Thangka Image Inpainting Using Adjacent Information of Broken Area

Huaming Liu, Weilan Wang and Hui Xie

Abstract—**A new method which use adjacent similar block in broken areas of image to inpaint the broken patch is proposed in this paper. This method can realize non-ergodic search, reduce the search range sufficiently and find the best matching block very fast. It seem particularly good to inpainting for the damaged region which has strong relevance with its adjacent pixels or surrounding area. The proposed way is due to using the inpainting method [1] which is based on exemplar patch and based on grey cross-correlation algorithm of image match to search similar blocks proposed by Criminisi. As the searching strategy of conventional grey cross-correlation algorithm is ergodic, the speed of matching is slow. In most cases, there are more than one, several similar matching blocks (also called similar exemplar patch, which can fill-in the broken image areas) by the algorithm. One of them is selected randomly when repairing broken image, it will influence the final result of repairing if it isn't the best matching block. Experiment shows that the method of this paper not only improves the speed of image matching and search for matching block precisely, but also can improve efficiency of repairing and get a satisfied inpainting result.**

Key words: **adjacent pixel block, broken region segmentation, image inpainting, matching block**

I. Introduction

Nowadays a great number of image inpainting techniques are being utilized in many special application fields, this techniques such as Inter-frame Technology [2], Diffusion Technique[3], Texture Synthesis [4], Image Decompositions [5] ,etc., and each of them has both its own advantages and disadvantages [6]. Crimini's restoration technique which is based on exemplar block is implicated in this paper to repair the little spots, small traces of nicks as well as large areas with single or many texture's areas in the process of repairing thangka, in addition, the contour line of repaired damaged region is very distinct. However, we find, in actual inpainting experiments, that some of the images which are not repaired satisfactorily. Why? We find that many substitutes can be found when searching exemplar blocks by ergodic. We can choose one of the matching blocks freely to repair the damaged part. It will influence the final effect of repairing that we expect if substitute isn't the best choice. In order to cope with the insufficiencies of the grayness ergodic algorithm, a new algorithm is proposed by analysis and study, the algorithm is based on the fact that the damaged region has strong relevance with its surrounding area. The aim of this proposal is to find the best matching block on damaged areas, narrow the range of ergodic search, and reduce the possibility of many matching blocks' appearing, so the accuracy of matching blocks is much closer to we wanted. The findings of experiments indicated that this new algorithm not only reduced the occurrence of mistakes, but also improved the efficiency and, achieved a satisfied result.

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II. Segmentation of broken areas

The first step of image inpainting is to segment the broken regions, many algorithms of image segmentation are proposed according to the characteristics of broken image themselves. We can segment thangka image broken regions through improved straight line-based tracing detection of region method[7] by using the character of grey fluctuation inner of broken regions less than grey fluctuation of boundary, and reach the practical need of image segmentation.

The algorithm steps of segmentation the broken area in thangka image are:

（1）to make markers for all broken pixels;

（2）to find the first broken pixel point, which is called the seed point;

（3）as Fig 1 shows, the Search Algorithm of four-neighbor area are adopted, to put the found seed point by (2) into the queue, then the first element in the queue are fetched, and then ordinal search its four direction of 0,1,2, and 3, if there is a broken pixel point in any a direction, the broken pixel point are put into queue;

（4）to make markers of broken region after 4 direction of the first element in the queue are searched and the first element in queue are moved;

（5）when the queue is null, it means broken areas, in which seed point located, has been finished segmenting;

（6）the next seed point will be search again, repeat the process of（2）,（3）,（4）,（5）and all of the broken areas are segment in the image in the end.

Each broken area has their marker in unified mode after finish the segmentation of image. The location of each

broken area should be denoted for immediate orientation the broken area in repair.

○ Denotes the broken pixel ● Denotes the non-broken pixel

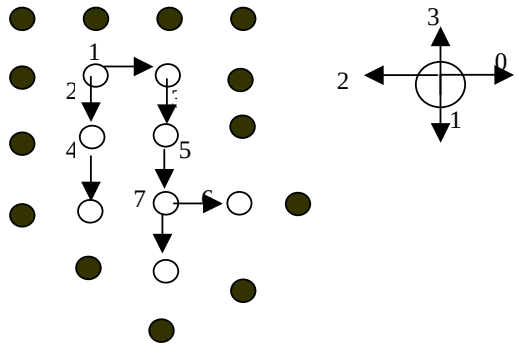


Fig 1 searching broken regions

III. Searching for Similar Exemplar Block

A. Calculation of similar block

Let I denotes image, Ω denotes a broken region, and $I-\Omega$ denotes a sample area. It is very important to arrange a right sequence in repairing broken areas of edge, if the repaired sequence which is selected is improper, it will influence the inpainting effect. The priority of waiting repairing block in the broken area of edge are calculated according to the algorithm of the isophote-drive [7], the waiting repairing block with the highest priority will be repaired firstly. Suppose the awaiting repairing block which has the highest priority is Ψ_p, its similar exemplar blocks Ψ_q need to satisfy the condition:

