Digital Images Inpainting using Modified Convolution Based Method

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Abstract. Reconstruction of missing parts or scratches of digital images is an important field used extensively in artwork restoration. This restoration can be done by using two approaches, image inpainting and texture synthesis. There are many techniques for the two pervious approaches that can carry out the process optimally and accurately. In this paper the advantages and disadvantages of most algorithms of the image inpainting approach are discussed. The modification to Oliveira inpainting model is introduced. This modification produces fast and good quality with one iteration without blur and removes large object with symmetric background.

Keywords: image restoration, inpainting, texture synthesis

1 Introduction

Most problems of any image are often corrupted by noise, scanned old photo paper, dust or stains resting on the scanning glass of a scanner, scratched images or others have logos or stamps.

For these problems, there are many methods to modify the damage area in a non-detectable way for an observer not familiar with the original images. Traditionally, skilled artists have performed the restoration of image (image inpainting) manually digital techniques are used for automatic images restoration and this field has received a great attention in recent years [1].

The restoration can be done by using two approaches, image inpainting and texture synthesis, whereas the meaning of the first approach is restoring of missing and damage parts of images in a way that the observer who doesn't know the original image can't detect the difference between the original and the restored image. It is called inpainting because the process of painting or fill in holes or cracks in an artwork [2].

The second approach is filling unknown area on the image by using surrounding texture information or from input texture sample. Texture synthesis techniques could be employed to restore digitized photographs especially if a damaged area needs to be

filled with some pattern or structure. However texture synthesis usually fails if the area to be reconstructed contains an additional color or intensity gradient [3].

In recent years, for two dimensional digital images, most algorithms combine both texture synthesis and inpainting approaches to restore the image. The two approaches can be collectively used to fill the hole, since they remove unwanted features or holes in a digital image .

The common requirement for all image inpainting algorithms is the region to be inpainted manually selected by the user, this is because no mathematical equation capable of detecting or knowing the region to be inpainted without taking desired area

There are many applications of image inpainting range from restoration of photographs, films, removal of occlusions such as text, subtitle, logos, stamps, scratches, red eye and publicity from images, in addition to produce special effects [1, 4].

In this paper we proposed a contribution for image inpainting applications, where we introduce modification to Oliveira algorithm to reduce the time of inpainting and increase the quality of the result , the advantage of this modification is reducing the time of the algorithm one iteration instead of 100 and more. the second advantage is producing the result without blurring, and the third is removing large object from the image with symmetric background .

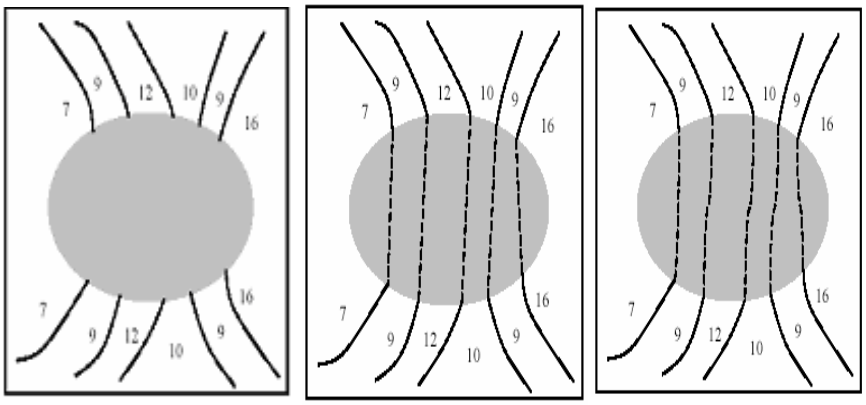
This paper is organized as follows. Section 2 gives an overview on the previous inpainting techniques. Section 3 presents the proposed algorithm. section 4 illustrate examples of the tested result . Finally the conclusion is drawn in section 5.

2 Previous work

Firstly, we should note the algorithms of image denoising and image deblurring do not apply to image inpainting, because the regions to be inpainted are usually large and the information is distorted. Otherwise image denoising and image deblurring algorithms the pixels contain both information about the actual data and the noise [1].

The image inpainting field can be carried by many techniques So, in the following section we introduce the most related methods which used in that field.

Bertalmio et al pioneered a digital image inpainting algorithm based on the PDE and be the extension to the level lines based disocclusion method or the same basic idea, after the user select the region to be inpainted the two methods iteratively propagate information from the outside of the area along the level lines isophotes (lines of equal gray values), the difference lies in the goal of maintaining the angle of arrival. In order to maintain the angle of arrival, the direction of the largest spatial change is used. The direction may be obtained by computing a discretized gradient vector and rotating this vector by 90 radians. Instead of using geodesic curves to connect the isophotes, the prolongation lines are progressively curved while preventing the lines from intersecting each other. This is done by using anisotropic diffusion see figure 1 that illustrates the two methods [1, 5, 6].



