Edge detection of archaeological site based on high resolution image

ZHU Jianfeng[1], **NIE Yueping**[1], **YANG Lin**[2]

1. *Institute of Remote Sensing Applications of Chinese Academy of Sciences, Beijing, 100101, China;*
2. *National Museum of China, Beijing, China*

Abstract: In the recent years, the usage of high resolution images has made a significant contribution to our improved archaeology. Given that the archaeological mark is critical for the analysis and predetermination of ancient sites, its edge feature is required to be detected against the surrounding. In traditional methods, time consuming and costs a lot. The archaeological marks are not always identified, especially when the edge features obscure in low contrast environment. The edge detection technology can not only highlight the edges of archaeological site, but also filter the noises from the surrounding environment. Therefore, it is particularly useful to extract the weak edge information automatically from high resolution image by computer algorithm. The representative methods based on edge gradient are Sobel, Roberts, Prewitt and Laplacian operator. However, they have the same drawback that it is sensitive to noise and the edge is not located accurately. The Canny operator can reduce the noise and keep the edge intact to a great extent and perform well to most of archaeological sites. We choose the classical relics in Xinjiang for comparison of different edge detection methods. It is concluded that the Canny operator achieve the best result in different environments in high resolution image from experiments. And it is applicable for archaeological prospection and feature extraction.

Key Words: edge detection, canny detector, archaeological site, high resolution image

CLC number: （需查询中图分类号） **Document code:** A

1 INTRODUCTION

China has a long civilization and rich cultural heritage. And a large amount of historical relics are yet required to discover and protect. During these archaeological researches, people get to know the ancient Chinese culture and learn from the laws of historical development. With the application of spatial observer technology in archaeological field, the research measures diversified. In the recent

Received: ; **Accepted**:

Foundation: Foundation Item: 1025 national science and technology support projects “Tracing Source Project of Chinese Civilization and Related Technology Research about the Protection of Cultural Relics” （2010BAK67B07）

First author biography: Zhu Jianfeng (1983—), male, Research Assistant…. (Graduated from ， Study on archeological information extraction and palaeoenvironment analysis, published articles:6) E-mail:jfzh123@163.com

years, the usage of high resolution images form optical sensors has made a significant contribution to our improved archaeology (P Sheets & T L Sever, 1998; C D Clark, et al., 1998; T L Sever, 1998). Given that the archaeological mark is critical for the analysis and predetermination of ancient sites, its edge feature needs to be detected against the surrounding (Nicola Masini & Rosa Lasaponara, 2007). In traditional methods, the archaeological marks are identified by interpretation in the image (R Lasaponara and N Masini, 2006; I Shennan and D N M Donoghue, 1998). So the accuracies of the results mainly depend on archaeologist's expertise and the resolution of the image they use, which is greatly affected by human factors. Also this method is time consuming and costs a lot. The archaeological marks are not always identified, especially when the edge features obscure in low contrast environment.

The edge is one of the most important features of the archaeological remains in the image. The purpose of the edge detection is to find the real edge that partitions the boundary between relic and surrounding. The edge detection technology can not only highlight the edges of archaeological site, but also filter the noises from the surrounding environment (T. Lindeberg, 1998; Chen Y S and Hsu W H, 1998). Therefore, it is particularly useful to extract the weak edge information automatically from high resolution image by computer algorithm. The extraction results mainly depend on whether the method is reasonable and the surface situation is favorable. The representative methods based on edge gradient are Sobel, Roberts, Prewitt and Laplacian operator (Duan R L, et al., 2005.). They post a better performance when the gray value in the edge area changes sharply and the noise of the image is low by convolution operation. But if the gray value varies slowly, the edge will get to be thick. Otherwise, all these operators have the same drawback that it is sensitive to noise and the edge is not located accurately. The canny operator can improve these drawbacks. In this paper, we make experiments on different relics to examine the validity of these edge detection methods under different classic environments.

2 METHODOLOGY

The edge in the image is caused by the changes of the physical characteristics of different objects. It is often the area of obvious gray changes or the border where gray values increase or decrease. The edge contains bounds of information, such as direction, shape, characteristic of step change and so on. The edge detection is an important study in the field of archaeological information extraction. It detects the border between the object and background by gray gradient.

The traditional edge detection methods mostly extract edge information from high frequency component of image mainly by differential operation. It works well when the edge gray transfers very sharply and the signal to noise ratio is low. The classical edge detectors are first partial differential operators such as Roberts, Sobel, Prewitt and the second partial differential operator Laplacian of Gaussian. Compared to first order differential operators, the Laplacian of Gaussian operator whose advantages are that it can not only detect most edges, but also locate the edges accurately because of isotropy, however, enhances the effect of noise and extracts two-pixel-width edge which is non-directional. But these methods are sensitive to noise, so the result is dissatisfied.

