Image Inpainting using Erosion and Dilation Operation

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Abstract

Image inpainting is a technique of filling unknown image region with known information from the surrounding of the unknown region in such a way that the result is logically accepted. Texture and structure completion in inpainting method is the main challenge in image inpainting and it is still an open problem to be tackled in the near future. In this paper, we propose a new inpainting algorithm based on morphological erosion and dilation. The erosion operation are used to shrink the unknown area and the dilation operation are used to take the information and texture of the surrounding area. The proposed method shows some promising results in synthetic, texture and natural image.

Keywords: *image inpainting, erosion, dilation, morphological operation*

1. Introduction

Image inpainting in digital image were firstly introduced by Bertalmio, *et al.*, in 2000 [1]. The purpose of image inpainting is to modify an image and fill the unknown or missing region with existing information from surrounding area of the unknown or missing region in such a way that the result is logically accepted. The inpainting algorithm must use minimum human interventions. Bertalmio, *et al.*, described that the only human intervention needed is to select which region to be inpainted [1].

Inpainting operation itself is not new. This operation has been done manually by experts since long time ago to modify painting or repair damaged area in a painting. After digital media was widely used, this operation was also brought into digital operation by experts. The increasing amount of digital image makes the need of automatic inpainting is also increasing. Since the first automatic inpainting algorithm introduced by Bertalmio [1], there were number of algorithms emerged. In general, there are 2 main problems in inpainting: completing the structure and completing the texture.

In [1], Bertalmio, *et al.*, use smoothness function in the edge of missing region to be used as the filling value. The idea is propagate information from the surroundings. This algorithm can fill the structure properly but the problem is to fill in the texture.

Bertalmio introduced the second algorithm in the following year. The algorithm uses Navier-Stokes equation for fluids dynamics [2]. The main idea of this approach was to think the image intensity as a stream function. The laplacian is used as the movement of fluid. It is brought to the missing region using a vector field defined by the stream function. In this research, Bertalmio use computational fluid dynamics to the computer vision problems. The result shows a good structure completion but it still does not deal with texture completion. The implementation also has many parameters to be set manually.

Alexandru Telea in 2004 introduced the use of Fast Marching Method (FMM) to propagate information from the surrounding missing region [3]. In this research, Telea try to simplify the inpainting algorithm. The result shows that the implementation is fast and simple. It is also has similar result with the previous algorithm by Bertalmio. This method also does not use texture completion.

In 2008, Hao Guo introduced a simple image inpainting method based on morphological erosion operation. The approach is to erode the missing region and use the information from edge of missing region. The method can bring the continuity of structure and texture information from the known area to the missing area. But there are still some exceptions in restoring complex structure information, curves, and corners [4].

Some publications try to focus more on the texture completion using wavelet. In [5] they use combination on inpainting process in spatial domain and wavelet domain. The method in [6] have use wavelet to separate the texture and structure sub-image. The structure sub-images are reconstructed with Curvature-Driven Diffusions and texture sub-image is filled in based on exemplar.

Texture and structure completion in inpainting method is still an open problem to be tackled in the near future. The algorithm is expected to be able to deal with complex structure and texture and also fast in implementations.

In this paper, we propose a new inpainting algorithm based on morphological erosion and dilation. The erosion operation is used to shrink the unknown area and the dilation operation is used to take the information and texture of the surrounding area. These morphological operations are simple to implement and give a good performance.

2. Morphological Operation

There are 2 main Morphological Operations: Erosion and Dilation. Both of them are used for binary images. In this section these operation are described generally.

2.1 Erosion

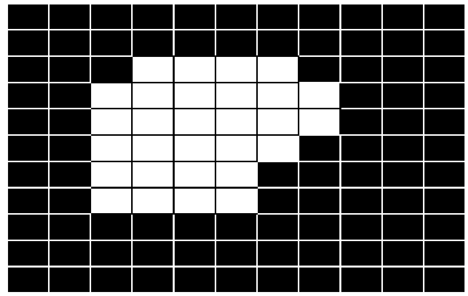
Erosion operation is a morphological operation for reducing the foreground area. The effect of this operation is shrunk foreground. The foreground is reduced from its outer edge to inside its area. If there is a hole inside the foreground area, the hole enlarges. It uses a structuring element and it is done with a convolution operation between the image and the structuring element. This operation is for binary images.

The erosion process will set the foreground pixel to be background if there is part of the structuring element that reaches the background while the center of the structuring element reach the foreground edge. Figure 1 gives an illustration of erosion process with the example of 3 x 3 structuring element.

