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Research Paper

DIGITAL IMAGE INPAINTING USING EROSION

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The term inpainting comes from art restoration, where it is also called retouching. Medieval artwork started to be restored as early as the Renaissance, the motives being often as much to bring medieval pictures "up to date" as to fill-in any gaps. The need to retouch the image in an unobtrusive way extended naturally from paintings to photography and film. The purposes remained the same, to revert deterioration (e.g., scratches and dust spots in film), or to add or remove elements. In the digital domain, the inpainting problem first appeared under the name "error concealment" in telecommunications, where the need was to fill-in image blocks that had been lost during data transmission. One of the first works to address automatic inpainting in a general setting dubbed it "image disocclusion", since it treated the image gap as an occluding object that had to be removed, and the image underneath would be the restoration result. Popular terms used to denote inpainting algorithms are also "image completion" and "Image fill-in". The erosion, which is a morphological operator, is used for inpainting. In this paper, the image to inpainted is eroded repeatedly, to fill the damaged region of the.

Keywords: Digital image impainting, Error concealment, Erosion, Image completion, Image fill-in

INTRODUCTION

In the digital world, inpainting (also known as image interpolation) refers to the application of sophisticated algorithms to replace lost or corrupted parts of the image data (mainly small regions or to remove little defects). Digital techniques are becoming a widespread way of performing inpainting, ranging from attempts to fully automatic detection and removal of scratches, all way to software tools that allow a sophisticated but mostly manual process.

This paper, introduces an algorithm for digital image inpainting. To revert deterioration, we need a software code that can remove the damaged/scratched regions in an undetectable way. Thus the objective of image inpainting is not to recover the original image but to create some image that has a close resemblance with the original image.

The morphological operator used in the algorithm is 'erosion'. When an image is eroded, the image will get contracted or

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shrinked. Erosion removes isolated noisy pixels and it smoothes the object boundaries.

The main idea is to erode a damaged image repeatedly for required number of times and saving the information of the pixels of this image and then combining the original damaged image and the eroded image. Thus the damage region is constructed and the image is said to be inpainted.

LITERATURE SURVEY

There are two types of image inpainting techniques. They are:

- Structural Inpainting
- Textural Inpainting.

Structure Inpainting

Bertalmio *et al.* was the first to propose digital inpainting in the year 2000. He proposed a digital inpainting technique algorithm based on Partial Differential Equation (PDE) (Bertalmio *et al.*, 2000). This method is an extension of level lines based on disocclusion method. After user selects the region, this method iteratively propagates the information from outside the inpainting area to inside the inpainting area (diffusion) along the level isophote lines(lines of equal gray values), the difference lies in the goal of maintaining angle of arrival. In order to maintain the angle of arrival, the direction of the largest spatial change is used. The direction of propagation of information is obtained by computing a discretized gradient vector and rotating this vector by 90 degrees. Instead of using geodesic curves to connect the isophotes, the propagation lines are progressively curved while preventing the lines from intersecting each other.

Noori *et al.* (2010) proposed a method in which mask coefficients are calculated using the gradient of the image to be inpainted. The gradient of known pixels in the neighbourhood of a missing pixel is used to compute weights in convolution mask. Noori inpainting is carried out by convolving the damaged image with a space-variant kernel. For every pixel, the kernels are calculated using its neighbours in both space and range domains to implement Bilateral Filtering (Noori *et al.*, 2011). Since the bilateral filters are efficient in denoising and hence used to inpaint by estimating the lost/ damaged pixel value by its neighbours.

Texture Inpainting

The exemplar based approaches constitute an important class of inpainting algorithms and have proved to be very effective. An algorithm for handling large fill areas which combines the use of texture synthesis and Isophote driven Inpainting by a priority based mechanism in a unified framework was proposed by Noori *et al.* (2011). This exemplar-based removal technique performs well for a wide range of images with good texture and structure replication but has some difficulty in handling curved structures. A major drawback of this exemplar method is the bias caused by selection of few incorrect patches in the priority based filling mechanism. These incorrect patches have a tendency to hijack the entire inpainting process by building upon the initial incorrect completions and have a spiralling effect that undermines the stability of the inpainting process.

