Optik 127 (2016) 148–151

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Research on automatic focusing technique based on image autocollimation

Xiao Zuojiang [a], Han Di [b,*], Zhu Haibin [c], Wang Liang [d], Xu Zhigang [c]

[a] Changchun University of Science and Technology, School of Life Science and Technology, China
[b] Changchun University of Science and Technology, College of Optoelectronic Engineering, China
[c] JiLin Dongguang Precision Machinery Factory, China
[d] The Military Representative Room of Armored Forces in Changchun, China

ARTICLE INFO

Article history:
Received 18 December 2014
Accepted 10 October 2015

Keywords:
Aerial camera
Image processing
Automatic focusing

ABSTRACT

According to accuracy requirements of aerial camera focusing and characteristics of CCD camera imaging, this paper proposed automatic focusing system of aerial camera based on image processing technology. Firstly, in accordance with self-made resolution target, image sharpness function and optimization of hill climbing algorithm, autocollimation defocusing compensation method was used to achieve correction of the aerial camera defocus caused by temperature and atmospheric pressure. Then the amount of defocus was calculated by introducing the aircraft height data, and defocus adjustment was realized by appropriate device. Finally, the experiment was carried out for simulating and testing of the system, and the results showed that: error of the system for camera defocusing correction is less than half of the camera focal depth, which can meet the requirements of the aerial camera, such as fast, high-precision focusing and so on.

1. Introduction

Image quality is one of the most important performance indicators for aerial camera. The optical image plane position will change in camera; defocus will be produced; images on the image plane will be blurred and which will decline resolution will be lower, which induced by the change of temperature, atmospheric pressure, photographic distance and the other environmental factors [1], when optical imaging reconnaissance is in high altitude. Satisfactory image quality can be obtained by automatic focusing technique without considering the influence of atmospheric pressure and temperature. There are two kinds of focusing methods for aerial camera [2–4]; one is based on image processing. In this way, it is so difficult to focus when contrast of target varies greatly or the scenery with low contrast, it will lead to focusing failure easily. Another is based on the focusing of photoelectric auto-collimation. This is the most common way to focus for aerial camera. This method has the advantage of high precision and strong versatility, but it needs an accurate detection system of light intensity at different locations near the focal plane. The system is more complex and with a long detection period of focusing. A focusing method of autocollimation based on image processing is presented in this paper. The resolution target was made on the basis of the imaging CCD pixel size in this method, which was imaged to CCD imaging surface by autocollimation. According to the image sharpness function of the resolution target, the focal plane position at CCD imaging surface can be quickly tested with optimization of hill climbing algorithm under any environment.

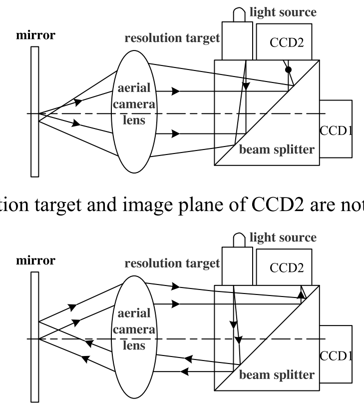
1.1. The principle of photoelectric autocollimation

1.1.1. The autocollimation principle of focusing

The principle of autocollimation focusing is shown in Fig. 1. The system is composed of a mirror, which is perpendicular to the optical axis, aerial camera lens, a resolution target, a light source, a beam splitter, CCD1 and CCD2. The resolution target is illuminated by the light source. Then, the rays transmit through the lens and then got reflected back by the mirror, which will through the lens again, the images are shaped at the plane of the CCD1. Imaging surface of the resolution target and CCD2 must be coplanar strictly. On the basis of the optical autocollimation principle, if the imaging surfaces of resolution target, CCD1 and CCD2 are located on the focal plane, the image will be imaged clearly at the imaging surface of the CCD1 after the rays emitted by resolution target transmits through lens, mirrors, lens; however if the imaging surface of resolution target, CCD1 and CCD2 are defocus, the image cannot be imaged clearly.

* Corresponding author. Tel.: +86 15948360868.
E-mail address: 363836458@qq.com (D. Han).

http://dx.doi.org/10.1016/j.ijleo.2015.10.037
0030-4026/



(a)resolution target and image plane of CCD2 are not coplanar

(b)resolution target and image plane of CCD2 are coplanar

Fig. 1. Autocollimation focusing principle.

