Real - time processing of image data of ultraviolet annular imager

Wu Weiping[1,2], Wang Dong[1], Zhang Bin[1], Sun Tianyu[1]

(1. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China;
2. University of Chinese Academy of Sciences, Beijing 100049, China)

Abstract: For accurately calibrating Ultraviolet annular imager, aiding alignment exactly and measuring its structure, an image data processing system was developed by analyzing the optic structure and data characteristic of the Ultraviolet annular imager. Effectively scheduling two threads reduced the bottle - neck of image data processing system; a method of filling mask increased the performance of local area lightening; painting of overlay curve can improve alignment precision; the function of picking up inside curve would heighten measuring efficiency. The calibration results show that the image data processing system can synchronously parse 3 bands data, checkout their CRC errors, display images, draw overlay line, and draw cross - sectional curves and lighten local areas with those techniques, when the data flow is up to 22.5MB /s. The system works steadily in all those process and human - computer interaction runs rapidly. No data package was lost in the calibration experiments. The overlay curves can provide pixel level precision alignment. The system ensures measuring efficiency and it also provides exact data for inversing space distribution and dynamic structure of air radiation in all directions.

Key words: ultraviolet annular imager; image processing; real - time; calibration; aid alignment

CLC number: TH73 **Document code:** A **Artical ID:** 1007 - 2276(2013) S1 - 0233 - 05

紫外环形成像仪图像数据的实时处理

吴伟平[1,2],王 栋[1], 张 滨[1], 孙天宇[1]

(1. 中国科学院长春光学精密机械与物理研究所,吉林 长春 130033; 2. 中国科学院大学,北京 100049)

摘 要: 为了对紫外环形成像仪精确定标,并辅助其精密装调和结构检测,通过分析紫外环形成像仪的光学结构和其图像数据的特点,设计并实现了紫外环形成像仪图像数据实时处理系统。通过双线程的有机调度,有效降低了系统瓶颈;采用掩码填充方式提高局部高亮显示的性能;使用绘制叠加线的方法提高装调精度;设计了剖线提取等关键功能提高定标效率。定标过程表明,应用这些方法该系统在 22.5MB/s 满负荷数据流条件下同时对 3 个波段进行数据解析、CRC 校验、图像显示、辅助线绘制和局部高亮显示等功能,整个过程系统运行稳定,人机交互流畅,未发生丢包现象;辅助线可提供像素级的对准精度,保证了装调精度和检测效率,为反演大气辐射多方位的空间分布及动态结构提供了准确的数据支持。

关键词: 紫外环形成像仪; 图像处理; 实时; 定标; 辅助装调

收稿日期: 2013 - 01 - 05; **修订日期:** 2013 - 02 - 10

作者简介: 吴伟平(1980 -),男,博士生,主要从事航天遥感器电子学仿真测试等方面的研究。Email: rainciomp@ sina. com

导师简介: 金龙旭(1965 -),男,研究生,博士生导师,主要从事空间相机智能控制技术的研究。Email: jinlx@ ciomp. ac. cn

0 Introduction

The ultraviolet annular imager adopts a fire – new design and can observe in all direction of the observed area. The imager also can get the earth limb and nadir images of atmosphere simultaneously on the near – earth orbit, and overcome the drawback which the observed area is usually zonal in limb and nadir observation mode. The images that get by edge of detector of annular imager stand for the ultraviolet radiation in different altitude of earth limb direction, and the images that get by central of detector of annular imager stand for the ultraviolet radiation and earth brightness of earth nadir direction. The figure of observation area shows as figure 1. For effectively detecting of atmospheric composition (such as O_3、NO_2), central wavelengths of annular imager three wave bands are 260nm、290nm and 360nm. We adopt refractive and reflecting optical system making up of reflector and lens. That system is mainly composed of two main parts. One part is coaxial optical system; the other part is visual field condensation cell. Meanwhile, the optical system adopts reflector condensate half annular field to satisfy the target. The reflector is composed of 12 refractive pyramids. The three wave bands adopt the same optical system by turning optical filter cam before lens, which can change one waveband to another.

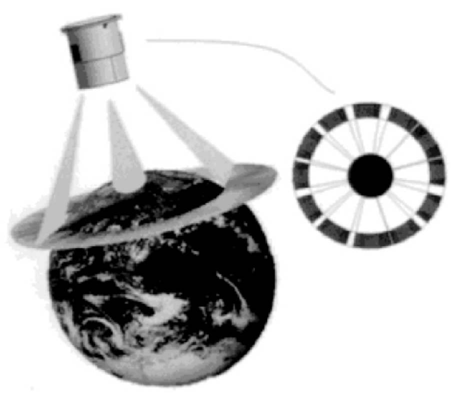

Fig. 1 Observation model of ultraviolet annular imager

Since the observation area, waveband and target of ultraviolet annular imager are different from the others, its structure, function and control method have respective characters. And the image data disposing method can also do these general functions, such as real – time sampling, image displaying, data saving; Corresponding image data processing method in addition to image real – time acquisition, display, storage and other basic requirements, but also need to design ruler, and the cross – sectional curve, angle correction, regional highlight and other a series of auxiliary functions. Those functions will provide the necessary support for the ultraviolet annular imager machinery alignment, spectral calibration, uniformity correction experiments and so on. In this paper, we adopt acquisition card on PCI bus receive image data downloaded from ultraviolet annular imager, and we also use VC + + 6.0 programming in high – performance computers for data storage, distribute, display and aid processing.

