Acta Technica 62 No. 1A/2017, 521–530

Design of high-speed acquisition system based on computer fuzzy image and information data

Guo Lei[1], Gao Zhigang[2]

Abstract. In order to meet the requirements of fuzzy image display, performance prediction accuracy and collection efficiency in various fields, high-speed acquisition system based on computer fuzzy image and information data was designed in this paper. In the design of this system, the rasterization operation on the fuzzy image data was carried out by the fuzzy image processing module of the system, and the obtained black and white pixel images were rendered. The rendered black and white pixel images were partially and integrally filled with color respectively by the vertex shader and the pixel shader in the color fill module, and the full color image of the obtained fuzzy image was transmitted to the computer monitor for display. Kalman filter was used to process the fuzzy image information data. The final experimental results show that the system designed in this paper has high display effects, accurate behavior prediction and collection efficiency.

Key words. Fuzzy image, high-speed acquisition system, system design.

1. Introduction

The high-speed acquisition system of image information data is widely used in the fields of public security, fire protection, aviation and spaceflight. Restricted by the speed of object motion, the high-speed motion objects have a high probability of producing blurred images. In many cases, the information contained in the blurred image is very important, so the high-speed acquisition of the fuzzy image data has become the focus of the scientific research organizations. High-speed acquisition system of fuzzy image data from previous studies used a variety of acquisitions, but they were unable to meet the requirements of fuzzy image display, behavior prediction and the collection efficiency of the system in various fields. In the image acquisition system, the real-time processing is the core of the system. In traditional image acquisition system, the system design of "camera-image card-computer" is usually adopted. The image algorithm is implemented by computer software, which

[1]Xi'an Aeronautical University, Xi'an 710077, China

[2]College of Astronautics, Northwestern Polytechnical University, Xi'an 710072, China

can meet the practical application in low speed and single sensor image acquisition. However, in a high-speed image acquisition system, the frame speed of the high speed camera usually reaches 100-200 frames per second. In the multi sensor visual testing system, the serial operation of sensors, the input and output ports, the transmission speed and all algorithms can only be implemented by software with many other restrictions, so it is difficult to guarantee the real-time performance of the system.

2. State of the art

At present, great progress has been made in the design of high speed data acquisition system. However, the focuses of the performance of the high speed data acquisition system for blurred images in the past were different, but they were all unable to achieve the high-performance design. For example, the high-speed acquisition system for blurred image information based on FC-AE-ASM is a high-speed acquisition system of fuzzy image information designed on the basis of aviation information collection system, and it can realize super high-speed acquisition of fuzzy image information data. The whole system has high prediction level and display level, and its collection efficiency is acceptable, but it is expensive, so it is less used in daily enterprises [1]. High-speed acquisition system of blurred image based on PXI bus carried out the design of display terminal for fuzzy image restoration, used the display processor optimization of acquisition high performance resources, and realized the display of high-level fuzzy image by the system, but the collection efficiency of this system still has more rooms for improvement [2]. On the basis of guaranteeing the display level, the high-speed acquisition system of the fuzzy image data based on FPGA and USB can effectively improve the processing and storage efficiency of the system by using FPGA and USB. But the functions of the system are simple, so it is only suitable for fields without high demands for high-speed acquisition system of fuzzy image. In order to improve the display effect, performance prediction accuracy and collection efficiency of the system, a high-speed acquisition system of high-performance fuzzy image data is designed [3]. In addition, machine vision has been developed in recent years. It uses charge coupled devices or CMOS cameras to ingest images and convert them into image signals, and then sends them to the image processing system, so as to obtain morphological information captured targets, such as pixel distribution, brightness, color, and to change them into the digital signal (Li et al. 2015) [4]. Through image enhancement, image segmentation and other means of processing, it can extract target features, and then make judgments and give control actions and other measures. Machine vision is widely used in many fields, such as face recognition, tracking and localization, real-time monitoring, printed product quality inspection, image coding, security surveillance and so on, and it plays an increasingly important role [5].

3. Methodology

The high-speed acquisition system of fuzzy image data has many hardware devices. The system uses the visual processor, the coordinate processor, the fragment processor, and shader to collect fuzzy image information data and uses the Kalman filter for auxiliary operation, so the system can achieve the high-level display of blurred images by the system, accurate prediction of behavior, and high-speed acquisition. The operating flow of the whole system can be observed by computer [6].