(a) (b) (c)

Figure 1 Image inpainting **a-** the original image, **b-** inpainted by level lines , **c-** inpainted by bertalmio

Chan and Shen proposed two image inpainting algorithms (the Total Variation **TV** and the Curvature-Driven Diffusion **CDD**).

The Total Variation (TV**)** inpainting model uses an Euler-Lagrange equation and inside the inpainting domain the model simply employs anisotropic diffusion based on the contrast of the isophotes. This model was designed for inpainting small regions and while it does a good job in removing noise, it does not connect broken edges (single lines embedded in a uniform background) [6, 7].

The Curvature-Driven Diffusion (CDD) model extended the TV algorithm to take into account also geometric information of isophotes when defining the strength of the diffusion process, thus allowing the inpainting to proceed over larger areas. CDD can connect some broken edges, but the resulting interpolated segments usually look blur [8,9] .

The PDE methods which used for all previous illustrated methods required difficult implementation process and nontrivial iterative numerical methods such as anisotropic diffusion and multiresolution schemes. Also, the information given to the practical implementation such as various thresholds or discretization methods is little, thus some steps are mentioned as numerically unstable.

From pervious discussion, the inpainting processes are very slow, a few minutes for inpainting small region.

A Telea proposed a fast marching algorithm that can be looked as the PDE based approach without the computational overheads. It is considerably fast and simple to implement than other PDE based methods, this method produces very similar

results comparable to other PDE methods. The algorithm propagating estimator that used for image smoothness into image gradient (simplifies computation of flow), the algorithm calculate smoothness of image from a known image neighborhood of the pixel as a weighted average to inpaint, the FMM inpaint the near pixels to the known region first which is similar to the manner in which actual inpainting is carried out , and maintains a narrow band pixels which separates known pixels from unknown pixels, and also indicates which pixel will be inpainted next. The limitation of this method is producing blur in the result when the region to be inpainted thicker than 10 pixels [2].

Oliveira proposed a fast image inpainting method which depends on the convolution operation, let the small region to be inpainted as Ω and $\partial\Omega$ be its boundary. the algorithm consists of four steps , the first is the selecting of the damaged region to be inpainted manually. The second is detecting the region boundary. The third is initializing Ω by clearing its color information and the fourth for each pixel in the region to be inpainted make the step that difference from algorithm to algorithm. In this method repeatedly convolving the region to be inpainted with a diffusion template, $\partial\Omega$ is a one-pixel thick boundary and the number of convolution iterations is independently controlled by a certain threshold on the change of pixel value from the previous iteration or by the user , most of the results produced in this method by more than 100 iteration and the inpainting process progress from the boundary $\partial\Omega$ into the region Ω .

Convolving the image with the averaging filter to compute the weighted averages of pixels' neighborhoods is the same as isotropic diffusion. The algorithm uses a weighted average kernel that has a zero weight at the center of the kernel. Figures 2 show the pseudocode of the algorithm and two diffusion kernels. The positives are that the algorithm is really fast and works well for images which do not have many high contrast edges or high frequency components (e.g. natural textures).

Finally this algorithm produces the result in few second with both the diffusion kernels after more than 100 iterations and faster than any image inpainting algorithms but produce blurring [4].

```
Initialize Ω
For( i=0 ; i<num_iteration ; i++)
Convolve masked region with the
```

a	b	a
b	0	b
a	b	a

c	c	c
c	0	c
c	c	c

Figure 2 Oliveira method Pseudocode and two diffusion kernels used with the algorithm. a= 0.073235, b = 0.176765, c = 0.125

Proposed method modifies this algorithm to reduce the time of restoration and remove the blurring from the image, note that all inpainted images in [4] produced after more than 100 iterations but proposed algorithm produces results without blurring and with one iteration and remove large object with symmetric background**.**

