MATEC Web of Conferences 114, 03011 (2017) DOI: 10.1051/matecconf/201711403011
2MAE 2017

A New Method on Calibrating PSF of Remote Sensing Space Plane Arraycamera

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Abstract: Point spread function (PSF) of an imaging system is an important parameter to a remote sensing imaging system, and it is the important basis for image restoration [1]. The knife-edges method has been widely used to measure PSF because it provides a relatively easy way to get the point spread function. However, the location of the edge points in edge spread function (ESF) is difficult to determine of the knife-edges method, resulting in the inaccuracy of the point spread function. In this paper, we propose a new method to solve the problem of phase influence for calibrating PSF of space plane array camera. This method include: the design of target, the process of calibration and data processing. Then this method was used on calibrating PSF of GF-4 satellite panchromatic camera. The results showed that the new method could determine the PSF correctly.

1 Introduction

PSF, which is derived from physical optics, provides an accurate representation of the real blurs about an imaging system. A variety of methods have been used to calibrate the PSF of a remote sensing imaging system. Some commonly used methods are described as follows:

(1) Impulse input method [2]. Theoretically, the PSF is an impulse input of spatial response of an imaging system. However, in practice this method is very difficult to apply for an imaging system because it is difficult to obtain an impulse input for an imaging system.

(2) Pulse input method [3]. This method is to find a linear object that is a contrast to surrounding objects from the remote sensing image. It also estimates the PSF from its edge response.

(3) Knife-edges method [4, 5, 6]. This method is to search a knife-edge object form the remote sensing image. The profile of the edge is called ESF. The differentiation of the ESF results in a one-dimensional version of the PSF.

(4) Other method [7]. Some researcher brought forward some other methods such as image-derived point spread function method.

The knife-edges method is the most commonly used method to calibrate the PSF of a remote sensing imaging system. It has two major advantages: one is that the target of knife-edge on the ground is easy to design, and the other is that it is easy to understand and compute. But the knife-edges method also possesses some problems. The major problem is it is difficult to determine the location of sampling points in the ESF.

In this paper, we proposed a new method include staggered array target design and process of calibration.

2 Design of staggeret target

To be influenced by many factors such as vibration of the test platform, the phase of single point target is stochastic. To get effective point resource image, we design a staggered array target (Figure 1). This target could assure that there would be one point in a pixel.

There are 100 square points whose widths are equal to pixel width in the target ($e_{i,j}(i = 0,1,\cdots 9,\ j = 0,1,\cdots 9)$). The points are non-light tight, and other area is light-tight in the target. The distance of every point in x and y direction is W.

$$W = (x+0.1)*(\frac{f_{col}}{f_{cam}}*d)$$
$$x > 10 \tag{1}$$

f_{col} is the focus of collimator, the f_{cam} is focus of camera, d is the width of one pixel in camera focal plane device.

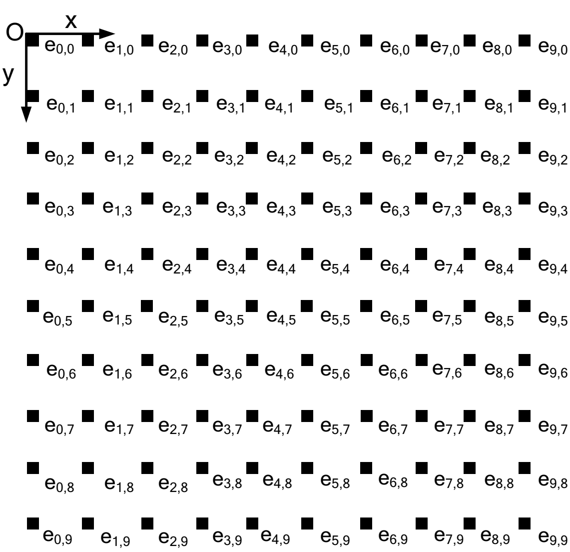

Figure 1. Ponits Target Design

Suppose the phase of point $e_{0,0}$ is $(\varphi x_{0,0}, \varphi y_{0,0})$, then the phase of point $e_{i,j}$ is:

$$\varphi x_{i,j} = \mathrm{mod}(\varphi x_{0,0} + i \cdot 0.1,1)$$
$$\varphi y_{i,j} = \mathrm{mod}(\varphi y_{0,0} + j \cdot 0.1,1) \tag{2}$$

Mod(x,y)is the reminder when x is divided by y. Formula (2) means that the phase difference of neighbouring pontits in x and y direction is 0.1.