1 System theory and composition

Ultraviolet annular imager receives incident light. The incident light is divided into different bands by a spectroscope, and then each band of light converges to the respective image plane. The photoelectric conversion completed by the CCD in image plane, and the image data packaged by the FPGA transmits through the LVDS interface to the image processing system. The image processing system received image data by acquisition card, and then sent image data to high – performance computers through the PCI bus for data processing and aiding alignment function design (shown in figure 2) . Due to design of the ultraviolet annular imager structural is high precision, difficult, complex process of alignment, the auxiliary alignment function of the image data processing system must be able to provide real – time, high accuracy measurement and calibration functions.

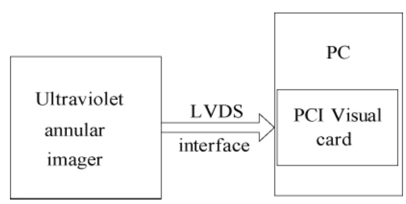

Fig. 2 Makeup of image data processing system

2 Design of software structure

The image processing software is divided into two threads (see figure 3) : The first thread is a data receiving thread which need a higher priority and will be responsible for controlling image acquisition card to read data into the memory buffer. The second thread is a data processing thread which can be a lower priority and will be responsible for acquainting the data from the memory buffer, storing them to the hard disk, unpacking data to packets and displaying images. The second thread identifies the type of band data packet through the packet header information, and then distributed them to the processing module for each band; each band processing module identifies the auxiliary packet and the image data packet according to the header information. When the ancillary packet received, the packet will be real – time analyzed and displayed; When the image packet received, the packet will be fill to the corresponding region of the image in accordance with the data protocol. When a whole frame is filled, the user can determine whether select auxiliary function, including to draw the hexagonal standard frame, draw a circle marked frame, draw a 90°cross calibration line, drawn 60° cross line, draw a cross – sectional curve, lighten local area and so on. After the auxiliary functions have been added, the double – buffered display technology will be used to display an image, which can avoid flashing when image updates.

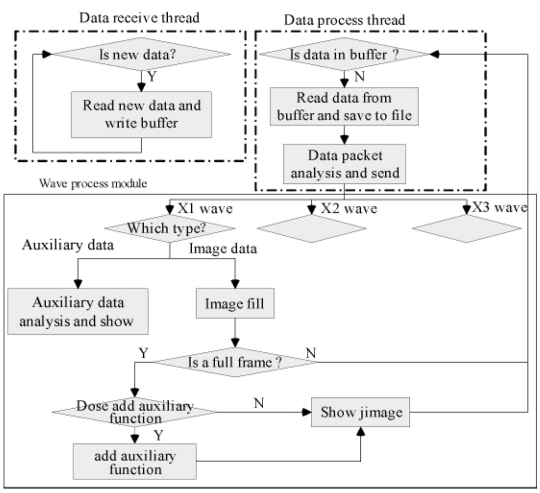

Fig. 3 Process flow of ultraviolet annular imager

3 Implementation of the auxiliary functions

3.1 Drawing of overlay line and cross – seational curve

In order to ensure absolute symmetry of visual field of ultraviolet annular imager, six edge of the visual field form a regular hexagon and the center of visual field coincides with the center of the square (Show as figure 4) . Therefore, the image data processing software will provide method to calibrate the position of visual field and expediently analyze homogeneity of each visual field. To do this, the image data processing software will overlay three cross lines on the image, when displaying the image in real time. The three cross lines will intersect at the center of the square, space apart from each other at an angle of 60° and can be rotated in accordance with the point of intersection. The values of the image points passed through by the line form cross – sectional curve displayed in real time. When the position of visual field was calibrated, each marginal field was adjusted to right position, which can make three cross line pass the center of visual scene. Using that function, the alignment accuracy of adjusting visual field achieved less one pixel. Through the cross – sectional curve, the homogeneity of the visual field can be analyzed.