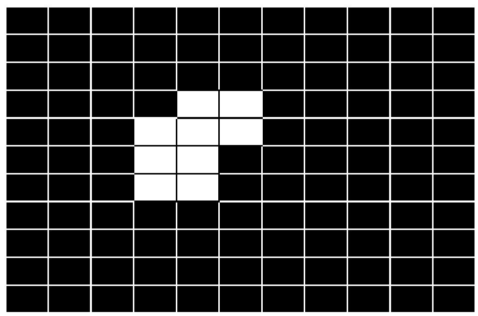
2.2 Dilation

Dilation operation is the reverse operation of erosion. While erosion is for reducing the foreground, dilation is for enlarging it. The foreground is stretched from its outer boundary. If there is a hole inside the foreground, the hole shrinks. Same like erosion, dilation operation are using structural element. The structural element is used in convolution with the image.

1	1	1
1	1	1
1	1	1



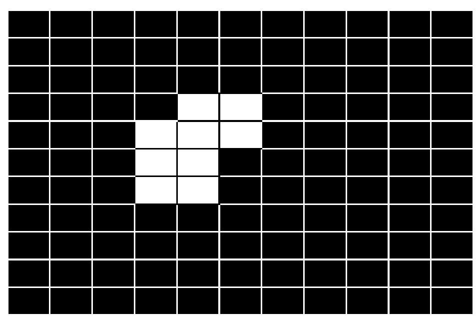
(a)



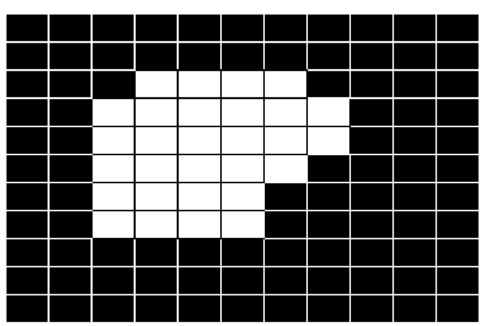
(b)

Figure 1. (a) Structuring Element and Image before Operation; (b) Erosion Operation Result

1	1	1
1	1	1
1	1	1



(a)



(b)

Figure 2. (a) Structuring Element and Image before Operation; (b) Dilation Operation Result

The dilation process will set the background pixel to be foreground if there is part of the structuring element that reach the foreground when the center of the structuring element still in the background area. Figure 2 give an illustration of dilation process with the example of 3 x 3 structuring element.

3. Methodology

In this section, we describe the methodology and implementation details of our proposed method. The data in this research are images collected from numerous site in the internet. The images are grayscale image.

The area to be inpainted is marked with white pixel. The image is separated into 2 images. the real image and mask images. In the beginning, the mask image just contains black pixel. When the inpainted region are selected, the real image and mask image is painted with white pixels in exactly the same area. After selecting the inpainting region, the real image has some missing region covered with white pixels and the mask has black and white area with black pixels are background and white pixels are foreground.

The structuring element is convoluted with the mask. In every one complete loop, it produces eroded mask and dilated mask. In every pixel move in convolution process, when dilation process is done, the pixel in the same position is taken from real images and the location is also saved. Obviously, the dilated pixel is located near the missing region. The pixel value is used as the value when the erosion operator in the next step detects the erosion location. The value from dilation is used in eroding the image. In case the dilation value is more than one, the closest pixel to the erode pixel is selected. The closest pixel is obtained by calculating the distance of eroded pixel with dilated pixels before. Here is the formula for calculating the distance,

$$argminf(x,y) = \sqrt{(|x_1 - x_2|)^2 + (|y_1 - y_2|)^2} \quad (1)$$

The convolution process is repeated until the white area in the eroded mask disappears. The Pseudo code can be viewed in Figure 3.

The experiment is conducted using several images to test how far the algorithm can handle with no strange result.

4. Result and Discussion

In this section, the results of proposed algorithm are shown. The comparisons with 2 other algorithm are also presented here. The discussion is provided to give a clear explanation about the result.

4.1 Result

The implementation is done in python with opencv library. The use of opencv is to make a comparison with the existing algorithm implemented in opencv. They are FMM and Navier-Stokes.

The first experiment is conducted in synthetic image to test the structure completion. Figure 4 shows the result in synthetic image. The second experiment is conducted in textured image and the third experiment is conducted in natural image. Figure 5 shows the result of the second experiment and Figure 6 shows the result of the third experiment.

