Study of Image Inpainting Technique based on TV Model

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Abstract – This paper is related with an image inpainting method by which we can reconstruct a damaged or missing portion of an image. A fast image inpainting algorithm based on TV (Total variational) model is proposed on the basis of analysis of local characteristics, which shows the more information around damaged pixels appears, the faster the information diffuses. The algorithm first stratifies and filters the pixels around damaged region according to priority, and then iteratively inpaint the damaged pixels from outside to inside on the grounds of priority again. By using this algorithm inpainting speed of the algorithm is faster and greater impact.

Key Terms: Image inpainting, TV model, priority, peak signal to noise ratio (PSNR).PDE

I. INTRODUCTION

Image inpainting is an ancient art. In renaissance of Europe, people have repaired the cracks of the work of fine art. They can resume the damaged portions of a work of fine art and keep it whole by this way. Followed by development of computer technology, digital image inpainting was introduced into the field of image inpainting by Bertalmio [1]. Image inpainting is to fill in the image information on a blank domain based on the information available outside. In order to make it more legible, essentially, it is an interpolation problem. It has been widely applied in restoring scratched old photos and old movies, text removal from images, digital zooming and especial effects in movies now it is also applied in add or remove object in photos.

In general, image inpainting methods can be divided into two categories: structure-based inpainting and texture-based inpainting. Structure-based inpainting refers to the process of image inpainting which employs information around damaged region to estimate isophote from coarse to fine and diffuses information by diffusion mechanism.

Figure 1: Image inpainting process flow

The method includes the following models: BSCB model [1], TV model [2], CDD model [3] and elastica model [4] and so on. These models have a good inpainting effect on the small-scale and non-texture damaged region such as the scratches, the creases and the spots and so on, but it is easy to cause the blurriness when they are used to inpaint relatively large damaged region.The above essentially solve partial differential equations (PDE) describing information diffusion, while the numerical solution of PDEs requires a large number of iterations, so that the inpainting speed is very slow. Therefore, how to improvethe solution speed of these models has become a very valuableresearch. At present, the fast structure-based image inpainting algorithm has fast marching method [5] and Oliveira method [6] and so on. Fast marching method uses the weighted-average method to inpaint damaged image so that the edge-preserving is not ideal. Oliveira method is faster, but does not maintain the isophotes directions in the inpainting process, and therefore it was almost any ability to restore the details of the edges. The methods of texture-based inpainting are to fill missing information by texture synthesis techniques, and are suitable for inpainting relatively larger damaged region. It can also be divided into image inpainting based on decomposition and image inpainting based on texture synthesis.

It is well-known that image inpainting is an ill-posed Problem [3], which manifested information around damaged region, is insufficient to fully restore missing information. In image processing, the most commonly used method to eliminate morbidness is to join regularization items, whose basic idea is to use prior knowledge of physical problems, adding more constraint to the problem, which makes the solution of the problem continuously depend on the observational data, and additional items must be in line with prior knowledge of physical meaning [7]. Inspired by the above, we make full use of information around damaged region to iteratively inpaint the damaged region quickly in the inpainting template fixed-size case.
The basic idea is as follows:

*Step 1.*Segment the damaged region.

*Step 2.*Find the edge of damaged region.

*Step 3.*Calculate the priority of the pixels on the edge and sort in accordance with the priority, if the priority of the pixel is greater than a certain threshold T, then reserve the pixel, else delete it.

*Step 4.*Store the reserved pixels according to the orderof priority as a layer.

*Step 5.*Update the damaged region.

*Step 6.*Repeat the Step 2, the Step 3, the Step4, the Step5 until the area of damaged region is zero.

Step7. Iteratively inpaint is according to the size of priority from outside to inside.

The next section of this paper presents related work. Section III provides some basic ideal about TVmodel and the state of the art in the area of image inpainting. Section IV describes the

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proposed mode based on TV model, and some experimental results are illustrated in Section V. Finally, in Section VII some cxonclusions are drawn.