EROSION

Erosion is one of the two basic operators in the area of mathematical morphology, the other

being dilation. It is typically applied to binary images, but there are versions that work on grayscale images. The basic effect of the operator on a binary image is to erode away the boundaries of regions of foreground pixels (i.e., white pixels, typically). Thus areas of foreground pixels shrink in size, and holes within those areas become larger.

The erosion operator takes two pieces of data as inputs. The first is the image which is to be eroded. The second is a (usually small) set of coordinate points known as a structuring element (also known as akernel). It is this structuring element that determines the precise effect of the erosion on the input image (Mathematics of Binary Morphology). The mathematical definition of erosion for binary images is as follows:

Suppose that X is the set of Euclidean coordinates corresponding to the input binary image, and that K is the set of coordinates for the structuring element. Let Kx denote the translation of K so that its origin is at x. Then the erosion of X by K is simply the set of all points x such that Kx is a subset of X.

The mathematical definition for grayscale erosion is identical except in the way in which the set of coordinates associated with the input image is derived. In addition, these coordinates are 3-D rather than 2-D.

As an example of binary erosion, suppose that the structuring element is a 3×3 square, with the origin at its center as shown in Figure 1. Note that in this and subsequent diagrams, foreground pixels are represented by 1's and background pixels by 0's.

To compute the erosion of a binary input image by this structuring element, we consider

Figure 1: A 3×3 Ssquare Structuring Element

Set of coordinate points
$\{(-1,-1),(0,-1),(1,-1),(-1,0),(0,0), \quad (1,0),(-1,1),(0,1),(1,1) \}$
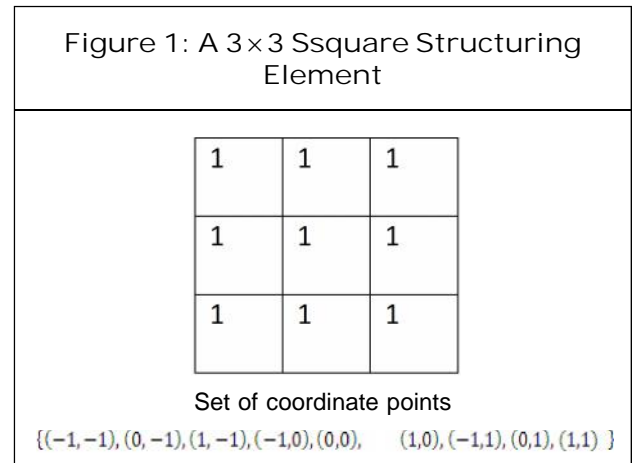
each of the foreground pixels in the input image in turn. For each foreground pixel (which we will call the input pixel) we superimpose the structuring element on top of the input image so that the origin of the structuring element coincides with the input pixel coordinates. If for every pixel in the structuring element, the corresponding pixel in the image underneath is a foreground pixel, then the input pixel is left as it is. If any of the corresponding pixels in the image are background, however, the input pixel is also set to background value.

For our example 3×3 structuring element, the effect of this operation is to remove any foreground pixel that is not completely surrounded by other white pixels (assuming 8-connectedness). Such pixels must lie at the edges of white regions, and so the practical upshot is that foreground regions shrink (and holes inside a region grow).

Erosion is the dual of dilation, i.e., eroding foreground pixels is equivalent to dilating the background pixels.The structuring element may have to be supplied as a small binary image, or in a special matrix format, or it may simply be hardwired into the implementation, and not require specifying at all. In this latter case, a 3×3 square structuring element is