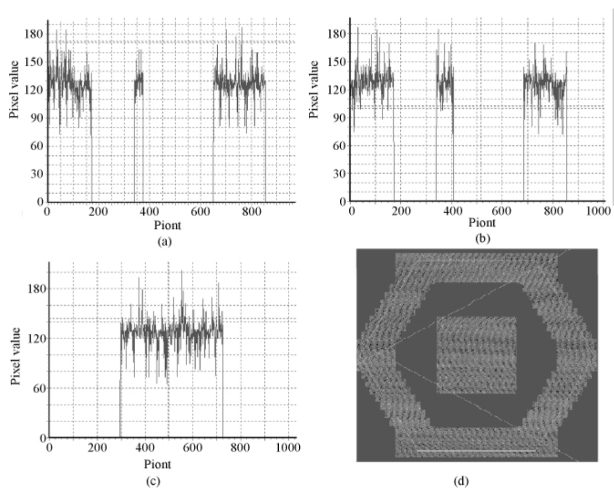

Fig. 4 Cross – sectional curve of ultraviolet annular imager

In standard coordinate system, the coordinate origin is set to the upper left corner of the image. The X – axis positive direction is the right level; the Y – axis positive di–

rection is vertically downwardly; the intersecting point is (x_0, y_0); L stands for the image length and H stands for height; α stands for the angle between any line and the horizontal axis; the line equation can be expressed as

$$y - y_0 = \text{tg}\alpha \times (x - x_0) \quad (1)$$

When $\alpha \in [0,45] \cup [135,180]$, the intersection point of the line and both edges of valid range are $(0, y_0 + x_0 \times \text{tg}\alpha)$ and $(L, y_0 + (x_0 - L) \times \text{tg}\alpha)$; when $\alpha \in (45, 90) \cup (90, 135)$, the intersection of the line and the edge of the valid upper and lower range are $(x_0 + y_0/\text{tg}\alpha, 0)$ and $(x_0 + (y_0 - H)/\text{tg}\alpha, H)$; when $A = 90$, the intersection of the line and the edge of the valid upper and lower range are $(x_0, 0)$ and (x_0, H). The intersection of each line and the edge of valid range can be calculated through each angle between line and the horizontal axis. It is very convenient that using the "LineTo" function draw cross - line. When the magnification of image is changed, the equation of edge can be taken into formula (1) to obtain the intersection. And then we can draw the cross - line according to new intersection.

We can obtain the cross - sectional curve according to the intersection of the line and edge of valid range. First, two adjacent sides are compared, and the axis of the longer side is choused (set $X = [k_1, k_n]$). Then, the point coordinates passed by the line is $(k_i, y_0 + (x_0 - k_i) \times \tan\alpha)$, $i = [k_1, k_n]$. The pixel value can be easily obtained through the coordinate of point. The obtained pixels are sent to show the cross - sectional curve and the maximum value of the entire curve is obtained, the minimum, mean and variance.

3.2 Local Highlight

To highlight the image characteristics of the edge of the field, the image data processing software highlight the edge of the field using the formula (2). The minimum value of the frame is mapped to 0, and the maximum of the frame is mapped to 255. The (monotonic rise) the value between the minimum value and the maximum value is nonlinear mapped to 0 - 255.

$$Y = \text{BYTE}\left(255\left[\frac{\text{double}(X - X_{\min})}{\text{double}(X_{\max} - X_{\min})}\right]^k\right) \quad (2)$$

When $k = 0.5$, the image brighter. Since equation (2) contain an extraction operation, the highlight display of the whole picture is too difficult to meet the efficiency requirements. Therefore, we only real - time highlighted the valid area, which is the rectangular area on each side of the highlight (see figure 5).

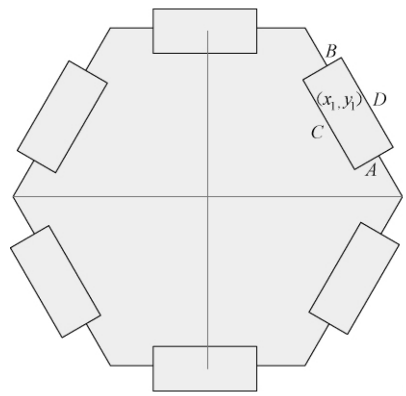

Fig. 5 Scheme of highlight area

In order to improve efficiency of highlighting local area, the method of setting image mask is used to highlight image. First, the memory space which is as big as the image is created as a mask area. Then, the areas which need to highlight in mask area are filled with the value 0xff; the areas which need to non - highlight in mask area are filled with the value 0x00. That is the mask of the image. When the image needs to be highlighted, the rule that determine where to highlight is to analyze the value in mask area. Only when the user changes the position or size of the highlighted area, the values in the mask areas need to be recalculated.

