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AUTONOMOUS SPACE-BASED SHAPE ESTIMATION USING RANGE SENSORS

Abstract

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Purpose: Spacecraft autonomy is an active area of research and development. Autonomous satellite systems require intelligence and decision making, including intelligent sensing, data collection and processing, collision avoidance and control. More specifically, there is a particular need to advance the state-of-the-art in autonomous Guidance, Navigation, and Control (GNC) technology in support of space-based Space Situational Awareness (SSA), and orbital debris removal missions. In these missions, an autonomous inspector spacecraft need to be able to detect, recognize, classify and track resident space objects (RSOs) of interest, including their location, size and shape. A critical and challenging question for such missions is the identification and characterization of the RSO being inspected via estimation of the object's shape. Typically, a combination of vision-based, lidar and radar is used to characterize the object. However, of interest in this work is the case when vision-based camera's performance is degraded due to poor lighting conditions. In that case, one would have to use lidar and/or radar for shape estimation. Lidar and radar sensors have the added benefit of providing range data.

Methodology: In this paper, we develop a random finite set (RFS) estimation approach for the joint tracking and characterization of an RSO's shape using high-resolution lidar and/or radar sensors that give multiple detections per RSO. The RFS approach is a rigorous Bayesian framework and has been used extensively in the last decade in autonomous car and robotic applications. It is a powerful approach for the estimation of extended objects, i.e., objects that result in multiple detections on the sensor. We will develop an estimation scheme for the reconstruction of the shape of the RSO. The estimation approach naturally generates a shape estimate performance metric that quantifies an RFS-based expected shape estimate error metric. This estimation performance metric can then be used to develop an optimized closed-loop guidance law to govern the motion of the inspection spacecraft around the RSO.

Results and Conclusions: The capabilities of the proposed approached will be illustrated on several simple yet insightful real-life satellite shape estimation examples with laser range data containing several occlusions. We will demonstrate our results in extensive MATLAB simulations, where we will study the effect of RSO size and shape complexity, and laser range measurement quality on the performance of the closed-loop guidance and navigation laws.