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Improvement of star identification based on star trace in star images

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ABSTRACT

Digital zenith camera system is a highly accurate positioning instrument in geodetic astronomy. It can capture 16 star images in one experiment unit in different azimuthal camera orientations and the stars in each star image should be identified using star catalogue. But the amount of calculation is very large, the efficiency of star identification is low. Now, the improvement of star identification is mainly through updating algorithm. Considering that there exist identical stars in these star images, this paper provides a new method to improve star identification. The star trace is deduced taking the earth rotation and instrument rotation into consideration. The errors of star trace are also analyzed. Then select the same stars that appear in the star images taken in the initial position and after rotating one angle. Using the identical stars instead of star catalogue and the star trace to identify the rest stars, the efficiency will get improved. The analysis of experimental data shows that there are many identical stars in these star images. The appearance of one star can be predicted according to the star trace. The star identification get improved by using the same stars in these star images. And it costs less time to identify the stars in star images, but the precision is approximately equal.

1. Introduction

With the development of CCD (Charge Coupled Device), Digital Zenith Camera System (DZCS) becomes a highly accurate instrument in geodetic astronomy [1,2]. The study about DZCS in abroad is relatively early [3,4,5]. Whereas, the domestic study is immature as opposed to foreign [6]. DZCS captures star images in different azimuthal direction [7]. Then we should match the stars in star images with the reference stars from catalogue to identify these stars. [8].

When using DZCS to orientate, the stars in every star image should be identified, the triangle star identification algorithm is often used [9,11]. There exist identical stars in these star images [10]. Although the image coordinates of these star points on CCD imaging sensor are different, they are identical stars in star catalogue. Select these identical stars in these star images. The speed and efficiency of star identification will get improved based on these identical stars. At present, the study of star identification is mainly about algorithm. Here, we study the star trace of one identical star in these star images captured in different azimuthal direction and find a new method to improve star identification. This paper deduces star trace accurately taking the rotation of earth and instrument into account. The star trace errors are also analyzed. The area of identical stars on CCD imaging sensor in these images is studied from the perspective of star trace, which is significant to star identification.

2. Star trace model

DZCS is divided into two parts: a turnable superstructure and a fixed substructure. The accuracy of the equipment is 0.3″. DZCS is composed of a zenith camera equipped with a CCD imaging sensor and a GPS receiver, as shown in Fig. 1.

It can capture 16 star images in one experiment unit in different azimuthal direction, as shown in Fig. 2.

Star light pass the focal point of DZCS, and the star image forms on the focal plane of CCD imaging sensor. During the period of taking star images, DZCS rotates along with the earth. Establish CCD image coordinate system o_p-$x_py_pz_p$ initially. Ideally, o_p is the principle point of the image, z_p axis is zenithal direction, x_p axis is parallel to east of the station and y_p is parallel to north of the station. In order to express simply, this placement of CCD imaging sensor is called condition P. After DZCS rotates one angle along with the earth, the coordinate system o_p-$x_py_pz_p$ becomes o_p'-$x_p'y_p'z_p'$, the rotation angle is θ. As we know, the star light is from far away distance, the star light can be treated as a set of parallel light, as shown in Fig. 3.

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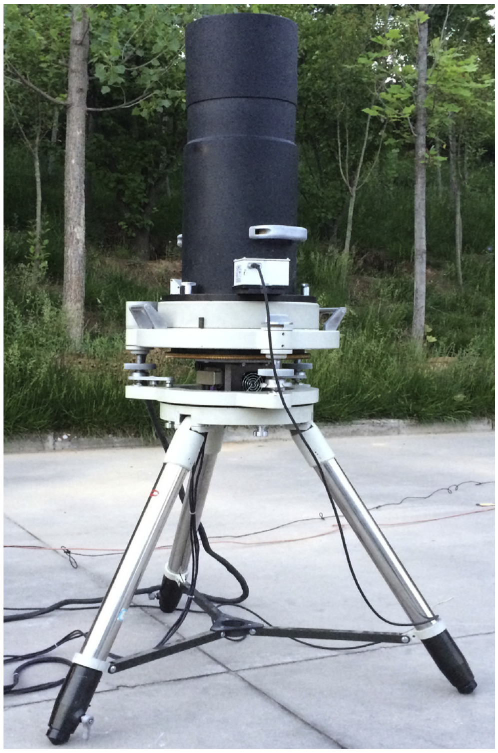

Fig. 1. Digital zenith camera system.

