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Fuzzy Contrast Enhancement Algorithm for Road Surface Image Based on Adaptively Changing index via Grey Entropy

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Abstract: With regard to the problem of declining of road surface image quality in high-speed processing, the grey entropy is applied to the road surface image enhancement to lay a good foundation for the automatic detection of cracks. We use the grey entropy of the texture of the local area in the road surface image to characterize the scale of the increase or decrease in the process of image local contrast enhancement and fine-tune the local contrast function for that we could effectively maintain the smooth region relatively smooth while enhancing the contrast of the image edge region. Finally, simulation results show that the algorithm is more effective to improve the quality of pavement crack image than other traditional algorithms and it is a good algorithm.

Key words: Grey entropy, enhancement index, local contrast, image processing

INTRODUCTION

In order to adapt the later care and maintenance needs of construction of roads, government departments around the world have invested a great deal of manpower, material and financial resources to maintain the healthy development of roads. As the traditional road surface detection methods require manual present in the site for inspection, investigation, recording, it costs a lot of human and financial resources, also holds up the traffic flow which may result in very serious personal injury accidents, inefficiency, poor precision and much ills else, so people began to study a real-time automatic secure and efficient detection technology or equipment. Detection of road cracks has been the key and difficulty in road disease testing. Currently, the study on the automatic acquisition equipment of road surface image has been more mature. With the development of the computer, electronics, camera and other technologies, the automatic detection hardware of road are constantly upgrading and improving. The post-processing and analysis of data collected will become the focus of c urrent study. As the pre-processing level and quality of the road surface image is directly relation to the edge detection, contour extraction, segmentation, recognition classification, automatic measurement and calculation in the post-processing important operation, many scholars combines the characteristics of the road surface image and the cracks detection requirement and they are looking for reliable tools applied to the road surface image processing.

The basic traditional road surface image processing technology (Huang and Xu, 2006;Ying and Salari, 2009) and its combination of complex ideas and algorithms are mean filter, median filter, parallel operation, serial operation, various gradient operators, statistical methods etc. and their same part is all combining the classical mathematical theory with the traditional digital image processing technology, extracting the essence of various algorithms and having comprehensive consideration, to construct a more powerful integrated operator and complex algorithms. With the sudden emergence and rapid development of the modern mathematics, statistics, system engineering and other engineering disciplines, cross-disciplinary, many emerging discipline, such as fuzzy mathematics (Wang *et al*., 2005), statistics in the new practical method, wavelet analysis (Subirats *et al*., 2006), artificial neural networks (Chou *et al*., 1994), mathematical morphology, partial differential equation (Weickert, 1999), fractal theory (Zuo *et al*., 2008), Markov random field (Delagnes and Barba, 1995), support vector machines (Li *et al*., 2009), integrated approach and some other branches of mathematics, etc., have been applied into processing and analysis of the road surface image. Especially, the presence of the uncertainty theory just fits

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the situation of the missing data and lacking information in the road surface image, providing the possibility of breaking the bottleneck that classical image processing techniques have relied on the classic mathematical theory and the precise mathematical theory.

The previous theories have promoted the development of the road surface image crack detection technique, the role they play is indelible and they improve the road surface image preprocessing and segmentation quality. However, these practices are the intelligent algorithms based on large sample theory, massive data and standard model techniques which either ignore the objective fact that the road surface image is acquired, processed and stored in high speed by the road surface image acquisition vehicle, blindly pursuing the accuracy and standard of the model constructed, resulting inefficient, or at the expense of completeness and accuracy of the model, gain some real-time processing efficiency. All in all, the existing algorithms always detect game between the quality and efficiency, often changes, and can not meet both "faster and better" testing requirements.

Relying on the grey system theory proposed by Deng (2002), taking the grey entropy Zhang *et al.* (1994) as a tool, based on the application of the grey system theory in the digital image processing, combined with the texture information of the pavement crack images, making full use of the advantage of that the grey system theory is good at dealing with the problem of "less data, poor information", we study the fast algorithm and intelligent systems of facilitating the crack detection, classification and identification and also widens the scope of application of the grey system theory which has positive significance for improving the road surface image crack detection level and developing surface automatic detection cause.