II. LITERATURE REVIEWS

In 2000 Bertalmio completed the inpainting region by applying a diffusion scheme based on partial differential equations (PDE) over the boundary of the area to be filled. The new algorithm called BSBC was proposed for removing large objects from digital images. The target regions were marked in color which is manual. It filled in the areas to be inpainted for three separate channels(R, G and B) by propagating information from the outside of the masked region along isophotes. Inspired by Bertalmio, Chan and Shen proposed two image inpainting algorithm [2, 3]. The Total Variational (TV) inpainting model [2] used an Euler Lagrange equation. This model was designed for inpainting small regions and good for removing noise, which did not connect broken edges. The Curvature-Driven Diffusion (CDD) model [3] extended the TV algorithm to aim at realizing the Connectivity Principle. The CDD inpainting model, like the TV and BSBC models, is based on the PDE method. Therefore it is directly applicable only to non-texture images. Igehy [4] integrated a composition step into texture synthesis algorithm, a smooth transition between real and synthetic grain may be realized. Texture synthesis can be considered useful in images which need replacing large areas with stochastic textures. However, it is useless for images that need replacing areas with structured texture. Criminisietal.[5] presented a novel algorithm for removing large objects from digital photographs. Their approach employed an exemplar-based texture synthesis technique modulated by unified scheme for determining the filling order of the target region and it is time consuming.

III. SOME IDEA OF IMAGE INPAINTING TV MODEL

As a PDE inpainting method, TV model is introduced as follows due to its simplicity in theory and its efficiency in computation and applications.

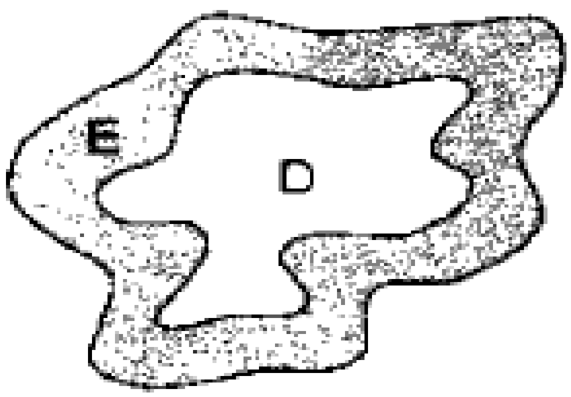

Figure 2: Region to be inpainted

In Fig 2, D is defined as region to be inpainted, and it is generally a ring, E is the outer neighborhood of D. Now in this method we assume that *u* is contaminated by homogeneous white Gaussian noise. The Total variational inpainting model is to find function *u* on the extended inpainting domain *E+ D*.

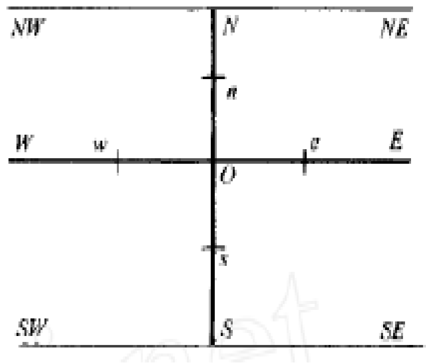

Figure 3: Target pixel and its neighborhood pixel

According to Euler-Lagrange equation we can see that u minimizing L (u) should meet the following condition:

$$-div \frac{\nabla u}{|\nabla u|} + \lambda_e(u-u^0) = 0,\ \lambda_e = \begin{cases} \lambda, (x,y) \epsilon E \\ o, (x,y) \epsilon D \end{cases} \quad (1)$$

Here λ plays a role of Lagrange multiplier. So this is total variation model of image inpainting, and the difference method is adopted for its numerical solution.

Let Ω be the region to be inpainted and dΩ be its boundary. The structure of the area surrounding Ω is added via isophotes and filled with colour via dΩ. Then texture is added. The purpose of inpainting is to restore the unity of the work. For the case of missing or damaged areas, one can only hope to produce a plausible rather than an exact reconstruction.

IV. NEW IMAGE INPAINTING ALGORITHM BASED ON TV MODEL

Image inpainting algorithm based on TV model is essentially a weighted-average algorithm. The smaller the difference between target-pixel and neighborhood-pixels is, the greater weight is, on the contrast, the greater the difference is, the smaller the weight is. Iteration is in fact aprocess of anisotropic information diffusion. Experiments show that there are more non-damaged pixels around damaged pixels, then the speed of the diffusion is faster, which means the converged speed is faster and inpainting isalso faster. Thus, this paper try to divide the damaged region of image into a number of layers, and then, doing the inpainting layer by layer. However, there is still a problem that there are some pixels whose non–damaged neighborhood pixels is less in each layer. Therefore, it will slow down the diffusion speed of information and reduce the reliability. In order to solve this problem, a threshold T was set, whose purpose is to filter these pixels that are placed in the next layer of the current layer. At that moment, there will be more available information around the pixel, so information diffusion will be faster and stronger. However, the traditional image inpainting method based on TV model iteratively inpaint damaged pixels line by line, and it did not treat damaged region as a whole, which will inevitably result in the available information around damaged regionhas not been maximized. In particular, when damaged regionis relatively narrow and horizontal, the problem that information diffusion is slow is more prominent. Therefore, image inpainting requires more iteration. The more available information around damaged

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pixels, the faster information spreading, and the convergence speed isalso faster.