Figure 2: Effect of Erosion Using a 3×3 Square Structuring Element
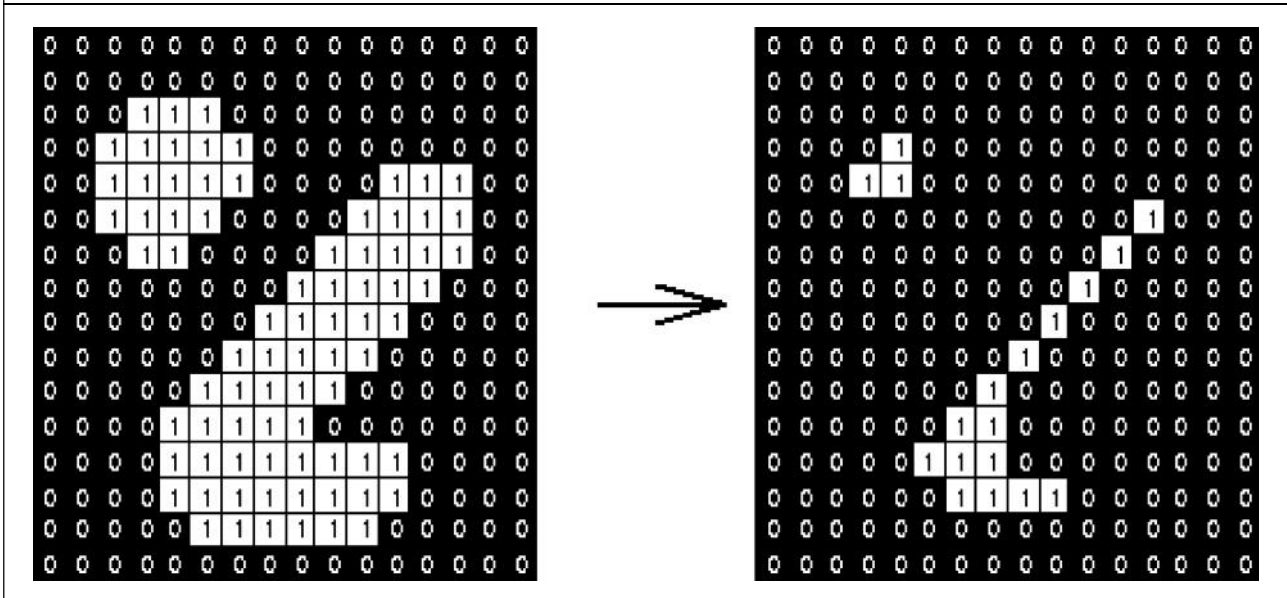
normally assumed which gives the shrinking effect described above. The effect of an erosion using this structuring element on a binary image is shown in Figure 2.

The 3×3 square is probably the most common structuring element used in erosion operations, but others can be used. A larger structuring element produces a more extreme erosion effect, although usually very similar effects can be achieved by repeated erosions using a smaller similarly shaped structuring element. With larger structuring elements, it is quite common to use an approximately disk shaped structuring element, as opposed to a square one.

MEAN

The mean/average of data set is simply the arithmetic averages of the values in the set, obtained by summing the values and dividing by the numbers of values. When we summarize a data set inn a frequency distribution, we are 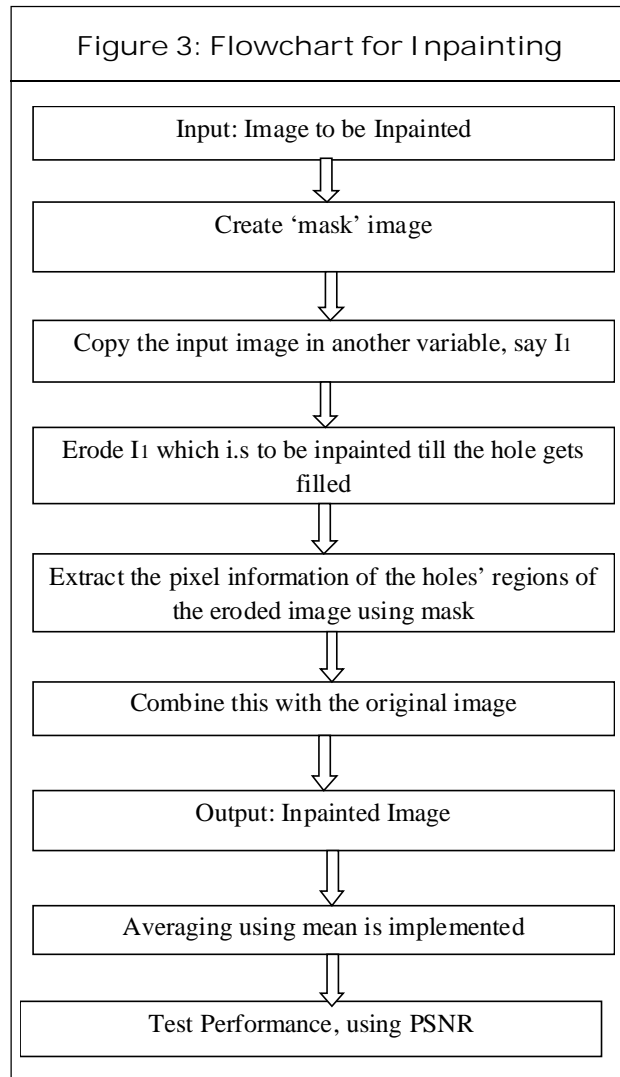approximating the data set by " rounding" each value in a given class to the class mark, With this in mind, it is natural to define the mean of a frequency distribution and is given by