$$\Psi_q = \arg\min d(\Psi_p, \Psi'_q) \quad (1)$$

where Ψ'_q is any a exemplar block in the sample of image, which is the same size with the awaiting repairing block, $d(\Psi_p, \Psi'_q)$ denotes distance between Ψ_p and Ψ'_q, the formula of calculation of distance is as follows:

$$d(\Psi_p, \Psi'_q) = \sqrt{\sum_{i=1}^{m} (v_{ip} - v_{iq'})^2} \quad (2)$$

Where m denotes numbers of pixels which are in the awaiting repairing block Ψ_p, and v_{ip} is that patch block inside Ψ'_q the ith point which has been identified in the color pixel gray value. Similar exemplar block Ψ_q, is the least distance with the awaiting repairing block in the sample region. The disrepair pixels in Ψ_p can be repaired by block Ψ_q. When the search is ergodic case in whole image, the numbers of the found exemplar block which has the least distance may be only one, but in many cases, may be more than one, the reason of this case generation will be analyzed in detail in the *B* section.

B. Analysis on many similar blocks generated

The damaged region of image are repaired by similar exemplar blocks which are ergodic searched, the range is the sample area ($I-\Omega$). If similar exemplar block included the broken pixels, it can not repair image as a exemplar block. In addition the similar block which is found in broken area at all, and it can not repair image. Therefore, it is apparent that the searching ergodic of the similar exemplar block in the damage region is meaningless. On the other hand, if the searching ergodic of the similar exemplar block in the non-damaged region, maybe many similar blocks will be generated. For example, Fig2-b,c,d are similar blocks of 5×5 which are obtained by formula (2), they have the same least distance with the block waiting for repairing of Fig 2-a. In technically, each of Fig 2- b,c,d can be used to repair the block of Fig 2-a, if we repair broken region by Fig 2-b,d , it's can not achieve a satisfied repairing result, and Fig 2-c is the best one to repair the block. Suppose use Fig 2-c to repair image by Fig 2-c, fill the image block of Fig 2-e into the blank area of Fig 2-a. Maybe there appear more similar sample block when match image, chosen one of sample as a sample block randomly while repairing, if this exemplar block is unsuitable, it will lead to a bad result. Literature [1,8,9,10] don't relate to the case that there are many similar blocks when search similar exemplar block. The broken area, which has close relation with adjacent information, can be repaired by adjacent similar block of broken-area. The method can reduce the searching range while searching ergodic, shield parts of similar block, increase accuracy of searching similar block, and it can reduce probability of bad repairing result.

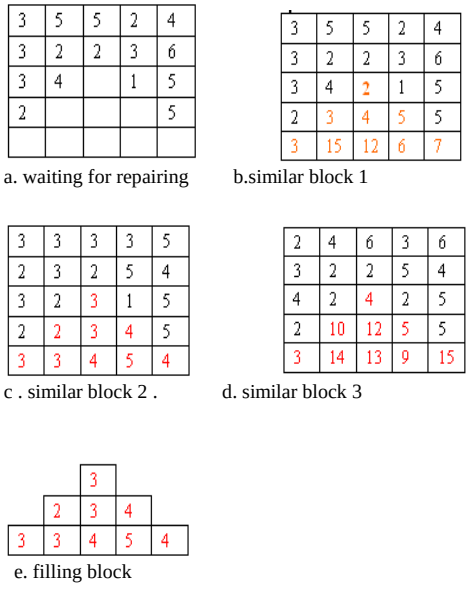


Fig 2 Explanatory legend of multi similar sample block generated

IV. The Algorithm on Searching Adjacent Similar Block of Broken Area

In order to find the sample area of the adjacent similar block of the broken region, the steps are followed:

(1) Find the edge of broken area before repairing.

(2) Select a template, which size is between 19×19 and 41×41, and this paper selects template, which size is 41×41. The edge pixels of the broken area are located in the center of each template, and non-broken pixels, which are in the template, will be put in a linked list, and the broken pixels will be disposed. All of pixels are unique in the linked list.

(3) Pick out the first pixel point A in the linked list, which is located in the center of the template in size of 9×9, if the broken pixel is covered with the template, then the pixel A will be deleted from the linked list.

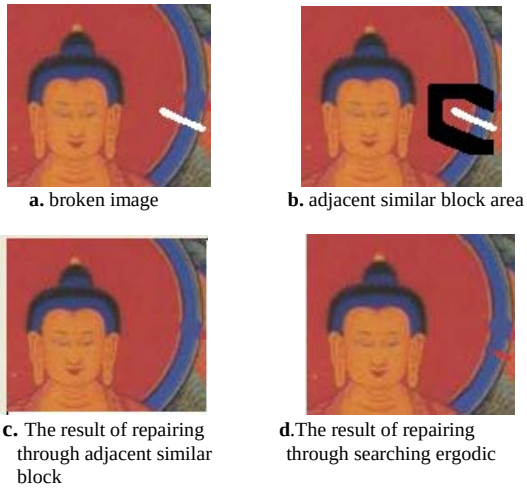
(4) Pick out next the pixel in the linked list, repeating the step (3).

