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Research on Fast Object Detection of CCD Astronomical Image

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Abstract. As the imaging technology improves the resolution of the astronomical image, how to effectively and efficiently extract objects has become a big challenge. As the dimension of the CCD image matrix is increasing with the increase of the astronomical image resolution, the traditional method which needs to detect objects point-by-point can't satisfy practical usage due to their low detection efficiency. A novel traversal method based on the extraction of the block matrix is proposed in this paper, which overcomes the limitations of traditional traversal methods. The proposed method extracts these data that are larger than the threshold to generate new small matrices by four corners positioning to avoid the traversal of the whole matrix for object detection. Then these small matrices are respectively traversed. The experiments show that the proposed algorithm can greatly improve the computing and searching efficiency.

Introduction

The object detection of high-resolution images is one of the most important means of studying the universe [1].There are extensive and urgent demands for optical imaging technique of spatial high resolution in terms of optical remote sensing, astronomical observation, and deep space exploration project and so on. The Sloan Digital Sky Survey (SDSS) is a multi-band data CCD astronomical observing project. It can measure the distance of more than 100 million galaxies and quasars, and upcoming surveys will provide greater data volumes. At home, LAMOST is also known as Guo Shou-jing telescope [2]. It will produce 107 orders of magnitude spectral data in the next 5 to 10 years [3]. Therefore, efficient and accurate detection will be a large challenge [4]. In [5], Masias et al. reviewed the current algorithms of astronomical object detection, and summarized three methods: Firstly, they are based on contour extraction and matching. Secondly, they are based on peak detection and filtering. These methods are currently most used in the field. Thirdly, they are based on centroid detection. According to the characteristics of CCD astronomical image, the method of peak detection is used in this paper. Eight connected method is usually used to find the center [6].

The traditional algorithm usually needs to use the statistical characteristics for noise reduction. However, the noise reduction needs to traverse the whole matrix, which is not conducive to real-time processing. Aiming at this problem, this paper uses a threshold to extract these gray values that meet the condition from the original matrix. These gray values are located to extract some small matrices from the original matrix according to their coordinates, and then these small matrices are traversed. Thus the reduction of the number of traversing the whole matrix greatly improves the efficiency of the algorithm.

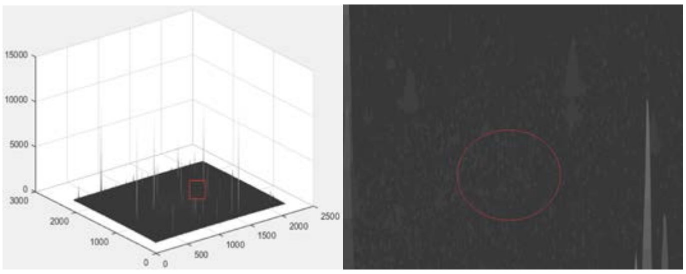
Noise Reduction of Traditional Algorithm.

Noise Analysis. The model of CCD astronomical image is given in [7] (As shown in equation (1)). r(x, y, t) represents the original image. c(x, y, t) represents the Gaussian noise caused by the circuit. d(x, y, t) represents a Poisson noise caused by dark current and background. s(x, y, t) represents a moving object signal. n(x, y, t) represents a star. Fig. 1 is a typical CCD astronomical image.

r(x, y, t)=c(x, y, t)+d(x, y, t)+s(x, y, t)+n(x, y, t) (1)

The background of the original astronomical image contains a lot of noise due to the impact of photon noise and electronic noise and so on. The noise and the object both show some irregular cone in the 3D image in Matlab (As shown in Fig. 2), so the noise has a great influence on the peak detection. Therefore, the first step of object detection is to eliminate the influence of noise and background. Aiming at this problem, the traditional algorithm is usually to set a threshold for noise reduction.

Fig. 1 Original image



a. Full picture b. Enlarged portion

Fig. 2 3D display of the original image

Noise Reduction. Astronomical images are usually stored with the format of FITS. In Matlab, astronomical images will be converted into a matrix. The background of the astronomical image obeys the Poisson distribution and converges to the Gaussian distribution (As is shown in Fig. 3). According to this characteristic, the matrix is denoised with using the mean and the standard deviation of gray values of the image to obtain a sparse matrix with few non-zero values [8].