IMAGE ENHANCEMENT BASED ON GREY ENTROPY

Background of new algorithm: In the traditional fuzzy contrast enhancement algorithm, we begin with fuzzy membership functions to map the image from the spatial domain to fuzzy domain, delimit the fuzzy local contrast in fuzzy domain, enhance the contrast function with the fuzzy enhancement operator, then calculate the new fuzzy membership function adjusted by the contrast function and finally reverse the image from the fuzzy domain to the spatial domain. In the previous algorithm, we usually use the classic power function enhancement method to enhance the fuzzy local contrast. In order to get a better effect, here, we deal it from another angle, make full use of the local pixel distribution information, use the grey entropy to measure smoothness of the image and enhance the contrast operator adaptively.

Idea of new algorithm: As the edge pixels show fluctuations in the value, the higher the volatility of the pixel value in the neighborhood is, the smaller the value of grey entropy of the pixel in the neighborhood is, otherwise, when there is no edge pixel in the neighborhood window, the changes of the pixel value in the neighborhood is relative flat, so the value of each component constituted of the grey entropy is close to each other, so the value of the grey entropy is large. Taking into account the principle that we can use the grey entropy to distinguish the edge and the non-edge region, we take the grey entropy of the pixel value in the neighborhood window as an important index, construct the contrast transformation function of image, in order to achieve the contrast changes due to the varies of the grey entropy in the neighborhood. Combining the distribution properties of image pixel and grey entropy, construct the contrast enhancement function by using the grey entropy as the basic measure of factor in order to make the grey entropy value of neighborhood varying with region fluctuation adaptively, so as to dynamically adjust the enhancement strength of the fuzzy local contrast which ultimately improve the quality of the image.

Steps of new algorithm:

- **Step 1:** Set the current pixel be f(k, l) (k = 2, ..., M-1; l = 2, ..., N-1). Because the range of pixel value of the grey image is [0, L-1](L = 256), it may be occur that real number part of the logarithmic have no meaning for the zero present in the domain. So we need to transform the image by one unit on the right and map the image to the fuzzy domain

$$u(k,l) = \frac{f(k,l)+1}{L} \quad (k = 1,\cdots,M; l = 1,\cdots,N) \tag{1}$$

- **Step 2:** Choose the pixels in a 3×3 neighborhood window and normalize the pixels in the neighborhood, namely

$$g(k,l) = \frac{u(k,l)}{\sum_{i=k-1}^{k+1}\sum_{j=l-1}^{l+1} u(i,j)} \tag{2}$$

$$(k = 2,\cdots,M-1; l = 2,\cdots,N-1)$$

- **Step 3:** Compute the grey entropy values of pixels in the neighborhood of image and finally establish a grey entropy table sh to save them as the neighborhood edge information:

$$sh(k,l) = -\sum_{i=k-1}^{k+1}\sum_{j=l-1}^{l+1} g(i,j)\bullet\ln(g(i,j)) \tag{3}$$
$$(k = 2,\cdots,M-1; l = 2,\cdots,N-1)$$

- **Step 4:** In the neighborhood window of the image, firstly compute the mean value in the neighborhood of the image and get the local fuzzy contrast:

$$v(k,l) = \frac{1}{9}\sum_{i=k-1}^{k+1}\sum_{j=l-1}^{l+1} u(i,j) \tag{4}$$

$$F(k,l) = \frac{|u(k,l) - v(k,l)|}{u(k,l) + v(k,l)} \tag{5}$$

- **Step 5:** By using the grey entropy corresponding to the current central pixel, construct the contrast-enhanced index Z(k, l) and the contrast-enhanced function F'(k, l)

$$Z(k,l) = \log_t(sh(k,l)) = \ln(sh(k,l))/\ln(t) \tag{6}$$

where, t is strengthen control parameter and t can be usually fitted by five. When you need to increase the intensity of the local contrast, the value of t can be extended appropriately.

$$F'(k,l) = F(k,l)^{Z(k,l)} \tag{7}$$

where, F'(k, l) is the new contrast value after adjustment by using the contrast enhancement index in the neighborhood window. When using the lena256.bmp image to test, we can see that the grey entropy value of the whole image is between 1.4396 and 2.1972, apparently the domain of the Z(k, l) must be between 0 and 1 which meets the demand F'(k, l)≥F(k, l) and increases the local region contrast of the image. Generally speaking, the more obvious the edge character in the neighborhood is, the smaller the corresponding grey entropy is, the smaller the contrast-enhanced index is, the bigger the attained contrast-enhanced power function is which automatically adjusts the enhanced strength in different neighborhoods of road surface image.

