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Star tracking and attitude determination using fuzzy based positional pattern and rotation compensation in Fourier domain

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Abstract In this article, a new approach is proposed for star tracking and attitude determination. To track stars and determine the attitude of the camera, a new star pattern matching algorithm is presented. The proposed star matching algorithm is a two-stage approach. In the first stage, all stars in the Field of View of the bright star are employed to construct the star pattern for matching. To handle the problem of missing stars and the inaccuracy of stars' position, fuzzy based positional information is employed to construct the pattern. To compensate for in-plane rotation of the camera, a circular grid is used, which converts in-plane rotation of the camera into the angular shift in the polar coordinate. Then, the Fourier transformation and its attributes are applied to discard the shift or the rotation effect. In the second stage of the algorithm, the angular distances between the bright stars are employed to refine the candidate matches of the first stage. We use SKY2000 master star catalog to create the database and test the proposed algorithm. The comparison of the results of the proposed algorithm with those of other methods shows the efficiency of the proposed algorithm.

Keywords Star tracking · Attitude determination · Star pattern · Circular grid

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1 Introduction

Star trackers are widely used systems in many space-based applications and satellites. Star tracking algorithms determine the attitude of the satellite or spaceship by matching the stars of the satellite camera with the stars in the catalog. Although other sensors like GPS, sun tracker and magnetometer may be used for attitude determination, star trackers have the advantage of producing a higher accuracy as well as the capability of attitude determination without prior information, which is known as the lost-in-space capability.

A star tracker algorithm consists of three stages: creating database, star matching and attitude determination. In the first stage, the necessary data for master or bright stars are extracted from the star catalog and stored as a database. This stage is conducted in an offline manner. In the second stage, the stars in the input image are extracted and matched with the stars in the database and finally, based on the matched stars the attitude of the camera capturing the input image is determined.

Different algorithms have been proposed for the task of star tracking. These algorithms may roughly be divided into two categories, including 1- lost-in-space and 2- recursive algorithms. In lost-in-space algorithms, the attitude (orientation) of the star tracker is determined without any prior information. In recursive algorithms, some information regarding the attitude of the star tracker is available. In the lost-in-space algorithms, the star matching algorithm should search the entire celestial sphere to identify an input star; however, in the recursive algorithms the limited part of the celestial sphere is searched to match the input star.

The star matching or the star identification algorithm is the essential part of a star tracking algorithm. Several

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