3 Modification of Convolution Based Method

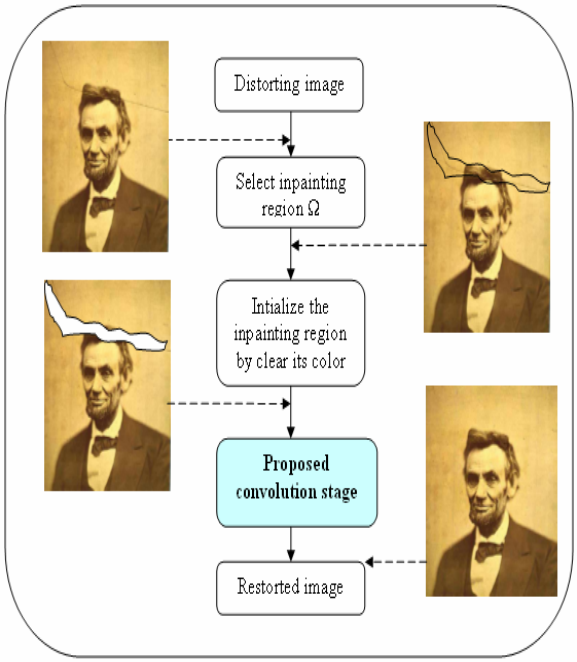


Figure 3 Image inpainting block diagram of proposed modification

The proposed method introduces a modification to Oliveira algorithm in [4] to reduce the time of inpainting and increase the quality of the results based on the modification of convolution stage. In figure 3 we show the block diagram of the proposed modification method, from this figure the proposed method as the same as Oliveira in some things , we must select the region to be inpainted manually and the region to be inpainted is initialized by clearing its color. But different in the method of filling, our method takes the image after the region to be inpainted selected and convolving the region with averaging filter has a zero weight at the bottom right corner instead of the center as show in figure 4 .

Only one convolution iteration that convolve the masked region with the kernel

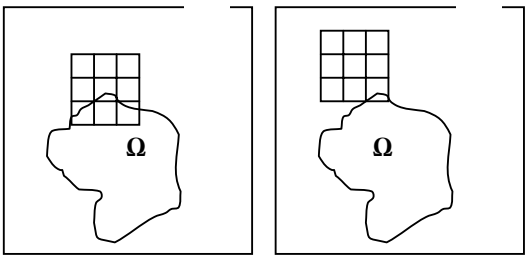
a	b	a
b	a	b
a	b	0

c	c	c
c	c	c
c	c	0

Figure 4 Proposed method Pseudocode and two diffusion kernels used with the algorithm. a= 0.073235, b = 0.176765, c = 0.125

We noted that the inpainted pixel by Oliveira produced from the surrounding neighborhoods pixels, some of these pixels are known such as (pixels outside the region) and the other unknown ones such as (pixels inside the region) as show in figure 5-a. Because of this reason Oliveira reiterate the convolution to more than 100 iterations to blur the colors out into the missing areas to approximate to the value of the neighborhoods.
Mathematically, repeated blurring and diffusion are identical , when an image is blurred, the colors of each pixel are averaged with a small portion of the color from neighboring pixels and contributes a small part of its color to each of its neighbors.

Modifying the diffusion kernel or the filter to zero weight at the bottom right corner instead of the center and making the convolution from the bottom right corner are sample but accurate and play an important role in the inpainting process ,from figure 4 and figure 5-b we noted that, this modification forbidden the need to iterate the convolution operation because the inpainted pixel produced from the above left neighborhoods pixels (known pixels) , now we don't need to repeated blurring (convolution) because the goal of repetition achieved from the first averaging iteration.



(a) (b)

Figure 5 the inpainting process a) - Oliveira method b) - proposed method

Finally the proposed modification achieved the following advantages

- Reducing the time of the inpainting process from more than 100 iteration to one.
- Producing the result without blur because no repetition in convolution.
- Removing large object from the image with symmetric background

The third advantage noted from the image with symmetric background, all pixels surround the removing object are the same, with modified algorithm we can substitute or restore the background when removing the large object from the above pixel.

4 Dissection of Results

After we apply the algorithm with C++ Builder we are sure that all results produced in time faster than Oliveira.

There is no need to make a comparison in time because the results produced with one iteration rather than 100 or more in any hardware. There is no need to make a PSNR comparison in quality because the results produced without blurring, in addition to removing large object from symmetric background as we show in the following figures.

Figure 6-a original image with scratch

Figure 6-b inpainted image

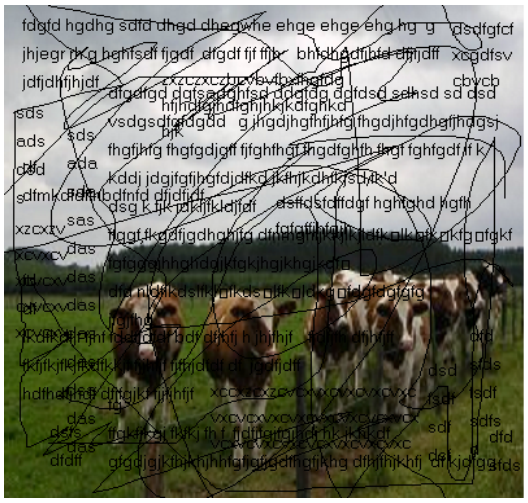


Figure7-a original image with super imposed text and edges with distorted area cover 15.5% .