This points target design ensures that one point must be in a pixel in every sampling picture [8].

3 Process of calibration data

① Picture sampling

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We take the target's picture using the camera which needs to be calibrated.

② Phase template

Suppose the value of DN light is 1, the value of DN dark is zero. When the square point is in one pixel, its DN value is itself. If the square point is not in one point, we can calculate the DN values (Figure 2):

$$\begin{aligned} dn_{i,j} &= DN_{light} * (1 - phase_x)\ (1 - phase_y) \\ dn_{i,j+1} &= DN_{light} * phase_x\ (1 - phase_y) \\ dn_{i+1,j} &= DN_{light} * phase_y\ (1 - phase_x) \\ dn_{i+1,j+1} &= DN_{light} * phase_x * phase \end{aligned} \tag{3}$$

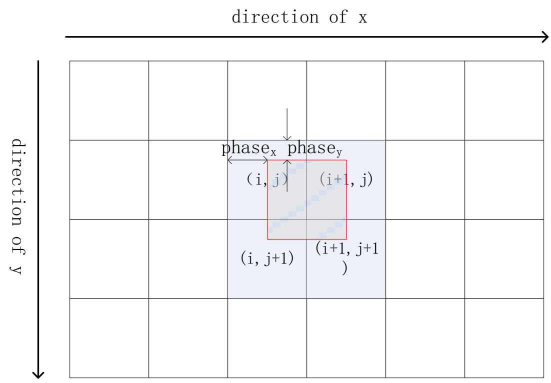

Figure 2. Phase of Point

Form formula (3), we could calculate phase template $D^{l,h}(x, y)$ ($l = 0,1, \cdots 9$; $h = 0,1 \cdots 9$).

③ Phase searching technique and fitting function

After we get the target picture, we cut it to 100 sub-picture $P^{m,n}(x, y)$ $(m = 0,1, \cdots ,9; n = 0,1, \cdots ,9)$ which is 11*11 pixels and include one point resource. Every brightness point is in location (6, 6).Then we search the phase of the sub-picture:

$$J(m, n) = \sum_x \sum_y P^{m,n}(x, y) \times D^{l,h}(x, y) \tag{4}$$

The value of (m, n) that maximizes $J(m, n)$ is the phase.

$$(m, n) = J^{-1}(\max(J(m, n))) \tag{5}$$

Where $J^{-1}(m, n)$ is the anti-mapping of $J(m, n)$. We could get the phase of every sub-picture according formula (4) and formula (5).

Then, we choose the phase (0, 0) sub-picture, and use the 2 direction Gauss function as the fitting function to get the PSF.

4 Results

GF-4 is the first high resolution satellite of earth synchronous orbit. Its panchromatic camera space resolution of sub-satellite point is 50m. We test GF-4 panchromatic camera image. The test instrumentations include air bearing platform, integrating sphere, designed target, collimator and image acquisition system. We put the target in the focal plane of collimator. The axis of collimator and

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the optic axis of camera are same. The target is lightened by integrating sphere, then imaging in camera's focal plane device through collimator and optical system of the camera.

Figure 3 is the PSF test picture, the contrast of non-light tight area and light-tight area is 20:1. Figure 4 is different phase sub-picture.

After finding phase (0, 0) sub-picture, we fit 2 direction Gauss function (Figure 5).The PSF test result of GF-4 satellite panchromatic camera is $N(0,0,0.868^2,0.912^2)$. Compared to the laboratory measured MTF of GF-4 satellite panchromatic camera, the error is lower than 5%.