As an optimal edge detector, the Canny operator which reflects the mathematical characteristic, is an approximating method to optimize the product of noise ratio and position. It is universally applied in the image-processing field. The basic idea is to process the image by Gauss smoothing firstly, and ascertain the edge points based on first derivative maximum. It obtains an optimal edge detector template through a numerical optimization technique (Li M, et al., 2007). During the processing of a two-dimension image, template with different directions is needed to execute convolution operation separately, and then the most possible edge direction is confirmed.

Canny operator smoothes the image and calculate gradient with first order derivation of Gauss function to accomplish noise suppression and obtain accurate edge position. It is equivalent to executing convolution to image signal. The Gauss function is expressed as follows:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \quad (1)$$

In which, σ is convolution kernels width of Gauss filter, controlling the smoothness result.

This processing can be expressed with mathematical equation. We define the original image with *I(i,j)*, and the filtered image with *S(i,j)* whose partial differential value in x is defined as *P(i,j)* and in y as *Q(i,j)*.

$$P(i, j) = \frac{x}{\sigma^2} \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (2)$$

$$Q(i, j) = \frac{y}{\sigma^2} \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (3)$$

By calculating the average finite difference in 2×2 neighborhood matrix, both the partial differential values can be expressed in the form of array as follows:

$$P(i, j) = \frac{1}{2}(S[i, j+1] - S[i, j] + S[i+1, j+1] - S[i+1, j]) \quad (4)$$

$$Q(i, j) = \frac{1}{2}(S[i, j] - S[i+1, j] + S[i, j+1] - S[i+1, j+1]) \quad (5)$$

The gradient amplitude and orientation of an image is expressed separately in the way of transformation from rectangular coordinate to polar coordinate.

$$M(i, j) = \sqrt{P^2(i, j) + Q^2(i, j)} \quad (6)$$

$$\theta(i, j) = \arctan\left(\frac{Q(i,j)}{P(i,j)}\right) \quad (7)$$

For locating edge accurately, the border where the gray gradient changes needs to be refined and only the points whose amplitude change greatest in the local is kept. This procedure is called the non-maxima suppression. The Canny operator uses a spatial neighborhood with 3×3 size and 8 directions to execute interpolation to all the pixels in the gradient amplitude image *M(i,j)* in gradient directions. The central pixel in the neighborhood is compared with the interpolation of two gradient amplitudes in every gradient direction. If the amplitude of central pixel is not bigger than the interpolation, it is marked as 0 which means not the edge point. After non-maxima suppression, the border is refined as one pixel width.

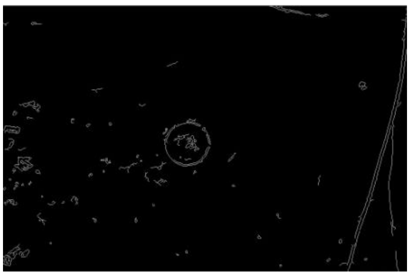
The thresholding result of amplitude non-maxima suppression is an edge array image which contains many false edges. It is difficult to confirm one threshold value to dispose of all these edges, while it becomes more effective with two thresholds (Li G P, et al., 2007; Zhang Z,et al., 2007). We get two edge images $T_1[i,j]$ and $T_2[i,j]$ filtered from double thresholds of τ_1 and τ_2 correspondingly. The edge image $T_1[i,j]$ is formed when the gray of pixel whose gradient value smaller than τ_1 is set as 0. So is the edge image $T_2[i,j]$. As a result of higher threshold, the $T_2[i,j]$ image includes less false edges and loses some useful edge information. Bounds of edges are kept in image $T_1[i,j]$. Hence, the edges of image should be linked based on image $T_2[i,j]$, supplied with image $T_1[i,j]$.

3 EXPERIMENTAL RESULTS

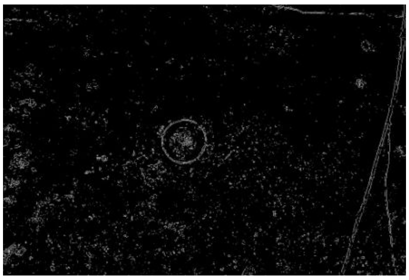
Xinjiang is particularly the case for civilization trace in western regions of China, with wide stretch of land and abundant precious ruins. It is also important for archaeologist to study the relationship between China and West Asia. And in parts of this area, the detection of archaeological sites there sometimes is difficult because of complex geographic environment. The edge detection based on image processing technology can extract the useful edge information. But it differs with the change of the geographical environment. We choose the classical regions and universal archaeological sites for comparison of different edge detection methods. For extracting the edges accurately, the Qucikbird images are used with 0.6m resolution. The high spatial resolution can satisfy the requirement of edge details recognition.