4.2 Discussion

The proposed method has shown a good result in all experiments. However, there are still many drawbacks. In the synthetic image, the proposed method can restore the structure well but there are defect in the bottom left of the image. This happened because the proposed method cannot perform well on horizontal damage. Since the convolution looping is done horizontally per row, this can lead to bad result if the damage area is a horizontal line. Figure 4b shows that the proposed method cannot give good result in detecting border of vertical intensity change. The damage is horizontal line across the vertical border. The value from dilation process is still the value from the old / left area and the erosion are in new / right area. This is happened because the convolution is moving from left to right direction and the dilation are done before the erosion process. It needs to detect the change of intensity to make a better result. The other methods are also performing poor result in the intensity change area. Figure 4b and 4c show that the other methods give a little blur result on every intensity change area, not only on horizontal change, but also in vertical change. The proposed method still perform good result on the vertical intensity change. The proposed method does not make blur result on every intensity change area.

The second experiment was tried in a texture image. The result shows that the texture can be restore well. However, when the damage line is crossing horizontally, the damage area cannot be restored well. The same problem appears here with the horizontal damage as the first experiment. But here the proposed method shows it can give texture to cover the area when the other methods give blur result. All methods are still poor in detecting structure change. Therefore they cannot complete global structure well. In Figure 5 we can see that the brick padding cannot be completed well with all the methods but the NS and Telea can hide it with blur image. If the damage area is big, the proposed method can give the texture but it cannot give a connected texture with the surrounding area. The others methods give blur result to cover the area. They are also cannot give connection with surrounding texture.

The third experiment was conducted on a natural image. This natural image has an equal crosswise structure on the center. Here we tried to make the damage around these structures more wide. The result shows that the proposed method can give a good restoration result in Figure 6b. This is due to the even texture and structure. The proposed method has done well in a natural image with horizontal structure damage. It is because the method looks for pixel value from surrounding area, which in this case have same horizontal structure. Figure 6 shows constant horizontal structure in the center. There are sky, forest, land with grass and lake. The structure has repeated in a large area around the damaged area. The other methods give blur result. When the damage is a big area like in Figure 6, the blur area are showed clearly. The proposed method gives a better result in this category image.

The algorithm still needs many improvements in the region filling strategy particularly when the image has horizontal damage. This drawback comes naturally since the process is done row by row. The pixel value from dilation process is used as is in erosion process without smoothing function. This is done in order to get the textured result. Some criterion must be applied in this part so that the region filling process can be more correct. The detection of intensity change area is also crucial for image synthetic image. For the natural image, it needs structural completion to give better result on completing the damage area and give right texture for right area.

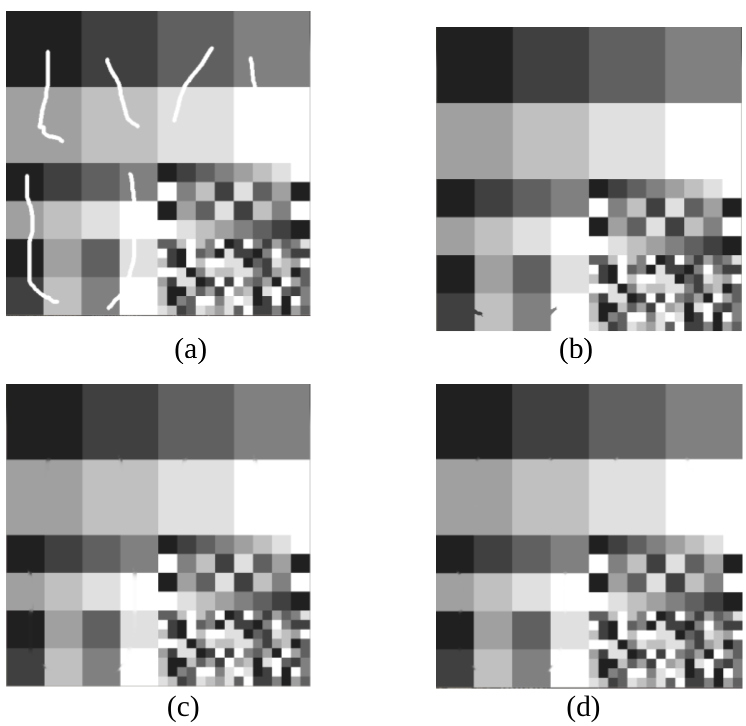
```
image_result = image - inpainting mask

while cpixel > 0:
    cpixel = 0
    imge = image_copy(image_eroded)
    imgd = image_copy(image_dilated)

    for i to image_width:
        for j to image_height:
            if any neighbor pixel in imgd image == 255:
                v = get image_result pixel (i, j)
                set image_dilated pixel (i, j) = 255
            end if

            if pixel image imdg (i, j) == 255:
                cpixel += 1
                conv = convolustion matrix structuring element imge (i,j)
                if conv < (9*255):
                    set image_eroded pixel (i, j) = 0
                    set image_result pixel (i, j) = v
               end if
            end if
        end for
    end for
end while
```