The fuzzy image processing module uses the visual processor, the frame buffer, the coordinate processor and the fragment processor to process the data of fuzzy image. Visual processor unit (GPU) is a kind of display chip especially for image processing and computer CPU image processing (Guo et al. 2014) [7]. In the processing of the fuzzy image information, the acquisition of the target image coordinate is the basic work of the visual processor. The coordinate value of the target image is processed by the coordinate processor and is then transmitted to the frame buffer for temporary storage. The coordinate processor first transforms the stereo coordinates of the target image into two-dimensional coordinate, then converts the blurred image into the raster image by the rasterization operation and carries out the block restoration on the raster image, thereby resulting in black and white pixels [8].

In order to read black and white pixels information of fuzzy image, it is necessary to connect the frame buffer through the bidirectional diagnostic control interface and display the processing result directly on the computer screen [9]. Black and white pixel images need to be rendered to match the hue of the blurred image. Figure 1 shows the structure of the rendering pipeline of the blurred image processing module.

As can be seen from Fig. 1, the rendering of the visual processor is performed mainly by coordinate processors and fragment processors. The amount of memory that a coordinate processor and a fragment processor can hold is extremely low, so they can only process the black and white pixel image data of the blurred image in real time, and the output of the results will be stored in the frame buffer. The coordinate processor processes the coordinate values of the black-and-white pixel image information data, and the processing result is transmitted to the fragment processor. At the same time, the visual processor transmits the original blurred image information to the fragment processor via its own interface. The fragment processor simulates its texture memory before receiving the original fuzzy image information data, so as to improve the computing power of the fragment processor, which is convenient to the zero offset rendering of black and white pixels by the fuzzy image processing module [10].

The color flow of vertex shader to black and white pixel images and the processing flow of fuzzy image processing module are corresponding. A fuzzy image processing module is used to process the blurred image, and the processing results are transmitted to the vertex shader for real-time color filling [11]. The structure of the vertex shader is shown in Fig. 2.

As can be seen from the diagram, vertex shaders have strong computing abilities, and they can handle four different types of registers at the same time. Color spaces

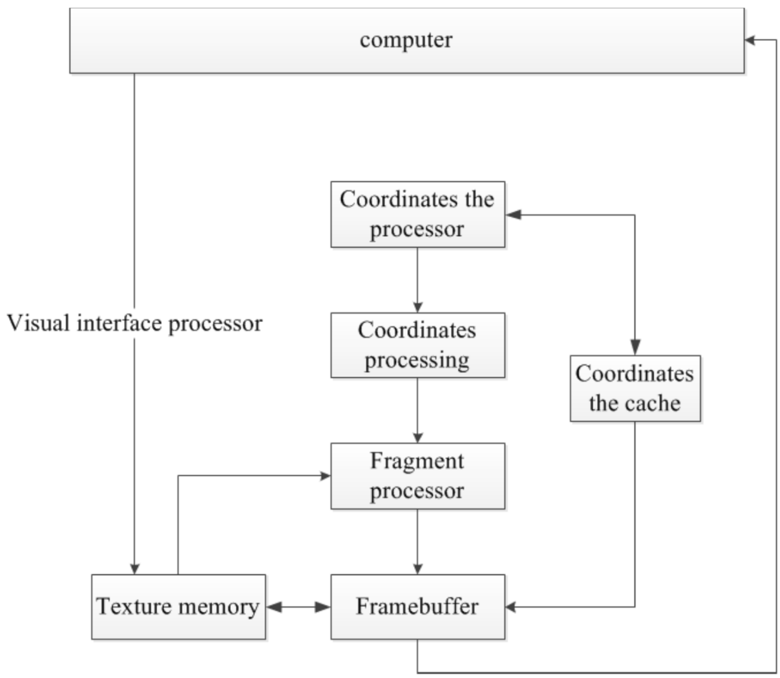

Fig. 1. Structure of the rendering pipeline of the blurred image processing module