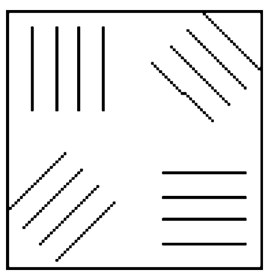


Fig. 2. Schematic diagram of resolution target cells.

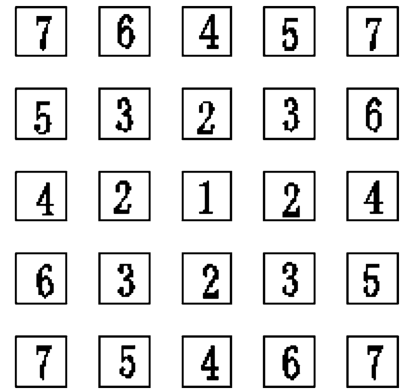


Fig. 3. Schematic arrangement diagram of resolution target.

Therefore, as long as the clearest image of resolution target can be tested, the location of the CCD surface will be the lens focal plane position. By utilizing image processing and the system hardware, this system makes use of image sharpness evaluation function to help finding out the position of the clearest image so that the users can obtain the best imaging position to achieve automatic focusing.

2. The design of autocollimation focusing resolution target

In this system, f = 350 mm and F = 5.6. Pixel size of the CCD is 5.5 μm × 5.5 μm. The spatial resolution is no less than 42 lp/mm. Nyquist frequency of the CCD is 91 lp/mm. So the spatial frequency of the resolution target is no more than 91 lp/mm, otherwise it cannot be distinguished by the CCD. According to *JB*/*T*9328-19999, the minimum line width of the resolution target is ascertained by 5.61 μm and the maximum line width is 11.2 μm. The resolution target is divided into seven different line width units in accordance with $1/2^{1/6}$ ratio and designed by 25 units. Each unit is composed of four groups parallel lines of light and dark which has equal length with adjacent 45°. In Fig. 2, line interval is equal to the line width. As full considerations are taken into that resolution of lens is the same in the same field of view, then the 7 units with different line width are admeasured to the 25 units as shown in Fig. 3. Finally we can find that the distance of same line width unit to the central unit is the same and the central unit is the smallest line width unit. The greater the central distance is, the wider the line width is.

3. Selection of the automatic focusing function

A key problem of achieving automatic focusing by using the method of image processing is how to select image sharpness evaluation function. At present, the frequently used methods of discrimination are [5,6]: improved method of gray comparison, improved method of edge sharpness, the method of squared gradient focusing function and wavelet transform method. There is a good effect for the improved method of edge sharpness to process images with rich details, texture features and highlighted background. And the method of squared gradient focusing function has a better processing effect for noise and highlighted region, but the calculation is so large that the real-time is not ideal. Processing with rich-details images is not very ideal for method of gray comparison, and it is easy to suffer error focus in dealing with highlighted background images. However, it can calculate fast because of a small amount of computation. The images with texture features are able to be processed by the wavelet transform method, but it will be failed in the images with rich details, texture features and highlighted background.

The resolution target is a kind of image which has texture features and highlighted background. In order to take the accuracy and response speed into account simultaneously, when the system is adjusting its focus, the coarse tuning can use the improved method of gray comparison. The evaluation function is:

$$I=\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{\left|f(i,j)-\overline{\text{gray}}\right|}{f(i,j)} \tag{1}$$

where $m\times n$ is image size; $f(i,j)$ is the pixel gray value; $\overline{\text{gray}}$ is the average gray value.

The improved method of edge sharpness is used by fine tuning. The evaluation function is:

$$I=\frac{\sum_{a=1}^{m\times n}\sum_{b=1}^{8}df/dx}{m\times n} \tag{2}$$

where $m\times n$ is image size; df is the gray variation amplitude; dx is the distance increment between pixels.

4. Selection of the search mode of automatic focusing

In the ideal case, it is similar to the human brain that searching mode of hill climbing can achieve good results. When the focal plane moves from some position closed to the focal point, detection intensity values which is away from focus position is not strictly changed by monotone increasing mode but there exists the local maximum, which under the influence of noise, fast motion of the CCD, instability and vibration of light source and other factors [7,8]. Especially in the fine tuning process, the peak of fluctuation caused by interference is very close to the step because it is very small, and rather easy to fall into local peak for fine tuning process, which makes the final search results not so accurate, resulting in the process of focusing poor accuracy, even not completely focused, and the automatic focusing will be failed.

Therefore it is necessary to do some improvements for the previous searching methods to adapt to the conditions of outside interference, making entire focusing process more reliable, more