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Infrared Image Edge and Texture Analysis Method based on Visual Habit

Yu Tian-he[1], Yu Xiao-yang[1] and Dai Jing-min[2]

[1]Harbin University of Science and Technology, Harbin 150080, China
[2]Department of Automation Measurement and control Engineering, Harbin Institute of Technology, Harbin 150001, China
ythaa@163.com

Abstract

The general edge extraction algorithm is not ideal to process infrared images, which is low contrast and blurred edge. In this paper, we used the multi-fractal spectrum to edge of infrared image. We extracted the edge information of the image and calculate the measure and fractal spectrum with multiple singular values of each pixel. Analysis of the similarities and differences of multiple measure, the function in edge extraction, meanwhile, analyzed the fiction of fractal characteristics to edge image extraction. This method differs from the traditional gradient algorithm, It determines whether the edge or not just according to the local extreme points , but according to the pixels in the local and global relationships to determine whether the pixel is a real edge. It can neglect important edge pixel and texture pixel, which is more in line with the human visual mental. It provide a good reference for recognition of infrared image and further processing.

***Keywords**: multi-fractal; edge detection; infrared image*

1. Introduction

Infrared image is more and more widely applied in the areas of security, because the infrared light is less affected by weather conditions, and the advantages are more obvious than visible light in the case of the fog and haze and darkness. But the contrast and signal to noise ratio are all lower than the visible light, and in most cases it is the human eye to observe the target for infrared image, which is very meaningful work to the infrared image edge detection and image enhancement. Because it is difficult to obtain the desired image edges with conventional edge detection method, the method of multi-fractal is proposed to detect the edge of infrared image, according to the characteristics of the image itself and human visual psychology to extract the important target in the image edge, to make a meaning basis for the subsequent work of image segmentation and image enhancement.

Edge, as numerical boundary of two different gray in image, it is also one of the basic characteristics of image. Now commonly used edge detection algorithms, such as Sobel, Laplace, Canny operator, *etc.*, [1-4], which is thought by the original image gray gradient analysis of local extreme points, it is sensitive to noise, while the factors of infrared image contrast to its great impact. At present domestic and international some of the non-linear method are explored about image feature extraction algorithm, rather than the conventional mathematical and statistical algorithms. Most surfaces of the natural objects are in line with fractal characteristics [5-8], and for the visual habits, the fractal characteristics of the image is very close to it. In a variety of scales measurement with fractal dimension, dimension does not vary with the change of the scale, but determined by the characteristics of the measured object, so it is able to measure the surface

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roughness of the image. For human visual perception, the larger the fractal dimension of the image, the more rough the image surface observed by vision. In this paper, we obtained image singularity and its multi-fractal spectrum by calculating and analyzing the infrared image pixel gray value with multi-fractal algorithm, thus both can ignore the noise and finely texture information, and accurately edge identification information, and further subsequent image processing.

2. The General Characteristics of Infrared Image

The infrared radiation of the object, through atmospheric propagation, and projected onto the surface of the infrared detector after filtering and focusing action of the infrared lenses, and thus converted into electrical signal, and then into infrared digital image by further processing. Infrared image reflects the heat distribution of the image scene captured, it is gray image no using any color. Accordingly, it is also gray-scale image it displayed. Infrared detector is a device capable of sensing thermal radiation field, and we can convert heat radiation energy into the gray value of two-dimensional image according to the degree of energy with it, energy can be converted to gray scale values through the infrared radiation emitted by the scene. There is difference between visible light and infrared light imaging, environment energy radiation, target and background energy radiation consist of the pictures in infrared imaging. Image gray value difference and temperature difference should be relatively, high temperature corresponding to the big image gray value, so with bright picture, accordingly, low temperature corresponding to the low image gray value and the picture is dark. As shown in Figure 1, we can see that gray values are concentrated in one area from infrared image and the corresponding histogram.