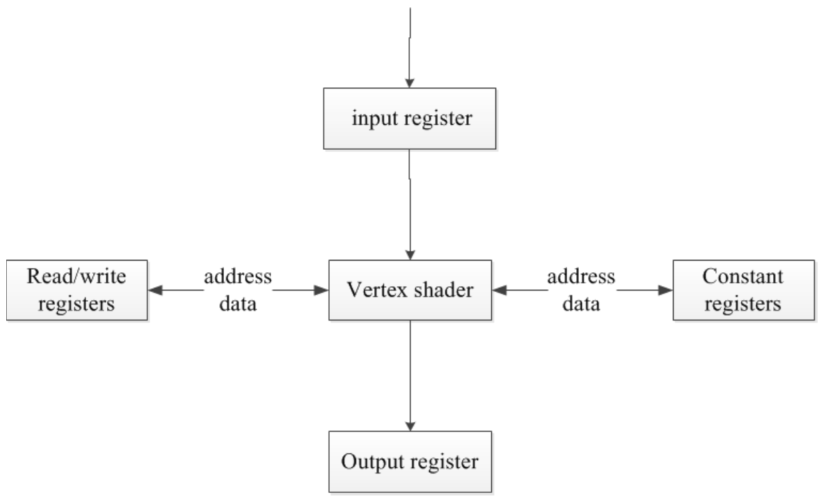

Fig. 2. Structure diagram of vertex shader

are usually divided into four types: red space, blue space, green space and three primary colors. The colors in the original blurred image are classified into four color spaces, and each color space is selected by a different register, so there are 4 different types of registers in the vertex shader. Registers store fuzzy image color information data, and other fuzzy image information data are also stored completely in real time. The input register stores data such as vertex coordinates, prediction displacement and prediction speed; the output register stores the color fill results of the vertex shader; the register and constant register are directly controlled by computer; the computer stores the coloring algorithm and language of the high-speed acquisition system of the fuzzy image information. Registers are also often used as temporary storage areas for data information of target objects in blurred images.

The pixel shader processes the rendered black and white pixel images in two ways: texture memory sampling and pixel computing. The pixel shader operator can provide add, multiply, dot product and so on for the high-speed acquisition system for blurred image information, and texture memory sampling and pixel computing are performed in the arithmetic unit. The operator samples the texture coordinates in the original fuzzy image data, and then obtains the important information data by pixel calculation. The pixel shader fills the black and white pixel images with large areas of color based on pixel results. At the same time, the filling result of the vertex shader is also passed to the pixel shader's storage register, and the operator combines the fill results of the two shaders to produce full color images. Finally, through the output register, the full color image information of the blurred image is transmitted to the computer display.

Kalman filtering is an optimal estimation method based on linear function observation data, and each processing process of the fuzzy image information data is well stored. When the system processes the fuzzy image information again, it will refer to the previous processing flow, and compare and perfect the reference value and the actual processing result, until the optimal processing result is obtained.

The fuzzy image model is constructed and the Kalman filter is used to analyze the fuzzy image parameters, so as to divide the fuzzy image information data and combine them into a plane fuzzy image, and the reason is that the information data plane blurred image is more intuitive.

Supposing that the length and width of a rectangular fuzzy image $g(k, j)$ to be processed are the ranges of horizontal and vertical coordinates of fuzzy image in model M, N, k, j respectively, the image split after the initial blurred image can be shown as$f(k, j)$, as shown in the formula

$$f(k, j) = Af(k-1, j) + v(k-1, j)\,. \tag{1}$$

Here, A is the fuzzy image matrix, and its value is related to k under special conditions; v is the estimated value of preprocessing of fuzzy image and it is often expressed as a unary regression function. With the deformation treatment to formula (1), the fuzzy image estimation $g(k+1)$ can be obtained, as formula

$$g(k+1) = HAf(k-1, j) + Hv(k-1, j) + n(k, j)\,. \tag{2}$$

Here, $k \in [0, M]$, $j \in [0, N]$, and k and j are natural numbers; H is transfer matrix of split image in blurred image and $n(k, j)$ is the estimated value of fuzzy image processing by Kalman wave filtering.

According to formulae (1) and (2), the restoration equation of the blurred image is shown in the formula

$$f(k) = f(k-1) + K(k)e(k)\,. \tag{3}$$

In the above formula, $e(k)$ is the difference between the actual value and the estimated value, so it is called the estimated optimization value; $K(k)$ is the weighting function of $e(k)$, and its value is equal to the inverse matrix of H. The bigger $K(k)$ is, the higher the sharpness of the image collected by the high-speed acquisition system of the blurred image information data will be and the smaller the system acquisition error will be. Using the following expressions, $K(k)$ can be obtained in this way

$$K(k) = P_1(k)H^{\mathrm{T}}[HP_1(k)H^{\mathrm{T}} + R(k)]^{-1}\,, \tag{4}$$

$$P_1(k) = AP(k-1)A^{\mathrm{T}} + Q(k-1)\,, \tag{5}$$

$$P(k) = P_1(k) + K(k)HP_1(k)\,. \tag{6}$$

Here, T represents one-dimensional length of the fuzzy image, $P(k)$ is the minimum estimation bias matrix for optimal gain, $P_1(k)$ is the estimation bias matrix of $Af(k-1)$, Q is the covariance function of v and R is the covariance function of n.