Figure 7-b inpainted image

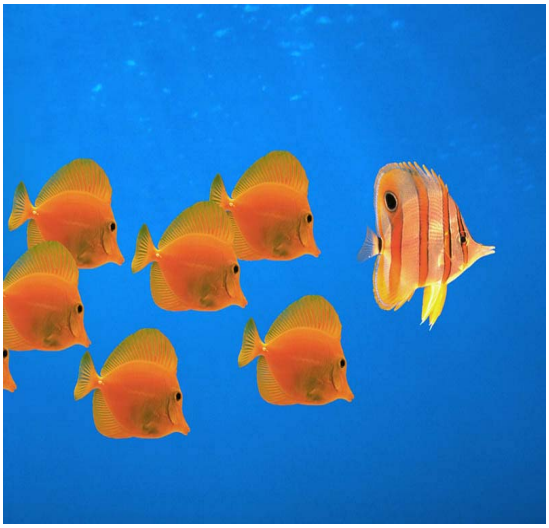


Figure 8-a original image with large object in symmetric background image with mask size 8.7%

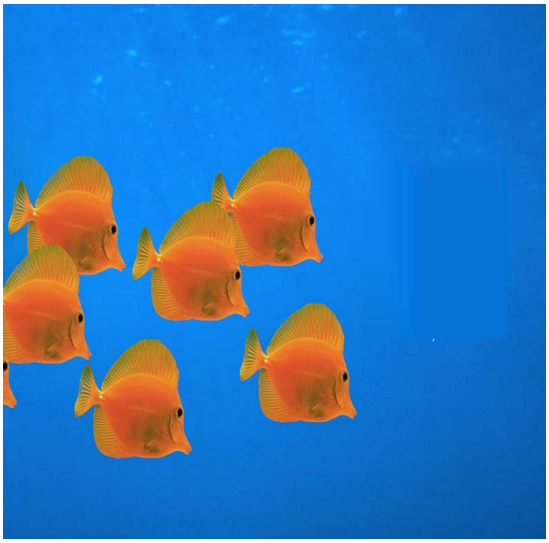


Figure 8-b inpainted image

Figure 9-a original image with large object in symmetric background image with mask size 16%

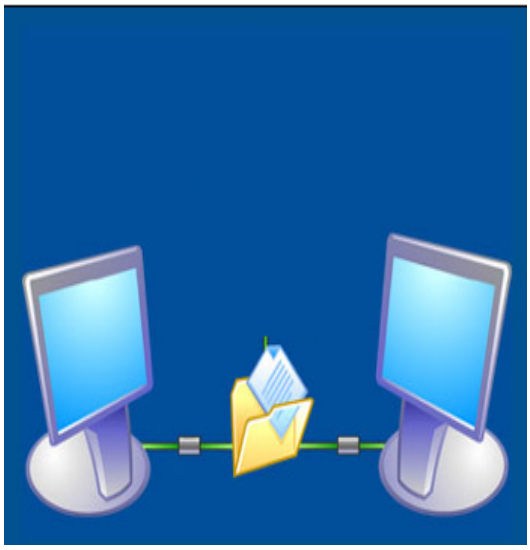


Figure 9-b inpainted image

5 Conclusion

We have offered a fast convolution based digital inpainting algorithm faster than oliveira algorithm with one iteration rather than 100 iteration and our algorithm remove large object in symmetric background images and without blur ,our algorithm fail or produce poor results when removing large object in natural image.

References

1. Marcelo Bertalmio et al " Image inpainting", proceeding of SIGGRAPH 2000 computer graphics processings pp. 417-424
2. A.telea " An image inpainting technique based on the fast marching method" journal of graphics tools, vol. 9, no. 1, acm press 2004
3. Hitoshi yamauchi, jorg haber and hans-peter seidel "image restoration using multiresolution texture synthesis and image inpainting" proceeding of computer grapics international 2003 pp. 1530
4. M. Oliveira , B. bowen ,R. mckenna , Yu-Sung chang "Fast digital image inpainting" in proc. VIIP 2001, pp. 261-266, [PUB],2001
5. Samuel adolfasson "Algorithms regarding automatic retouching of user selected regions in digital images" thesis, Stockholm, Sweden 2004
6. P.PERONA AND J. MALIK "Scale-Space Edge Detection Using Anisotropic Diffusion" IEEE transaction on pattern analysis vol. 12 No. 7 july 1990
7. F. CHAN AND J. SHEN "Mathematical Models for Local Deterministic Inpaintings" UCLA Computational and Applied Mathematics Reports 00-11, March 2000.
8. F. CHAN AND J. SHEN "Non-Texture Inpainting by Curvature Driven Diffusion (CDD)" UCLA Computational and Applied Mathematics Reports 00-35, September 2000.