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} f_i x_i = \frac{1}{N} \sum_{i=1}^{N} p(x_i) x_i$$

The mean is a measure of the center of the distribution. As seen from algebraic formula, the mean is weighted average of the class mark x_i with relative frequencies f_i as the weight factors.

PEAK SIGNAL-TO-NOISE RATIO

To test performance of the proposed technique/s, clean undamaged images are artificially degraded, and then inpainted. Although, the evaluation of inpainting technique/s is to be assessed by visual appearance and quality which is subjective in nature, a quantitative assessment would be more objective. There is no established quantitative measure for this evaluation. Hence

Figure 3: Flowchart for Inpainting

Input: Image to be Inpainted

Create 'mask' image

Copy the input image in another variable, say I1

Erode I1 which i.s to be inpainted till the hole gets filled

Extract the pixel information of the holes' regions of the eroded image using mask

Combine this with the original image

Output: Inpainted Image

Averaging using mean is implemented

Test Performance, using PSNR

in our work, the quantitative evaluation is performed by Peak Signal to Noise Ratio (PSNR). The PSNR is defined as

$$PSNR = 20\log_{10}\left(\frac{255}{RMSE\left(f_{clean}, f_{inp}\right)}\right) \quad ...(1)$$

where

$$RMSE\left(f_{clean}, f_{inp}\right) = \sqrt{\frac{\sum_{\forall i,j}\left(f_{clean}(u,v) - f_{inp}(u,v)\right)^2}{MN}}$$

...(3.14)

where $f_{clean}(u,v)$ is clean undamaged image, $f_{inp}(u,v)$ is inpainted image and $M \times N$ is size

of $f_{clean}(u,v)$ and $f_{inp}(u,v)$. Please note that this measure is applicable only when the undamaged original image is available.

RESULTS

To envisage the working of the algorithm, the white patch/scratch is put on the original image (shown in Figures 4a, 5a and 6a). The patches/scratches are removed using the proposed algorithm and inpainted results are shown in Figures 4b-6b respectively.

Figure 4: a) The White Patch is Put on the Original Vegetables Image, b) The Inpainted Image with PSNR = 57.54 dB

Figure 5: a) The White Patch is Put on the Original Artificial Doll Image, b) The Inpainted Image with PSNR = 55.47 dB

Figure 5 (Cont.)

Figure 6: a) The White Patch is Put on the Original Artificial Doll Image, b) The Inpainted Image with PSNR = 55.47 dB

APPLICATIONS

- The interesting application about inpainting is removing any unwanted data or object from a given image without deteriorating the visual quality. This can be used in many areas such as blanking out certain portions of TV frames etc. Damaged images can be restored.

- In photography and cinema, is used for film restoration; to reverse the deterioration e.g., cracks in photographs or scratches and dust spots in film. It is also used for removing red-eye, the stamped date from photographs and removing objects to creative effect.

- This technique can be used to replace the lost blocks in the coding and transmission of images. It can also be used to remove logos in videos.

- In this method the pictures which with age are often damaged and also removal of scratches on photos, which can revert deterioration using inpainting.

- Inpainting technique can be used to remove text overlapped on a image, which helps in extracting the original image for a clear view.

- This can also be used in creating special effects and animations by which few objects can be made missing. For example, removal of ropes which are used for support in real and removal of shadows.

CONCLUSION

In this paper we have introduced algorithm for image inpainting that replicates the basic techniques used by professional restorator. This technique firstly searches for the area to be masked and this area is smoothened easily

using the surrounding area information. This technique is less complex compared to other techniques in inpainting and also has less simulation time.

In the near future there is a scope to extend our project to textural image inpainting. Larger areas can be restored better by using two masks rather than one mask as is used in the present algorithm. We can also extend the project to video inpainting.

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