In order to reduce the computational complexity of the fuzzy image data high-speed acquisition system, the one-dimensional image collected by the system should be restored. Now that the one dimensional images are moving in uniform rectilinear motion; based on the Kalman wave filtering, $HAf(k-1)$ can be calculated, and then the estimated optimization value of $e(k)$ can be obtained, using the formula

$$e(k) = g(k) - HAf(k-1)\,. \tag{7}$$

The recovered estimate is shown in the formula

$$f(k) = e(k) + Af(k-1)\,. \tag{8}$$

4. Result analysis and discussion

In the experiment, the display level, the performance prediction accuracy and the collection efficiency of the high-speed image acquisition system designed by the fuzzy image data were verified. The verification method was that the high-speed acquisition system with high performance of fuzzy image information was compared with the system designed in this paper. The selected contrast systems were the high-speed image acquisition system based on PXI bus and the high-speed acquisition system based on FPGA and USB for the fuzzy image information.

The experiment tested the display effect of the three systems, on the blurred image first. Figure 3 shows initial fuzzy images that needed high-speed acquisition of information data. With the acquisition of the blurred image by the three systems under the same conditions, the output results were obtained, as shown in Figs. 4–6.

Fig. 3. Initial fuzzy image

Fig. 4. Output image of high-speed acquisition system of blurred image information based on FPGA and USB

As can be seen from Figs. 4–6, the high-speed acquisition system of fuzzy image information based on FPGA and USB could barely display the license plate of the blurred image in the experiment under the same conditions. But in the complex fuzzy image, it could be seen as invalid display. Therefore, on the basis of guaranteeing the display level, the high-speed acquisition system of the fuzzy image data based on FPGA and USB effectively improved the processing and storage efficiency of the system by using FPGA and USB. But the functions of the system were simple, so it was only suitable for fields without high demands for high-speed acquisition system of fuzzy image. The high-speed acquisition system of fuzzy image information based on PXI bus had good display effects, but it carried out the design of display terminal for fuzzy image restoration, used the display processor optimization of acquisition high performance resources, and realized the display of high-level fuzzy image by the system. So the collection efficiency of this system still has more rooms for improvement. Compared with the two systems, the display effects of this system are closer to the real object, so the system has excellent display effects.

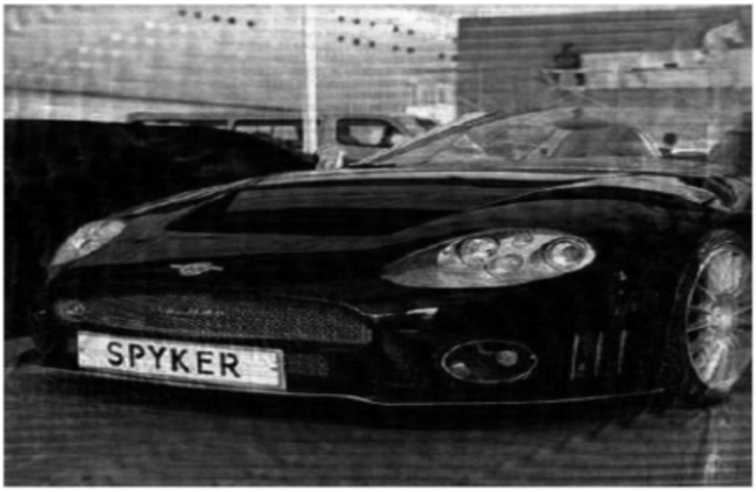

Fig. 5. Output image of high-speed acquisition system of fuzzy image information based on PXI bus

Fig. 6. Output image of the system presented in this paper

The experiment also used the prediction of the behavior of the cars in figure 4 by these three systems (the direction of the north was 0°), and analyzed the working hours of the three systems statistically. Table 1 shows a comparison table of the behavior prediction of three systems, and Table 2 shows the statistical table of the total use time of three systems.