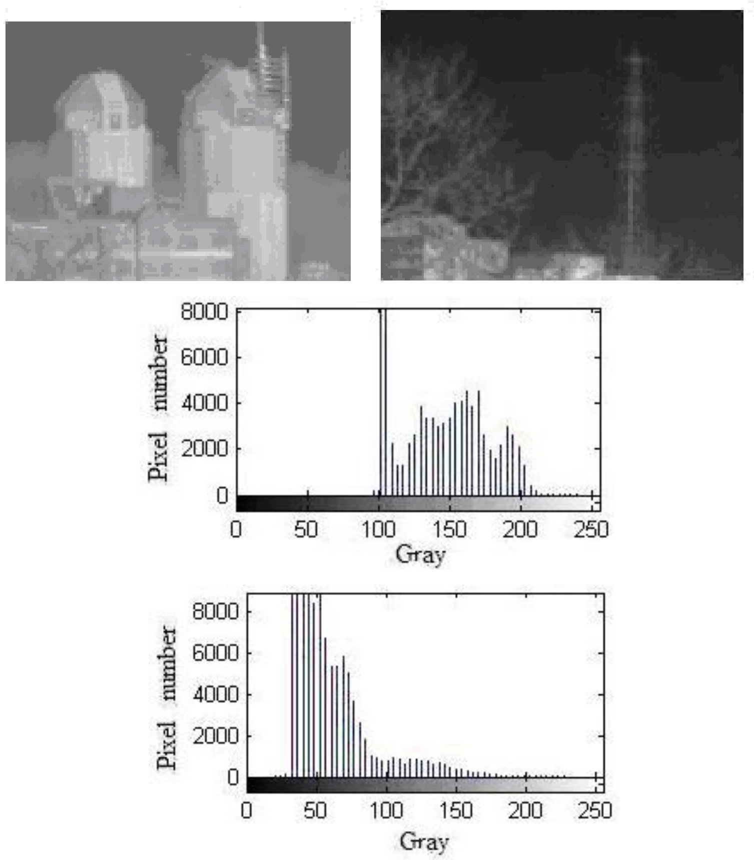


Figure 1. Infrared Image and its Histogram

Resolution of infrared images is lower compared with visible images, and they also have big difference for the same scenery gray-scale imaging. For characteristics of surface detail, many details of the objects surface characteristics can be reflected by visible light, but infrared ray can't. The edges of Infrared image would be edge smooth caused by the temperature drift, and there are also edge missing, thus with more low-frequency component, which reflected by that the edge feature of infrared image is blurred than visible light image. Since infrared images tend to have diverse, different noise, and the noise distribution is very messy with no law, which caused the feature that signal to noise ratio of the infrared image is usually lower than other types of images. Also in infrared detector, the distribution of pixel values is not very uniform due to its characteristics of each unit are not consistent absolutely ,which also resulted in the characteristic of fixed pattern distortion in infrared images.

3. Multi-Fractal Image Analysis

Fractal is nonlinear discipline, and the object researched are often some of the non-differentiable, or not smooth geometry. We can not only completely characterize complex geometric objects in nature with a fractal dimension, then we need to more than one dimension to fully characterize its features. The so-called multi-fractal is the method that describing the overall characteristic of some complex geometry exist in nature through a number of different dimensions, the fractal dimension is constant when it is used to measure the roughness of surface in the case of a variety of scales and resolution, which is the invariant characteristic of fractal dimension [8-12].

Fractal spectrum function can be described situation of each dimension and obtained all levels characteristics of fractal system. Therefore, we can also through first study the local system, and finally get the final overall performance of the system. Multi-fractal is quantification for singular structure of measure, especially suitable for some of the objects difficult to be analyzed and handled with mathematical models, and multi-fractal is to be with good properties on the local and overall when described objects, So multifractal provides new tools for detecting edge detection. It was showed in the experiment that it could not be described the relationship between local and overall when described image with single fractal dimension, the fractal dimension of many image with larger visual difference similar, indicating that the accuracy of single fractal was not enough.

