Chinese Astronomy and Astrophysics 40 (2016) 66–78

CHINESE
ASTRONOMY
AND ASTROPHYSICS

A Method for Correcting Telescope Pointing Error in Optical Space Debris Surveys† ⋆

SUN Rong-yu[1,2△] LU Yao[1,2,3] ZHAO Chang-yin[1,2]

[1] *Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008*

[2] *Key Laboratory of Space Object and Debris Observation, Chinese Academy of Sciences, Nanjing 210008*

[3] *University of Chinese Academy of Sciences, Beijing 100049*

Abstract In the data processing of optical space debris observations, the background stars may be mismatched or unable to get matched due to the influence of the telescope pointing error, then it is difficult to calculate the plate model and to determine accurately the object position. Based on the characteristics of debris CCD images, a multiple neighborhood matching method based on feature stars is proposed. The experimental results show that the influence of the telescope pointing error can be removed, and that the efficiency and correctness of background star map matching are improved significantly. Meanwhile, the time cost of this method is low, so it is beneficial to the real-time data reduction.

Key words astrometry, techniques: image processing, telescopes, methods: statistical

1. INTRODUCTION

When a ground-based optical telescope is used for the space debris observations, the equatorial coordinates of objects are usually obtained by means of astronomical positioning. The astronomical positioning is a kind of relative positioning method, with which the object position is calculated from star positions according to the relative positions between the image of the measured object and those of background stars[1]. In practice, firstly, the star positions are extracted from a star catalogue, then after a series of coordinate transformations for the epoch, topocenter, etc., and by means of a intermediate coordinate system

† Supported by National Natural Science Foundation (11403108, 11125315)

Received 2014–09–24; revised version 2014–10–22

⋆ A translation of *Acta Astron. Sin.* Vol. 56, No. 3, pp. 253–263, 2015

△ rysun@pmo.ac.cn

doi:10.1016/j.chinastron.2016.01.007

defined on the tangential plane, the ideal coordinates of stars on the image at the observing time are obtained. Thus, a projective relation between the equatorial coordinates and the measured coordinates of stars on the image is finally obtained by matching the ideal coordinates with the measured ones, and through this relation the object position is calculated[2]. To meet the needs of space debris observations, a very large viewing field is required for the special-purpose ground-based optical telescope of space debris observations, hence on the image the number of background stars is quite large, generally several hundreds even a thousand, while the telescope points precisely, considering the real-time requirement, the image matching of stars can be realized by simply matching the measured coordinates of stars in the neighborhood of the ideal coordinates of stars.

In the observation of space debris, as relative motions exist between the space debris and the background stars, in order to guarantee the signal-noise ratio of the object image and to optimize the detecting capability of the equipment, the telescope follows the motion of the object, thus on the observed image the debris image appears as a spot, but the star images are prolonged[3]. Considered that the space debris moves rather rapidly with a large angular velocity, in the fast tracking process, the mechanical instability of the telescope is liable to make its pointing appear dynamical errors; in addition to the static errors introduced in the manufacture and assembly of the telescope[4], all this will affect the correctness of neighborhood matching of background stars, and reduce the calculating accuracies of the plate model and space debris position, even result in a serious shortage in the number of matched stars to disable the calculation of plate model. Hence, in the data processing, it is necessary to consider how to realize the high-accuracy matching of the theoretical positions of stars with their actually measured ones on the image of space debris observation when the telescope has a rather significant pointing error, so that to derive a real plate model.

The matching of the theoretical positions of stars with their measured ones on the image of space debris observation is essentially the problem of star map matching in the dense star field. The star map matching is a process to search for the structure mode, which is optimally matched with the mode in the observed star map, from a mode database, and its method has been studied for years in the fields of astronomical observation and space navigation. At present, there are generally two kinds of mature algorithms for star map matching: one is that based on the angular distances of star pairs, a simple geometric configuration is constructed to be the matching mode and to make matching. Its representative methods include the triangle algorithm[5−6], pyramid algorithm[7] and the improved one based on the classical triangle algorithm[8], etc. With a conceivable idea, this kind of methods can be easily implemented; another one is that taking the selected primary star to be the matching element, the distribution feature of the stars around the primary star is taken as the matching mode, and that with the highest similarity is adopted as the matching result. Its representative methods include the grid algorithm[9], the algorithm of identifying the radial and circular distribution features[10] etc. Besides, the heredity algorithm[11] and