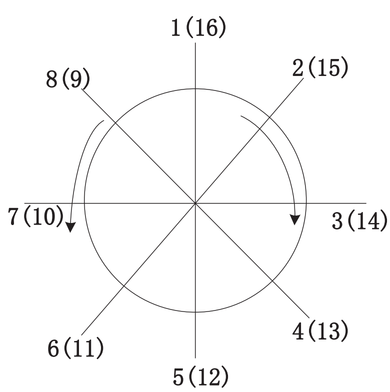

Fig. 2. Star images captured in different azimuthal direction.

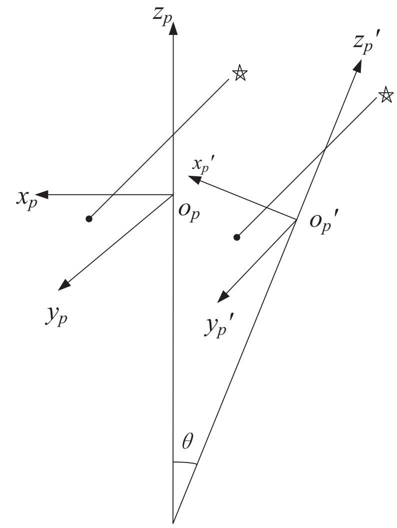

Fig. 3. Change of CCD imaging sensor coordinate systems.

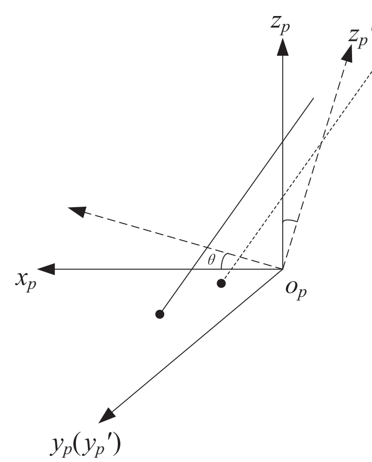

Fig. 4. Simplified CCD imaging sensor coordinate system.

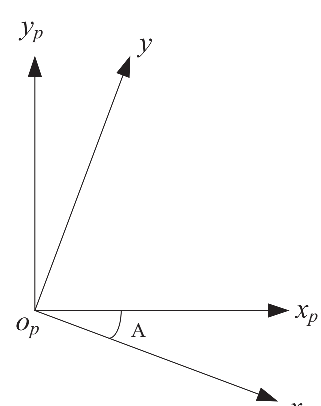

Fig. 5. Relationship between star image coordinate system o_p-xy and condition o_p-x_py_p.

Fig. 3 can be simplified, as shown in Fig. 4.

In general, the placement of CCD imaging sensor is not in condition P, there exists an angle A between the actual placement of CCD imaging sensor and the condition P. Establish star image coordinate system o-xy. Assume that the CCD image coordinate of one star point on CCD star imaging sensor is (x_0, y_0) in coordinate system o_p-xy, then convert it into coordinate system o_p-x_py_p, as shown in Fig. 5.

$$\begin{aligned} x_{p0} &= x_0 \cos A + y_0 \sin A \\ y_{p0} &= y_0 \cos A - x_0 \sin A \end{aligned} \tag{1}$$

The CCD image coordinate of one star point in coordinate system o_p-x_py_p is (x_{p0}, y_{p0}). Then solve star trace. The coordinate of the focal point is $(0,0,f)$, the star image coordinate is $(x_{p0}, y_{p0}, 0)$. The coordinate of the star point is $\left(x'_{p0}, y'_{p0}, 0\right)$ after rotating angle θ along with the earth. The relationship is:

$$(-x_{p0}, -y_{p0}, f)\begin{pmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{pmatrix} = (-x_{p0}\cdot\cos\theta + f\cdot\sin\theta, -y_{p0}, x_{p0}\cdot\sin\theta + f\cdot\cos\theta) \tag{2}$$