Conventional edge features of the method considers only the geometry of the image edges, and multi-fractal methods Hölder index not only analyzes the geometric characteristics of the image, but also the use of the singular spectral functions for calculating and analyzing image edge statistical properties at different scales. This is appropriate to ignore the not important edge details and highlight the main comparative edge. A variety of measures Amendment Act (max, min, sum, iso, adp) overcome the shortcomings noise-sensitive in experiments. When analyzed, the kind of the method used to calculate measure will influence the actual distribution of a variety of fractal singular spectrum. There exists characteristics of associated between multi-fractal spectrum function, but the geometrical characteristics described by them are not entirely the same. Therefore, multi-fractal singularity spectrum function can be obtained through the difference of the division ways or different measure and calculation method chosen for for its study object[12-17].If we set Ω for an area in the image, then:

$$P_{sum}(\Omega) = Card_{sum}(I(x,y)) = \frac{I_{sum}(x,y)}{\sum I_{sum}} \tag{1}$$

$$P_{\max}(\Omega) = Card_{\max}(I(x,y)) = \frac{I_{\max}(x,y)}{\sum I_{\max}} \tag{2}$$

$$P_{\min}(\Omega) = Card_{\min}(I(x,y)) = \frac{I_{\min}(x,y)}{\sum I_{\min}} \tag{3}$$

$$P_{iso}(\Omega) = Card_{iso}(I(x,y)) = \frac{I_{iso}(x,y)}{\sum I_{iso}} \tag{4}$$

Among them, $(x,y) \in \Omega$, $P_{\max}(\Omega)$ representative of the maximization of the pixel gray value measure in regional Ω, it is a measurement of the maximum gradation measure. $P_{\min}(\Omega)$ represent that pixel gray and measurement in Ω area, and it is the pixel gray level of the area, related to the types of singularities and highly. $P_{sum}(\Omega)$ is the measurement that the number of the same gray points (x, y) in the area. $I_{iso}(x,y)$ represents a value of the largest subset that the grays are same, such as a region there are k pixels of different gray scale, then it is 1, if all the pixels have the same gray, then as k,which is related to the type of singularity. In order to get the best visual effect in calculation, we need to understand each measurement and their parameters, and determine what kind of measurement to be used through trial and error analysis according to the statistical properties of the graph.

The Hölder index of (x, y) can be calculated by measurement, the formula as following:

$$\alpha(x,y) = \frac{\log P(I_{x,y,n})}{\log n} \quad (n = 2i+1, i = 1,2,3....) \tag{5}$$

$\alpha(x,y)$ reflects the local image singularity at an n×n, values in the case of i<=8,the multifractal parameter adjustment is the focus of multi-fractal analysis, and its basis is the image features and need of image processing. We can describe the multi-fractal with $\alpha \sim f(\alpha)$ based on measurement theory, wherein α is called Hölder index, which can be used to control the singularity of the probability density and the reflected the local fractal dimension of small area in infrared image, called singularity index. $f(\alpha)$ is called multifractal spectrum and global information of infrared image can be reflected by it. The distribution of $f(\alpha)$ would be different if singularity of different information are not the same. For the singularity index of each point,[$\alpha_{\max}, \alpha_{\min}$]can be divided into N lattice by calculating the maximum and minimum values α ,then count the number belonging to each grid.

$$f(\alpha) = \lim_{n \to \infty} \frac{\log N(\alpha)}{\log n} \tag{6}$$

$f(\alpha)$ is the Singular values of the image global characteristics and it can be obtained by linear fitting $(\log N(\alpha), \log n)$,multi-fractal is similar to a parabolic curve and it can be analyzed that whether the image is with multi-fractal characteristics from shape of the parabolic. According to a large number of experiments, we have gotten that there is certain regularity about the distribution of a and $f(\alpha)$,it is a texture point when the value is near 2, when the value is near 1,it represents edge pixel. The characteristics of fractal spectrum also reflect the nature of the image, the shape of $f(\alpha)$ is deviated to right when the value of the object being measured changes fiercely, it indicates a strong singular characteristic, the image is relatively smooth if parabolic is deviated to left.

