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A SPACE-BASED OPTICAL RAPID CELESTIAL POSITIONING METHOD FOR SPACE DEBRIS ORBIT DETERMINATION

Abstract

Millions of space debris pose a severe threat to orbiting spacecraft, making space debris surveillance an urgent necessity, in which rapid and accurate celestial positioning is crucial. Conventional celestial positioning methods typically rely on extensive star identification, resulting in high computational costs. However, onboard computing resources are limited, necessitating the transmission of large volumes of image data to the ground for processing. This consequently leads to another challenge: the high costs of data transmission and computation, which makes the real-time space debris surveillance mission impractical. To solve the problem, a space-based optical rapid celestial positioning method for orbit determination is proposed, allowing low-cost, efficient, and accurate space debris monitoring to be performed directly on satellites. The algorithm consists of three steps. First, attitude determination is performed by extracting bright stars from a short-exposure frame and applying the K-vector method for rapid angular distance matching. Second, regional star identification is conducted by combining a long-exposure frame with known satellite attitude information. Precise dim star matching is performed within a localized celestial region based on the angular distance matching score transfer method, reducing the number of matched star pairs and thereby decreasing computational costs and redundant matches. Finally, celestial positioning is completed based on the identified stars. A sequence of positioning results is fitted using a least-squares method with a quasi-relative orbital motion polynomial parameter model, improving positioning accuracy and enabling space-based autonomous generation of observation tracklet, thus providing essential data for space debris orbit determination. Simulation tests and ground-based optical star image experiments demonstrate the efficiency and accuracy of this method.