10:30am in descending direction, frozen eccentricity and perigee at 90 degrees, and provides global coverage of the world every 26 days.

The attitude dynamical model is described by nonlinear equations involving the Euler angles. The attitude sensors available are two DSS (Digital Sun Sensors), two IRES (Infra-Red Earth Sensor), and one triad of mechanical gyros. The two IRES give direct measurements of roll and pitch angles with a certain level of error. The two DSS are mounted on the satellite body such that they are nonlinear functions of roll, pitch, and yaw attitude angles. The gyros are aligned in the 3 satellite axes and furnish the angular measurements in the body frame reference system.

Gyros are very important sensors, as they provide direct incremental angles or angular velocities. They can sense instantaneous variations of nominal velocities. Therefore, an important feature is that it allows the replacement of complex models (several different torques acting on the space environment) by using their measurements to turn the dynamical equations into simple kinematic equations. However gyros present several sources of error of which the drift is the most troublesome. Such drifts yield along time an accumulation of errors which must thus be accounted for in the attitude determination process.

There are many real time processing algorithms and in general conventional nonlinear filters are used for attitude determination, but herein one proposes to use an extension of the H_∞ linear filter and the Extended Kalman Filter for the nonlinear case of attitude estimation with non-linearity in both the dynamics and the measurement model. The aim is to highlight and magnify the

properties of the H_∞ filter in terms of its favourable characteristics. In the Kalman filtering, with the probability density function of the noises given, we can use that knowledge to obtain a statistically optimal state estimation. In the H_∞ filter the nature (dynamics and noises) is assumed to be perverse and actively seeks to degrade our state estimate as much as possible, but the H_∞ filter deals with it aiming ultimately at robustness.

Actually, the so named extended H_∞ filter provides a rigorous method for dealing with systems that have model and noise uncertainties. Thus, extended H_∞ filter is simply a robust version of the extended Kalman filter because it adds endurance to unmodeled noise and dynamics. The derivation and customization of the filter to this specific application (attitude determination) are described together with details of implementation. Besides, one preferred to use real measured DSS, IRES, and gyro data to assess the procedure in a real application.

Comparison between the results of conventional and H_∞ filter show that one can reach consistent accuracies in satellite attitude determination within the prescribed requirements and some additional computational effort, besides providing estimates of the gyro drifts which can be further used to enhance the gyro error model.