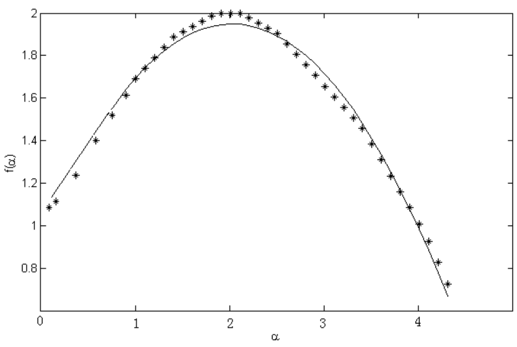


Figure 2. Multi-Fractal Spectrum of Infrared Image

The data in Table 1, are values of edge points, texture points and smooth points, wherein the singular value of edge points are α <0.8, $0.85 < f(\alpha) < 1.3$; while α <1.25, $1.3 < f(\alpha) < 1.75$, which are defined as the texture points and there singular value are large; it is a smooth region When the singular value is between 1.8 and 2.8 and fractal spectrum value $f(\alpha)$ is between 1.75 and 2,the large the number of smooth area pixels, the probability is bigger also. We can concluded from Table 1, summary, For the pixels smaller singular values, changes of adjacent pixels gray values is large, edge and texture judgment

Decided by calculation of region and whole, which can accurately distinguish edge and texture, fractal spectrum can characterize the difference of texture and edge pixels.

Table 1. Multi-Fractal Spectrum Data

Edge points		Texture points		Smooth points	
Singular Index	Spectrum value $f(\alpha)$	Singular Index	Spectrum value $f(\alpha)$	Singular Index	Spectrum value $f(\alpha)$
0.69	0.84	1.34	1.37	2.56	1.95
0.58	1.02	0.63	1.75	1.86	1.75
0.48	1.22	0.77	1.64	1.51	1.83
0.12	0.85	0.45	1.60	2.45	1.84
0.30	1.07	0.77	1.57	2.80	1.89
0.28	0.57	1.15	1.67	2.71	1.86
0.07	0.09	0.57	1.73	3.47	1.75
0.36	1.16	0.66	1.30	4.56	1.99
0.22	0.95	0.65	1.74	1.86	1.79
0.31	1.05	0.96	1.47	2.49	1.96

Human visual habit is opposite to understanding of edge and texture, as shown in Figure 3, two small ellipse inside ellipse in figure A can be understood as an edge, and as shown in B, when intensity of the same pattern of elliptical is to a certain extent, visual psychology will be changed, which we understand it as texture. Multiple analysis method can be distinguished the image texture and edge cases according to the human eye characteristics above, while a simple statistical algorithm can't be strictly distinguished texture and edges differences.

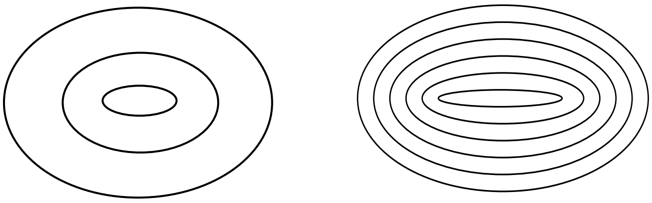
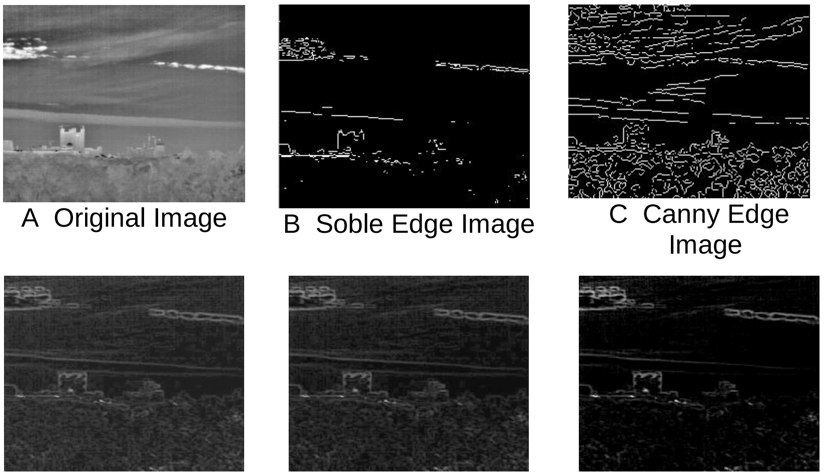