Table 1. A comparative table of behavior predictions for three systems (°)

	Based on PXI bus	Based on FPGA and USB	System in this paper
Actual direction of the car	-90	-90	-90
Predicted vehicle direction	-86	-88	-90
The actual running direction of the front wheel	-60	-60	-60
Predicted front wheel running direction	-57	-58	-60
Actual running direction of the rear wheel	-40	-40	-40
Predicted rear wheel running direction	-56	-56	-40

Table 2. A statistics table of total usage statistics for three systems (ms)

Experimental data acquisition system	Processing time	Acquisition time	Total useful time
Based on PXI bus	16	10	26
Based on FPGA and USB	11	8	19
System in this paper	9	5	14

As shown in Table 1, the prediction accuracies of the three systems were remarkable, but the prediction accuracy of the system in this paper reached 100 %, so the system had extremely good predictive abilities. Table 2 shows that the total working time of the system in this paper on the blurred image in Fig. 4 was 14 ms, which was lower than that of the high-speed acquisition system based on fuzzy image data of FPGA and USB for 5 ms and lower than that of the high-speed acquisition system based on fuzzy image data of PXI bus as 12 ms. So it was proved that the system in this paper has the advantage of high collection efficiency. The experimental results show that the system designed in this paper has better display performances, the accuracy of prediction and the collection efficiency.

5. Conclusion

The system designed in this paper used fuzzy image processing module to raster the data of fuzzy image and to render images of black and white pixels, and used Kalman filter to deal with fuzzy information of image data. Through this study, the following conclusions were obtained: the efficient processing of high-speed acquisition system of fuzzy image data of the fuzzy image data is based on the high speed and accurate acquisition of fuzzy image data. If the processing result is not accurate, all the works performed by the collector are invalid. The system uses Kalman filter to process the fuzzy image information data, so the data are more easily to be collected. After the visual processor is rendered, the image data of black and white pixel still has some differences with the original fuzzy image information data. Combining vertex shader and pixel shader and filling black and white pixel image can guarantee the display effect of fuzzy image data high-speed acquisition system on fuzzy image, and also can improve the collection efficiency of the system. However, there are still some defects that need to be improved in this paper. For example, the high-speed acquisition system and the computer network system can be combined to achieve real-time data acquisition and delivery.

References

[1] Z. J. Geng: *Rainbow three-dimensional camera: New concept of high-speed three-dimensional vision systems.* Optical Engineering *35* (1996), No. 2, 376–383.

[2] R. Castañeda-Miranda, E. Ventura-Ramos, R. del Rocío Peniche-Vera, G. Herrera-Ruiz: *Fuzzy greenhouse climate control system based on a field programmable gate array.* Biosystems Engineering *94* (2006), No. 2, 165–177.

[3] Q. Zhou, J. Ma, Y. Dong, J. Li: *Design of the image acquisition system based on the low power microcontroller.* Electronic Measurement Technology *98* (2014), No. 03, paper 023104.

[4] J. Dubois, D. Ginhac, M. Paindavoine, B. Heyrman: *A 10 000 fps CMOS sensor with massively parallel image processing.* IEEE Journal of Solid-State Circuits *43* (2008), No. 3, 706–717.

[5] K. H. Ang, G. Chong, Y. Li: *PID control system analysis, design, and technology.* IEEE Transactions on Control Systems Technology *13* (2005), No. 4, 559–576.

[6] A. Telesca, F. Carena, W. Carena, S. Chapeland, V. Chibante Barroso, F. Costa, E. Dénes, R. Divià, U. Fuchs, A. Grigore, C. Ionita, C. Delort, G. Simonetti, C. Soós, P. Vande Vyvre, B. von Haller: *System performance monitoring of the ALICE data acquisition system with Zabbix.* Journal of Physics: Conference Series *513* (2014), No. 6, paper 062046.

[7] Y. N. Wang, T. Chen, Z. D. He, C. Z. Wu: *Review on the machine vision measurement and control technology for intelligent manufacturing equipment.* Control Theory & Applications *3* (2015), No. 03, 273–286.

[8] M. Delbracio, P. Musé, A. Almansa: *Non-parametric sub-pixel local point spread function estimation.* Image Processing On Line *10* (2012), No. 2, 8–21.

[9] Y. Y. Lei, L. I. Zhi: *Design of data acquisition system based on producer/consumer.* Machinery (2011), No. 09.

[10] M. N. Inanici: *Evaluation of high dynamic range photography as a luminance data acquisition system.* Lighting Research & Technology *38* (2006), No. 2, 123–136

[11] F. Ran, H. Yang, S. P. Huang: *Design of real-time color video capture system for area array CCD.* Optics and Precision Engineering *18* (2010), No. 1, 273–280.

Received June 6, 2017