- **Step 6:** Calculate the new membership value after enhancement

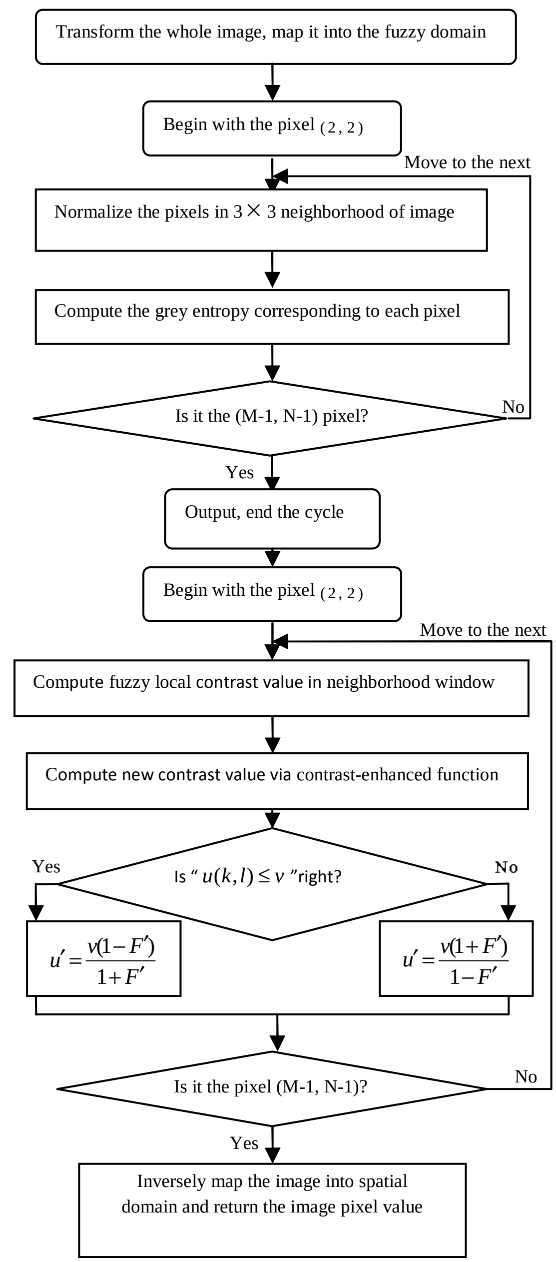

Fig. 1: Flow chart of image enhancement algorithm based on grey entropy

$$u'(k,l) = \begin{cases} \dfrac{v(1-F')}{1+F'} & u(k,l) \le v \\ \dfrac{v(1+F')}{1-F'} & u(k,l) > v \end{cases} \tag{8}$$

- **Step 7:** Restore the membership value to image pixel value

Fig. 2(a-d): Results with experimental image: (a) Original image, (b) Original image edge detection, (c) Traditional contrast enhancement, (d) Traditional contrast-enhanced edge detection, (e) New algorithm (t = 4), (f) New algorithm edge detection (t = 4), (g) New algorithm (t = 5) and (h) New algorithm edge detection (t = 5)

$$\hat{f}(k,l) = u'(k,l) \cdot L - 1 \tag{9}$$

The frame structure and algorithm flow chart is as follows.

Simulation result analysis of algorithms: In order to test the effectiveness of the proposed algorithm in this study,