The inpainting template *M* of 3×3 is selected in experiments. Priority *p* is calculated as follows:

$$p = \sum_{s \epsilon M} A \qquad (2)$$

Here *A* and *s* aredenote weight and the pixels in the template, respectively. If *s* is a damaged pixel, then *A* = 0; else if *s* is directly adjacent to the core, *A* = 2, and indirectly adjacent to the core, *A* = 1. Fig shows the flowchart of the algorithm.

The more available information around damaged pixels is, the faster information spreading is. This is the reason why computing priority in the paper, to ensure that iterative damaged pixel have more available information, making the diffusing information on each iteration as much as possible. Finally, the convergence is faster.

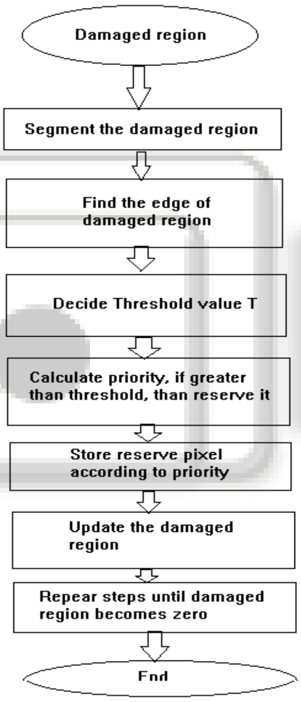

Figure 4: Basic flowchart for image inpainting algorithm

V. EXPERIMENTAL RESULT AND ANALYSIS

Generally speaking, the evaluations of inpainting effectiveness have two ways: objective evaluation and subjective evaluation. The objective evaluation method was used for the evaluation of inpainting effectiveness, which is mainly from the fidelity of image restoration to be measured. At present, the widely used objective evaluation methods are: mean square error (MSE) measurement, signal to peak signal to noise ratio (PSNR) measurement and improved signal to noise ratio (ISNR) measurement and so on. In this paper, peak signal to noise ratio (PSNR) was used to evaluate the inpainting results.

Given image is used as experimental subjects in this paper. Through the inpainting of damaged images verifies the effectiveness of the proposed method. The experimental results shown in figure say that new algorithm is faster than original TV algorithm.

As can be seen from Table 1, the inpainting speed and inpainting accuracy are improved by the proposed algorithm compared with the traditional algorithm based on TV model. The inpainting effectiveness of the algorithm is superior to the traditional algorithm. This also validates the correctness and rationality of our standpoint.

(a)Original image (b) Damaged image

(c)Inpainting result of TV algorithm (d) Inpainting result of proposed algorithm

VI. SUMMARY

	Inpainting algorithm based on TV model			Inpainting algorithm in the paper		
Iterations	R	G	B	R	G	B
10	18.748620	20.306043	23.872961	18.761382	20.322904	23.897729
50	20.686794	22.305174	26.148538	20.710204	22.343455	26.221788
100	22.970758	24.563541	28.569680	23.002391	24.637958	28.683413
300	34.465803	35.622947	39.180603	34.923339	35.979008	39.557426
500	39.085976	39.440427	42.657337	39.091503	39.430762	42.646423
1000	39.292272	39.643974	42.980719	39.291578	39.644114	42.978344

Table. 1:. The relation between iterations and PSNR

In each case, the goal is to produce a modified image in which the inpainted region is merged into the image so seamlessly that a typical viewer is not aware that any modification has occurred.

VII. CONCLUSION

The traditional model of image inpainting based on TV is essentially solving partial differential equations (PDE) describing the diffusion of information, while its numerical solution requires a large number of iterations, so that the inpainting speed is very slow. I make full use of the information around damaged region in the inpainting template fixed-size in the paper, which can make information diffusion stronger and the inpainting speed faster. In fact, the idea I put forward has certain guidance functions to other model based on partial differential equations.

ACKNOWLEDGMENT

I would like to thank Prof. A. M. Kothari &Prof. K. B. Sheth for their guidelines in making this paper. Inpainting, a set of techniques for making undetectable modifications to images, is as ancient as art itself. Applications of image inpainting are range from the removal of an object from a scene to the retouching of a damaged painting or photograph. For photography and film, inpainting can be used to reverse deterioration (e.g., cracks in photographs, scratches and dust spots film), or to add or remove elements (e.g., stamped dates, "red-eye," and, infamously, political enemies) from photographs.

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