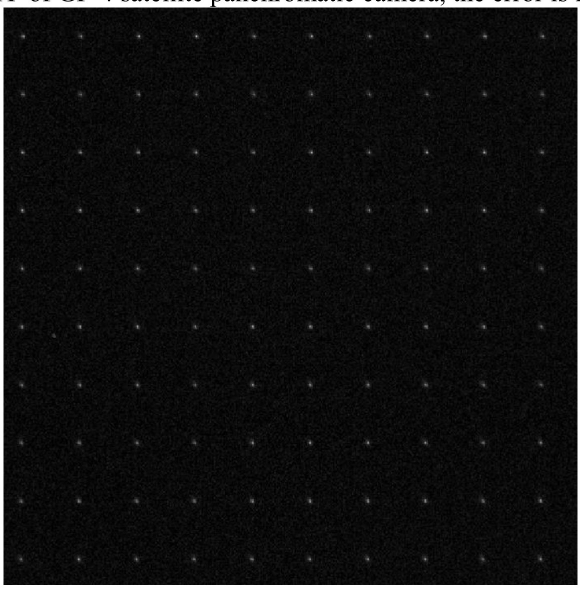

Figure 3. Targetimage of GF-4 panchromatic camera

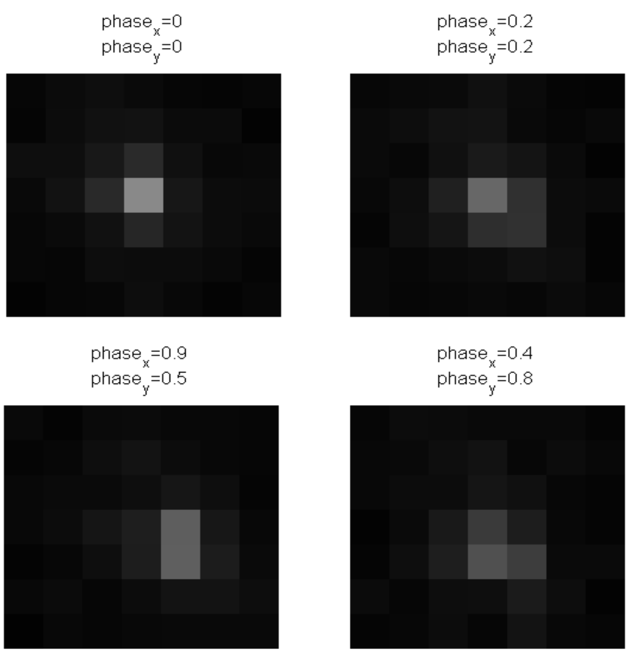

Figure 4. Point image of different phase sub-picture

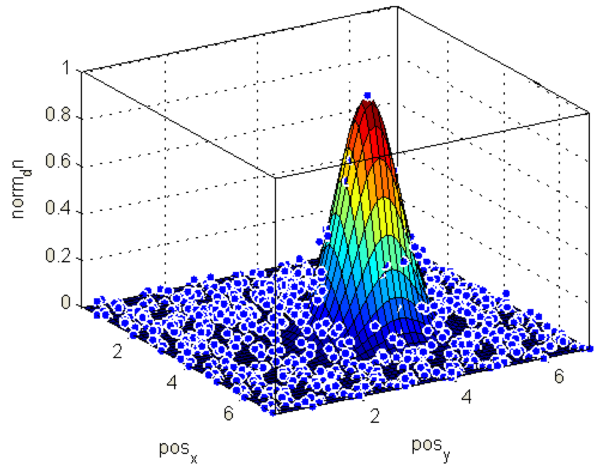

Figure 5. Result of PSF reconstruction

5 Conclution

In this paper, based on the study of the PSF calibration and the analysis of the problem of traditional knife-edges method, a new method on PSF calibration of space plane camera is proposed.

Researchers would evaluate a remote imaging system better and enhance the quality of the reconstruction remote images through the new method they could get PSF/MTF more correctly.

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