Figure 3. Pseudocode of the Proposed Method



(a) (b) (c) (d)

Figure 4. The Result in Synthetic Image: (a) The Damaged Image, (b) Proposed Method, (c) Navier-Stokes Method, (d) Telea Method

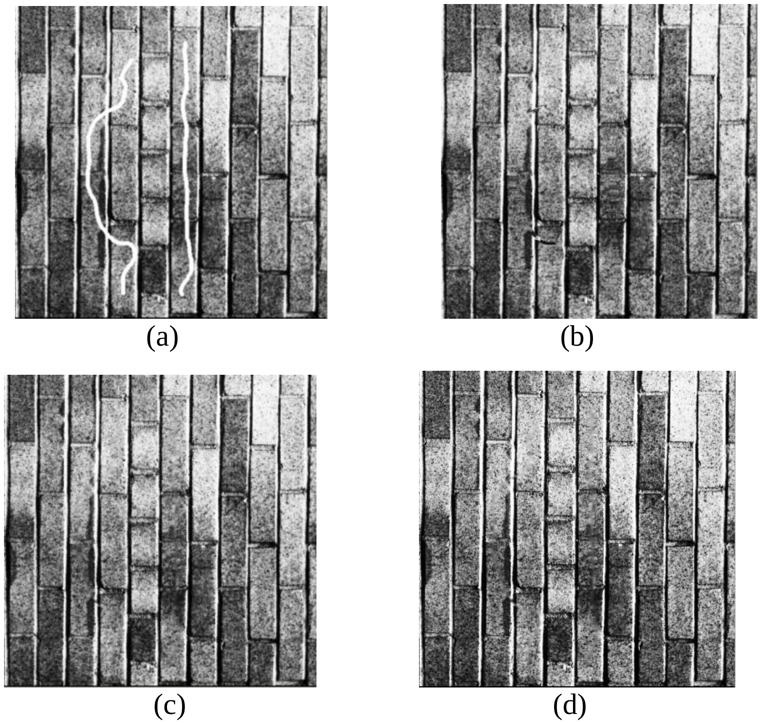


Figure 5. The Result in Texture Image: (a) The Damaged Image, (b) Proposed Method, (c) Navier-Stokes Method, (d) Telea Method

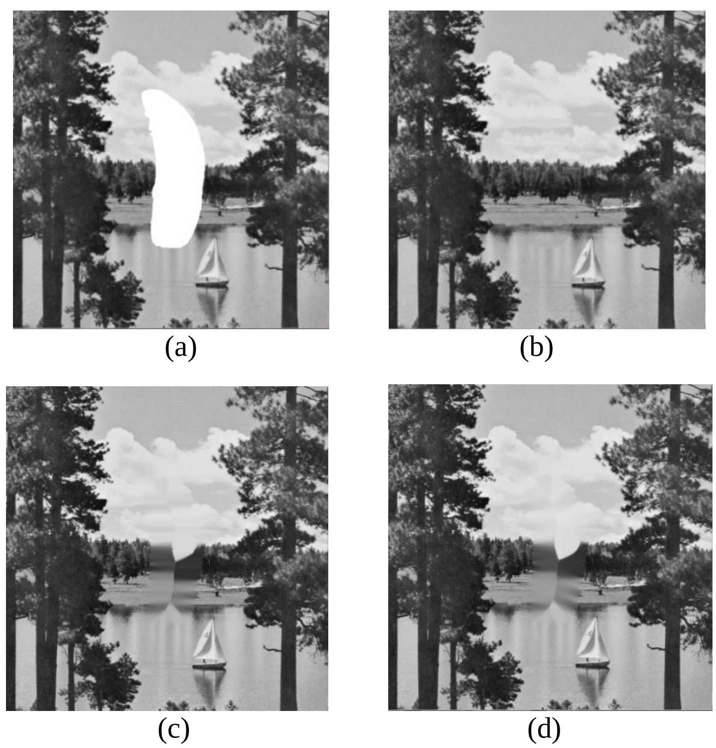


Figure 6. The Result in Natural Image: (a) The Damaged Image, (b) Proposed Method, (c) Navier-Stokes Method, (d) Telea Method

5. Conclusion and Future Work

In this paper we propose an algorithm for image inpainting based on two main morphological operation dilation and erosion. The proposed algorithm can perform well on restoring structure and texture in a damaged image. However, the method still has many drawbacks. The most visible weakness is in restoring long horizontal line damage. The proposed method still needs to be improved in region filling strategy. In the near future, we plan to add more rules in the region filling strategy to overcome the problems.

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