Figure 3. Comparison Figure of Human Eye's Understand for Image Edge and Texture

When extract edge with multi-fractal method, Hölder index images can be obtained in some measurement, the reason is that it will be gotten different extraction effect when different measurement is adopted. That is, the measurement image itself would be gotten some information of the image edge, and the effect of targeted edge extraction to some measurement and characteristic spectrum of single image would be better. It is effective using multi-fractal method for image edge extraction. The measurement can be modified by different ways in consideration of the situation of the texture frequency, so we can get edge information human eye understand from the results of edge extraction. Thus obtain image edge effect in line with human eye habits. The range of multi-fractal spectral can control the degree of precision to detect edges, the edges of different scales can be selected range according to the effect intend to achieve. Because the multi-fractal analysis may contain good characteristics of locality and global, meaning that it can be studied the overall characteristics of the signal by starting from local, which is a new research method multi-spectral $f(\alpha)$ analysis provide for the image edges detection.

4. Analysis of Test Results

As shown following, Figure 4-(A), is the original image, while making multi-scale edge detection for the image pixels by estimated multifractal spectrum, its weight fractal spectrum value is 1;4 (B) can be seen the edge detection result of Soble algorithm has missed out a lot of important information, the edge is not complete enough and partial information is not fully detected, thus the lack of consistency. Figure 4-(C), is the edge extraction rendering, there has been a lot of not important texture information and mixed with edge information, which cause poor effect. But for this image, the effect of multi-fractal analysis sum measurement algorithm is better than max measurement algorithm, there have been good results that important image edge information and trees texture that is the edge processing by sum measurement algorithm, while it only retains more information at the bottom part of the tree by Max measurement algorithm. This is also in line with people's general visual effects, that is for unnecessary detail texture information, with the method proposed in this paper, we can focus on the local details of the human eye interested and block the finely divided texture information in the detection of image edge. And if we want to get the edge, we need to obtain corresponding singularity index according to image pixels. It would seem, important information for each image is different, so which measurement would be used in calculation should be based on their specific image. Using some measurement and the corresponding image fractal spectrum characteristics are associated with each other, which all determined by its fractal characteristics and its statistical properties.



A Original Image B Soble Edge Image C Canny Edge Image

D iso Measurement Edge Image E Measurement Sum Edge Image F Measurement Max Edge Image

Figure 4. Effect of Edge Extraction Contrast

5. Conclusion

In this paper, the edge extraction method based on human visual customary has been proposed, using a variety of measurement multi-fractal spectrum for detecting and extracting infrared image edge. We first computes the singular values of the image pixels and then calculate the multifractal spectrum with this method. A comprehensive analysis of Hölder index fractal spectral function under various measurements, and the application of this image edge detection method consistent with the human visual habits, also unwanted noise and finely divided texture information can be blocked out provide a better way for subsequent processing. Through experimental verification, we get the infrared image edges and choose to ignore texture feature lines through the proposed method, and the edge characteristics of the object is the sensitive part of the human eye, which would be beneficial to further image processing.

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