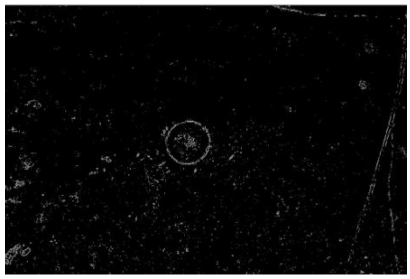
The ancient grave is an important type of relic in a huge amount in Xinjiang. Tasibulake grave is located in the hillside field of Altay prefecture. The environmental structure is simple surrounding this relic in the image（see Fig. 1(a)). The edge of the grave is detected together with road in all the five methods. From the comparison, the Canny operator performs best. It suppresses the noise to the greatest extent and keeps the contour completely（see Fig.1(b)）. By Prewitt, Roberts and Sobel operator (see Fig.1(c) (d) (e)), some of the noises in the image appear in the edge circles, and others distribute in the Gobi representing where the gray change sharply. Furthermore, the edges are not continual. The Log operator is less effective to noise suppression and the false edges increases obviously (see Fig.1 (f)).

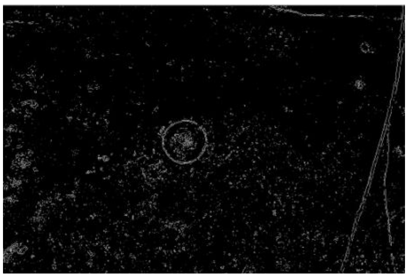
(a) Original image



(b) Canny


(c) Prewitt


(d) Roberts


(e) Sobel

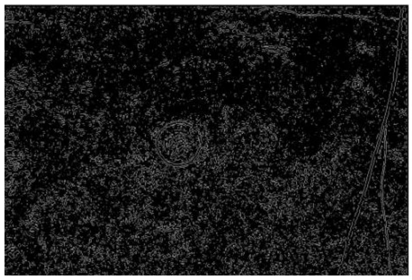
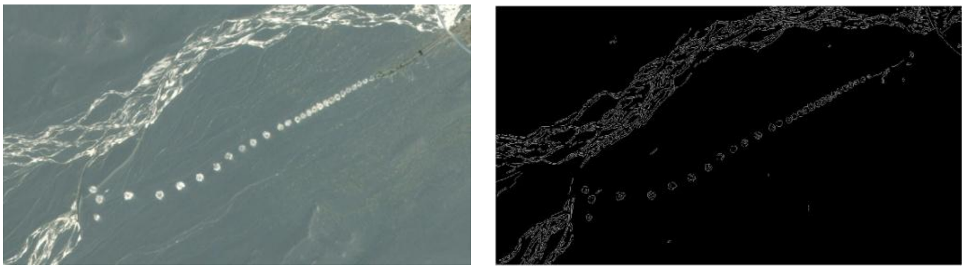

(f) Log

Fig. 1 Comparison of Tasibulake grave with different operators

Karez has a long history in Xinjiang and is important for people living in arid area. A general Karez is a four-part organization of illegal channels, open channel, shaft, and water logging dam four-part organization. As the Aihaiti Karez of Turpan prefecture shown in the Quickbird image (see Fig. 2(a)), the open channel and shafts are clearly found out from the Gobi desert. The shafts and illegal channel is the object for edge detecting, and they all can be detected with Canny operator clearly together with the river bed. There are little noises in the edge image (Fig. 2(b)). While the ancient city of Andiertim located in the desert in Hotan prefecture seems not highlighted as the detecting effect above. The edge of city wall is confused with other edges, though the shape is distinct, because the bare ground has the similar spectral characteristic with the city wall. In this condition, gray change has no particular difference. So the edges extracted are not only the ancient city walls, but also the bare ground border (see Fig. 3).

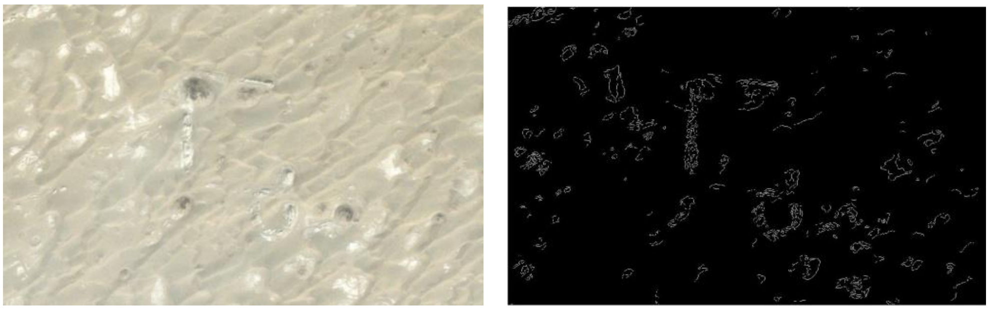
In our experiment, we find that the effect is controlled by the two thresholds of Canny operator to a great extent. If τ_2 is defined with higher values, it will lose some edges with little gray change and keep the edges with severe variation of gray value. On the contrary, if τ_2 is set lowly, the number of false edges detected rise up. The low threshold τ_1 plays an important role in controlling the detection termination and connecting the discontinuity contours. The low threshold τ_1 is generally not higher than half of τ_2. The inappropriate threshold will bring out many false edges, producing a great influence of detection effect. The two thresholds are defined after experiments for better result.