(5) The pixels in the linked list, in fact, are the adjacent similar blocks of the broken area, which forms the sample region.

The proposed the algorithm above is based on the close relationship between the broken area and its adjacent pixels, as the experiment shows, the algorithm can avoid the condition which generates multi similar blocks while searching.

V. Result of Experiment

Fig 3-a is a broken thangka image, the black region in Fig3-b is the resource of the adjacent similar sample of the broken area; the region are called the "adjacent similar sample region". Every pixel locates itself in the center of 9×9, and this block doesn't include the broken pixels. Fig 3-a has the characteristic, which is that the broken area has close relation with its adjacent information. The found similar blocks in the searching ergodic process is in the adjacent similar sample region while repairing this kind of images. Fig3 –c is the repairing result of using the adjacent similar sample region. Fig 3-d is the repairing result of searching ergodic, which is not better than the repairing result of Fig 3-c.



a. broken image **b.** adjacent similar block area

c. The result of repairing through adjacent similar block **d.**The result of repairing through searching ergodic

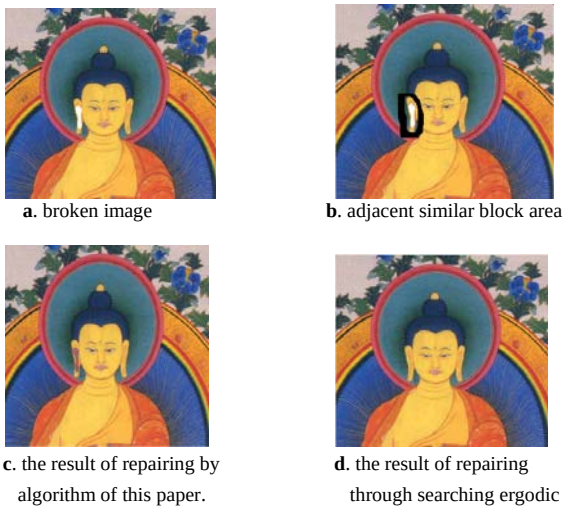
Fig 3. Image repair by adjacent similar block

Two algorithms are compared in Table 1.

When repairing the image, the broken region is in the left ear of Fig 4-a, the black region in Fig 4-b is the adjacent similar sample area of the broken image region. A little information resource can be used in the adjacent similar block area, so the image can't be repaired very well, the result of repairing by this area shown in Fig 4-c, the effect of repairing is apparently bad. If the available information of adjacent pixels in the broken area is limited, then the broken region will be not repaired very well, and here the method of researching ergodic in whole image can be used to select the

Table 1: Compared the algorithm of this paper with algorithm searching ergodic

Algorithm	Usage Scope	the number of similar block	algorithm complexity	repairing result
This paper	broken region has close relation with its adjacent information	comparatively little	complex	better
Searching ergodic	all broken images	comparatively much	commonly	commonly



a. broken image **b**. adjacent similar block area

c. the result of repairing by algorithm of this paper. **d**. the result of repairing through searching ergodic

Fig 4 comparison with algorithm of this paper and searching ergodic

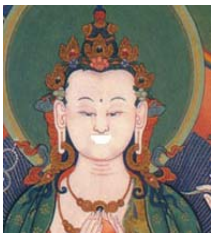


Fig.5 key block lost image

best exemplar block. At the same time, if the left ear is lost completely, it is possible to repair the image by finding the best exemplar block while searching ergodic due to the left ear and the right ear are symmetric in the image, so when search the best exemplar block, the broken left ear can be repaired by the information of the right ear. Fig 4-d is repaired by using the algorithm of searching ergodic, the result of repairing is better than the algorithm of the adjacent similar block. However, the image in Fig 5 shows a case that his mouth completely lose, the broken region can't be repaired by the adjacent similar block of the broken area or searching ergodic. Such broken block which looks like a broken mouth is called "key block" (because it is unique in the image, and lost information can't be found in the image). The simplest method to repair the broken image is just to delineate the people's mouth which is a common handcraft work, or to built up an Image Database of Thangka, the

broken region can be repaired by the similar image in database. Therefore the algorithm of this paper can help repair the broken image using the adjacent information of the broken region, and the broken region of the broken image has close relation with its adjacent pixel information.

VI. Conclusion

A new image inpainting algorithm has been proposed by analysis the characteristics of damaged region of thangka image and detection and mark for damaged region. Meanwhile, the proposed method of repairing the broken image by using the adjacent similar block of the broken area can solve one kind of repairing problem; which helps avoid the probability of appearing many similar exemplar blocks during researching ergogic and, also avoid causing a bad inpainting result. The advantage of this repairing algorithm is improving the efficiency of image repairing; achieving a satisfying result as well. There are some problems to deal with farther: so how it will be possible to find the best similar block among the ones in existence or try to find a new better algorithm that can be used to search for the best similar block at once? In addition, there are some other issues that need to be resolved: due to the complicacy of the distributing of the broken area of thangka image, and the condition of segmentation for the broken area will directly influence the quality of repairing image in thangka. Therefore, we should focus how to segment precisely the broken area of thangka images, and how to inpaint the key block if they are lost, and so on.

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