The gray value of astronomical image follows an approximate normal distribution, and most of the gray value is concentrated in a fixed area (As shown in Fig.3), which contains most of the background noise. Therefore, the process of noise reduction is an important step in the astronomical object detection in the traditional algorithm [9] (The image after noise reduction is shown in Fig. 4.).

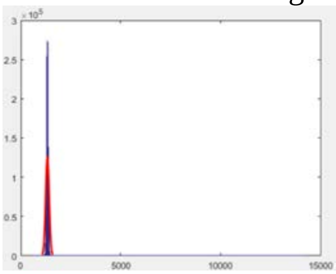
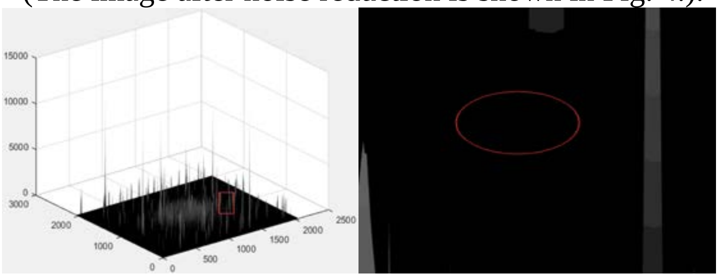


Fig. 3 Background histogram fitting



a. Full image b. Enlarged portion

Fig.4 Image after noise reduction

A sparse matrix is get after traversing the whole matrix for noise reduction, and then the sparse matrix is traversed for a second time to obtain objects by peak detection. Therefore, this algorithm will greatly reduce the efficiency of processing due to traversal times.

Proposed Algorithm.

As traversing the whole matrix needs to spend a lot of time, this paper does not process the image for noise reduction, but directly selects these values that meet the condition for extracting, proceed as follows:

Step 1: Image data read. The file is read with using the fitsread function, and stored in the matrix A;

Step 2: Image parameters calculated. The mean μ0 and the standard deviation σ0 of the original image are calculated respectively in Matlab;

Step 3: Screening threshold selected. The screening threshold is μ 0 + k σ 0, and the value of k is set to 8 in advance according to the analysis of a large number of astronomical images;

Step 4: Value selected. Values in matrix A that are greater than μ0 + kσ0 are selected. These coordinates of these selected values are stored in the matrix C, and then the matrix C is transposed to matrix D;

Step 5: Matrix extracted. Matrix D is blocked to get each small block of the coordinate matrix E with using the characteristics of the record in accordance with the abscissa in ascending order in matrix D;

Step 6: Partitioned coordinates mapped. Matrix E is mapped to matrix A by four corners orientation to get a series of corresponding small matrix (As is shown in Fig 5);

749	878	966	853	679
941	1267	1365	1203	867
1098	1513	1560	1292	913
973	1203	1222	1111	810
730	823	817	770	700
580	586	613	597	570

Fig. 5 Extracted matrix of four corners orientation

749	878	966	853	679
941	1267	1365	1203	867
1098	1513	1560	1292	913
973	1203	1222	1111	810
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Fig. 6 Peak detection of extracted matrix

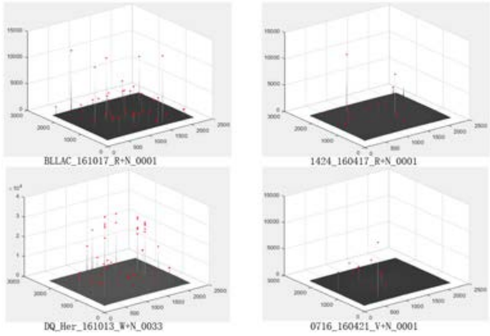

Fig. 7 3D Display of proposed algorithm

Step 7: Extracted matrices traversed. These small matrices extracted from matrix A are traversed, and corresponding results are obtained by peak detection (As is shown in Fig 6). Partial results of simulation is shown in Fig 7, and red dots are objects.