Canny operator has a better suppression of the noise and more accurate location and connectivity to edges than other operators in this paper. It is applicable for edge detection of archaeological site. However, with less regard for local feature information, it can't eliminate the local noise, and sometimes loss the edge where the gray changes slowly, causing the edge contour discontinuity. In summary, we draw a conclusion that, the Canny operator could detect different types of archaeological sites and work well, besides the edge gray contrast caused by environment factor may have a certain influence on the effect in the edge image.



(a) original image (b) Canny

Fig.2 Edge detection of Aihaiti Karez with Canny operators (Canny thresholds are 0.3 and 0.6)



(a) Original image (b) Canny

Fig.3 Edge detection of Andiertim City with Canny operators (Canny thresholds are 0.3 and 0.8)

4 CONCLUSIONS

Archaeological mark is the basic of remote sensing recognition. The edge detection method could extract the contour of the archaeological mark formed in the high resolution image, reflecting the site shape. This paper makes comparisons of the results from different detectors and relic types. It is concluded that the relics of Kraze, the grave and the ancient city are all appropriate to edge detection, provided with enough gray variation. And among the five universal edge detection methods, the Canny operator achieves the best result in different environments in high resolution image. The main conclusions of this paper are as follows:

(1) Canny operator performs best among these detection methods. It controls the noise greatly and extracts accurate thin edge with adjusting two thresholds. However, some more improvements are required to propose on local noise suppression and discontinuous edge connection.

(2) The edge with sharp gray variation is prone to being detected in the high resolution image. The detection results have little to do with relic type, but depend on surrounding environment a lot. In complex surrounding environment, the imperfect edge of relic or the fragment of object causes false edge contour distributed around the actual relic edge in the image, making the required information

from archaeological mark less prominent.

(3) The high resolution image provides detail information, making edge detection be possible. With the higher resolution, the detection accuracy will be increased up to a point. But the improvement of edge detection method is critical. So far, the edge detection method is yet helpful for archaeological prospection. It raises the efficiency and accuracy of remote sensing interpretation. For weak archaeological mark information extraction, it also provides important edge feature of an ancient site.

REFERENCES

C D Clark, S M Garrod, M Parker Pearson. 1998. Landscape archaeology and remote sensing in southern Madagascar, *International Journal of Remote Sensing,* **19** (8):1461-1477

Chen Y S and Hsu W H. 1998. A modified fast parallel algorithm for thinning digital patterns, *Pattern Recognition Letters*, **7**(2):99-106

Duan R L, Li Q X and Li Y H.2005. Summary of image edge detection. *Optical Technique,* **31**(3):415-419

I Shennan and D N M Donoghue. 1992. Remote Sensing in archaeological research, *Proceedings of the British Academy*, **77**:223-232

Li G P, Lu C H and Li J M. 2007. Characters edge detection and segmentation method based on Canny operator. *Machine Tool and Hydraulics,* **35**(12):42-44

Li M, Yan J H, Li G and Zhao J. 2007. Self-adaptive Canny operator edge detection technique. *Journal of Harbin Engineering University,* **28**(9):1003-1007

Nicola Masini and Rosa Lasaponara. 2007. Investigating the spectral capability of QuickBird data to detect archaeological remains buried under vegetated and not vegetated areas. *Journal of Cultural Heritage.* **8**: 53-60

P Sheets and T Sever. 1988. High tech wizardry, *Archaeology,* **41** (6): 28-35

R Lasaponara and N Masini. 2006. On the potential of QuickBird data for archaeological prospection. *International Journal of Remote Sensing,* **27**:3607-3614

T. Lindeberg. 1998. Feature detection with automatic scale selection. *Journal of Computer Vision*, **30**(2):79-116

T L Sever. 1998. Validating prehistoric and current social phenomena upon the landscape of Peten, Guatemal, in: D. Liverman, E.F. Moran, R.R. Rinfuss, P.C. Stern (Eds.), People and Pixels: Linking Remote Sensing and Social Science. Washington, DC: National Academy Press, 145-163

Zhang Z, Ma S L, Zhang Z B, Liu H, Gong Y X and Sun Q CH. 2007. Improved image edge extraction algorithm based on Canny operator. *Journal of Jilin university(science edition),* **45**(2):244-248