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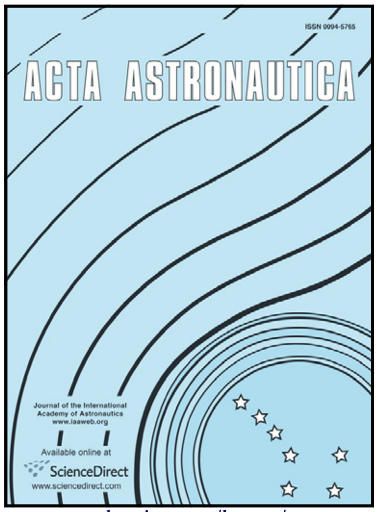

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A Novel Unscented Predictive Filter for Relative Position and Attitude Estimation of Satellite Formation

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Abstract: This paper presents a novel sigma-point unscented predictive filter (UPF) for relative position and attitude estimation of satellite formation taking into account the influence of $\boldsymbol{J}_2$. A coupled relative translational dynamics model is formulated to represent orbital motion of arbitrary feature points on the deputy spacecraft, and the relative attitude motion is formulated by considering a rotational dynamics for a satellite without gyros. Based on the proposed coupled dynamic model, the UPF is developed based on unscented transformation technique, extending the capability of a traditional predictive filter (PF). The algorithm flow of the UPF is described first. Then it is demonstrated that the estimation accuracy of the model error and system state for UPF is higher than that of the traditional PF. In addition, the unscented Kalman filter (UKF) is also employed in order to compare the performance of the proposed UPF with that of the UKF. Several different scenarios are simulated to validate the effectiveness of the coupled dynamics model and the performance of the proposed UPF. Through comparisons, the proposed UPF is shown to yield highly accurate estimation of relative position and attitude during satellite formation flying.

Keywords: Satellite formation; Unscented Predictive Filter; Coupled dynamics; Relative position and attitude; Estimation

1. Introduction

There is a growing interest recently to replace a large satellite with multiple small satellites in a formation to achieve specific mission objectives [1-4], due to the fact that a satellite formation is endowed with various advantages compared with a single satellite [5-7]. These advantages make satellite formation flying (SFF) an ideal tool for astronomical observations, communications, meteorology and environmental observations. Many space agencies have shown keen interest in formation flying strategies and various space missions have been proposed [8-14]. All of these space missions rely on precise relative position and attitude knowledge to achieve mission objectives; therefore, relative navigation models [15] and excellent filter technology are important for future applications of formation flying in space exploration.

The Hill's equation [16] and the Clohessy-Wiltshire (C-W) equations [17] are the most common tools to formulate the relative translational motion. Subsequently, variants on these

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