The method of filled mask area adopts the classic polygon - filling algorithm. In the standard coordinate system, the center point coordinates of regular hexagonal is (x_0, y_0). The length between the center point and the top dot of regular hexagonal is r. The length and width of rectangular region which need to be highlighted are l and w. The midpoint coordinates of upper right side coordinates is (x_1, y_1). So (x_1, y_1) can be calculated by these formula.

$$x_1 = x_0 + 0.75 \times r \quad (3)$$

$$y_1 = y_0 - 0.433 \times r \quad (4)$$

According to the geometric relationship, the midpoint coordinates of each side of regular hexagonal can be evaluated in the upper right coordinate of the rectangle of each side of the midpoint A, B, C, and D, as shown in table 1.

Tab. 1 Middle point coordinates of lift – up highlight area sides

Y	Point name	X
A	$X_1 + 0.433 \times w$	$Y_1 - 0.25 \times w$
B	$X_1 - 0.433 \times w$	$Y_1 + 0.25 \times w$
C	$X_1 - 0.25 \times l$	$Y_1 + 0.433 \times l$
D	$X_1 + 0.25 \times l$	$Y_1 - 0.433 \times l$

The each side equation of the upper right rectangle area can be expressed as $Y_a = f(X_a)$, $Y_b = g(X_b)$, $Y_c = h(X_c)$, $Y_d = i(X_d)$. Equation of each side was obtained by each side angle with X – axis and mid – point coordinates of each side. For any point (x_n, y_n), when the formula (5) – (8) are true, the point is in the highlighted area. Otherwise, the point is not in the highlighted area. Using that method, the mask value of the entire highlighted region can be obtained(show as figure 6).

$$Y_n - f(X_n) < 0 \tag{5}$$

$$Y_n - g(X_n) > 0 \tag{6}$$

$$Y_n - h(X_n) < 0 \tag{7}$$

$$Y_n - i(X_n) > 0 \tag{8}$$

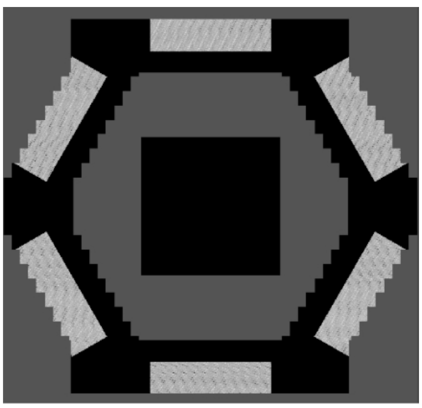

Fig. 6 Show of highlight areas of images

4 Conclusions

The experimental results of image data processing system show in figure 4. Under 22.5MB/s data stream of full load conditions, the image data processing system unpacks the image data of three bands, check the CRC, display the image, paint the auxiliary line, highlight the local area at the same time. The processing system stably run in the entire process; human – computer interaction is smooth; no data packet loss. IF the data flow is over 100MB/s, data packet will be lost with modern CPU processing speed. So we must adopt a acquisition card which can directly save data to hard disk or use two pc; one is used for saving data, another is used for processing data. But for our imager, 22.5MB/s is the fast data stream. So we can use that compact system structure. The calibration experimental results show that the image data processing method can meet the entire real – time requirement and successfully complete the mission of detection and alignment. The image data processing system provides a great convenience for the detection and alignment of the ultraviolet imaging spectrometer and ensure accurate and validated the results of testing and alignment.

Reference:

[1] Yu Xiangyang, Wang Shurong, Huang Yu, et al. Development of ultraviolet annular imager for earth limb and nadir sounding simultaneously [J]. *Acta Optica Sinica*, 2012, 32(12): 30 – 33. (in Chinese)

[2] Yu Lei, Wang Shurong, Lin Guanyu. Review of space – based imaging spectrum technique development for Ionosphere observations [J]. *Progress in Geophysics*, 2012, 27(06): 2308 – 2315. (in Chinese)

[3] Wang Shurong, Li Futian, Qu Yi. Space UV optical remote sensing technology and development [J]. *Chinese Journal of Optics and Applied Optics*, 2009, 2(1): 17 – 22. (in Chinese)

[4] Xue Panpan, Wang Xiaodong, Qu Hongfeng. Design and realization of high – speed image display system for extreme ultraviolet photon count imager [J]. *Laser & Infrared*, 2011, 41(12): 1378 – 1381. (in Chinese)

[5] Zheng Yuquan, Wang Hui, Wang Yifan. Selection and design of optical system for spaceborne hyperspectral imager [J]. *Optics and Precision Engineering*, 2009, 17(11): 2629 – 2637. (in Chinese)

[6] Peng Jilong, Zhu Guangwu, Wei Fei, et al. Solar extreme ultraviolet multichannel imager [J]. *Chin J Space Sci*, 2009, 29(4): 417 – 421. (in Chinese)

[7] Ren Jianwei, Wan Zhi, Li Xiansheng. Radiation transfer characteristic and calibrating method for space optical remote sensor [J]. *Optics and Precision Engineering*, 2007, 15(8): 1186 – 1190. (in Chinese)