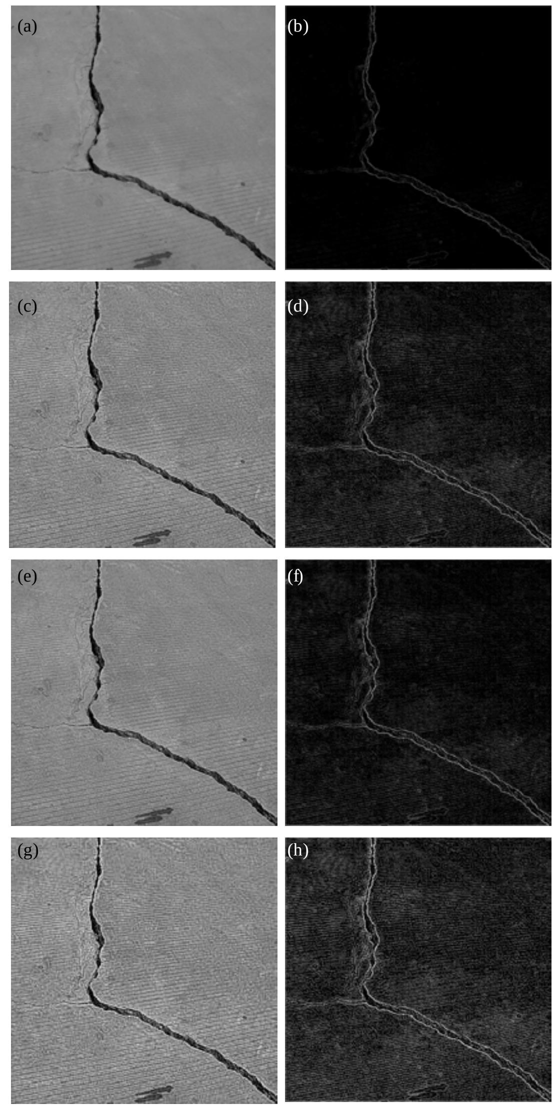

Fig. 3(a-g): Results with road surface image: (a) Original image, (b) Original image edge detection, (c) Traditional contrast enhancement, (d) Traditional contrast-enhanced edge detection, (e) New algorithm (t = 4), (f) New algorithm edge detection (t = 4), (g) new algorithm (t = 7), (h) New algorithm edge detection (t = 7)

we first use the image lena256.bmp to have a test and then use the true road surface image to detect the cracks. Road surface image enhancement algorithm is the steps completed before the crack edge detection and extraction in the automatic processing for the road surface image and the effect of the image enhancement will largely affect the follow-up results of the image edge detection.

Conversely, considering that the effect of the road surface image edge detection can reflect the quality of the image enhancement to some extent, therefore, during the inspection of the effect of the road surface image enhancement, we also compare the edge detection quality of the corresponding images which are processed with the same kind of edge detection method, thus the results of edge detection of the surface image processed by enhancement can be measured for enhancement quality as an indirect means.

From the treatment effect of the experimental image, the traditional contrast enhancement algorithm is better than the original image for sharpening the image, the image contrast is more obvious and the grey level of the image is more clearly. But in the process of the contrast enhancement, due to lacking effective identification mechanism for the image edge, the traditional contrast enhancement algorithm will inevitably enhance the smooth region of the image which may lead to the background of the image becoming relative roughness. Using the characteristics of grey entropy to identify the edge and the non edge, by constructing a contrast enhancement index, the new algorithm can make the contrast of the edge region larger while the contrast of the smooth area keeping only a modest increase, so we can intelligently control the enhancement strength of the different local regions, enabling the adaptive contrast enhancement and expansion. From the processing effect of the road surface image, while the traditional contrast enhancement algorithm enhances the crack edge of the image, also makes the surface normal texture near the edge further enhanced which will be detrimental to the latter part of the crack edge extraction and further processing. The new algorithm is better for enhancement effect of the crack edge and the normal texture contrast is not very high which will not cause the normal texture near the crack edge misinterpreted as cracks in the post-processing. Therefore, the new algorithm makes the target object enhanced and non-target object effective restraint and it is a good algorithm worth further study.

CONCLUSION

On the basis of grey entropy theory, this paper improved the traditional image contrast enhancement algorithm. After deeply discussing the pixel characteristics of the edge and non-edge region in the image, we use the grey entropy to measure the smoothness of the image, in order to achieve intelligently the contrast enhancement for the edge region of the image, while maintaining the non-edge region smooth. In the calculation of the grey entropy, we use a translation transformation to make the domain of the image map to the range of [1,256], thus avoid occurrence of that 0 of the domain of the image interfering the calculation of the grey entropy which achieved the algorithm stability. By the analysis of the algorithm implementation mechanism and the simulation results, it shows that, using the image fuzzy contrast enhancement algorithm based on the grey entropy in this paper to effectively enhance the target object while can maintain the smooth regions smooth, it is a worth further study and potential algorithm which laid a foundation for us to expand the application of the grey entropy in the image enhancement area.

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