Data and Experimental Environment.

These images for analysis in this paper are from WOSDU (Weihai Observatory of Shandong University), the pixel of these pictures is 2048 * 2048pixel, and the grayscale is 16bit. The format of storage is fits. The platform of software is MatlabR2015b. Running environment is the Windows 10 Professional Edition, and the configuration of hardware is the Intel Core i7-6700 and 16G memory.

Experimental Results.

Cosmic rays are charged high-energy sub-atomic particles from outer space, which cause isolated points in the astronomical image. This isolated point is also a kind of peak, but is not a celestial object. Therefore, this paper does not consider.

As the algorithm will be running in the interference of some other softwares, the result will have a little deviation. These astronomical images are calculated respectively by using the traditional traversal algorithm and the proposed algorithm based on extracted matrix. The experimental contrast is shown in Fig. 8.

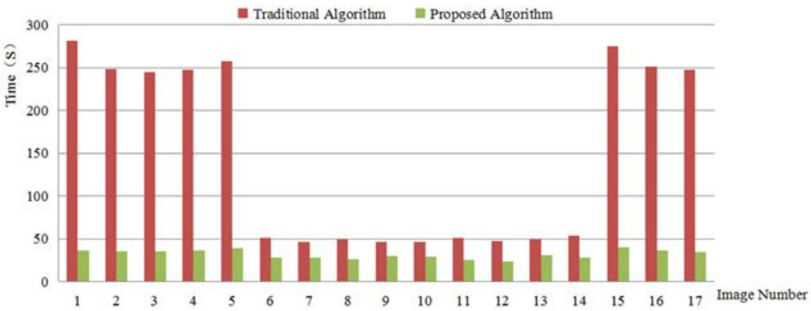

Fig. 8 Algorithm contrast

Table 1. Average running time of 17 tested CCD astronomical images by two algorithms

Algorithm	Average running time[ms]
Traditional Traversal Algorithm	146.470588
Proposed Algorithm	31.705882

As can be seen from Fig. 8 and Table 1:

(1) Efficiency of the algorithm. When it comes to the same image, the algorithm proposed in this paper is more efficient than the traditional algorithm, and sometimes even 10 times.

(2) Stability of the algorithm. Time variance of the traditional algorithm is a little bit big, but the proposed algorithm is very stable.

In addition, when it comes to the large number of images, these extracted small matrices of the proposed algorithm can be put on many distributed platforms for processing to improve the efficiency further.

Summary

Aiming at the problem of object detection of CCD astronomical image, this paper proposes a fast target detection algorithm based on extracted matrix combined with the characteristics of astronomical image data. Experimental results of the verification and analysis of several groups of images show that the proposed algorithm can greatly improve the efficiency and stability of the detection.

Acknowledgements

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References

[1] C.G. Ren, Y. H. Liang and Q. F. Yu: Acta Photonica Sinica Vol. 43(2014), p. 1429

[2] J. Liu, J. C. Pan and et al: Spectroscopy and Spectral Analysis Vol. 35(2015), p. 3524

[3] A.L. Luo, H.T. Zhang and et al: Research in Astronomy and Astrophysics Vol. 2(2012), p. 1243

[4] M. Selig, T. A. Enblin: Astronomy & Astrophysics Vol. 574(2015), p. 399

[5] M. Masias, J. Freixenet and et al: 2012, Monthly Notices of The Royal Astronomical Society Vol. 422(2012), p.1674

[6] Z.X. Ma, Z.Y. Wu et al: Journal of Shanghai Normal University(Natural Sciences) Vol. 45(2016), p. 230

[7] Y. L. Han, F. Liu: Electro-Optic Technology Application Vol. 28(2013), p. 37

[8] F. Jiang, X. T. Wu and et al: Journal of Computer Applications Vol. 35(2015), p. 726

[9] H. Liao: Technology Innovation and Application Vol. 21(2016), p. 72