Image Inpainting Algorithm for Region Filling Application

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Abstract— Image Inpainting is the process of reconstructing or retouching an image. It has a wide range of applications including region filling, object removal, denoising, compression, etc. It is an important work done in the field of image processing. This research work has been carried out to reconstruct an old image by filling the spatial information from the surroundings in the damaged portion such as scratches, tampered pages, missing areas and holes. This paper provides details regarding image inpainting using exemplar based method for both structure and texture reconstruction.
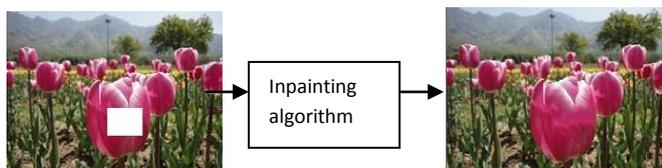
Keywords- *Image inpainting, region filling, structure and texture reconstruction*

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I. INTRODUCTION

Image inpainting is a technique of modification and filling in an image in such a way that it is non-detectable for an observer, who does not know the original image. The main objective of image inpainting is to reconstruct the damage or missing portion of an image. In ancient times, this work was carried out by the artists to keep the paintings "up-to-date". But in recent era, inpainting work has been digitized. The applications of digital image inpainting includes overlaid text removal, object removal, filling in the scratches in the photograph, red eye correction and is used to produce stunning visual effect in an image. Various techniques have been proposed by the researchers for image inpainting. There are two main approaches for image inpainting. Firstly geometric structure synthesis and secondly texture synthesis.

Input Image (Image to be inpainted)   Output image (inpainted image)

Fig-1: Image Inpainting Process

There are two basic approaches for image inpainting. The first approach is diffusion based image inpainting and second approach is exemplar based image inpainting.

In diffusion based image inpainting, the target region is filled by diffusing the information pixel by pixel from the source region or surrounding area. This results in image smoothing and blur is noticeable in the inpainted image when the area to be filled is large. Even texture is not exactly reproduced using diffusion based approach. Various algorithms have been proposed based on diffusion based approach. Partial Differential Equation (PDE) based algorithm is proposed in [1] which is an iterative algorithm. The information is propagated in the direction of minimal change using isophote lines. The geometric structure is preserved well and this algorithm is suitable when small region need to be inpainted. The next model was proposed as total variational (TV) Inpainting model [2]. This model uses Euler-Lagrange equation and anisotropic diffusion based on the strength of the isophotes. One can use this model when there is a reasonably small region to be inpainted for noise removal applications. But the drawback of this method is that it is unable to recover partially degraded image for curved structures. An extended TV model, called CDD model [3] was proposed to handle the curved surfaces in better way as it contains the curvature information of the isophotes. A fast marching method was proposed in [4]. It is faster and simpler method compared to other PDE based algorithms and used for applications including image segmentation, restoration, etc.

A lot of research is also carried out in exemplar based image inpainting. *Exemplar-based techniques* cheaply and effectively generate new texture by sampling and copying color values from the source [5], [6], [7], [8], [9]. An algorithm which is capable of reproducing both structure and texture information simultaneously was proposed in [10]. The information is filled in the target region pixel by pixel from the patch found in the source region. This process is carried out iteratively till the entire target region is filled. The priority is given to linear structure. So, this algorithm, efficiently synthesis texture, even for large inpainting region and at the same time preserves linear structures as well. This technique is extended in [11] by incorporating Bezier curves to construct missing edge information. After determination of structure information in an image, destroyed contours will be connected

in curve fitting process and damaged region will be inpainted using exemplar based image inpainting. This provides efficient results for different kind of images and is able to synthesis curved structures and texture well.

II. ALGORITHM DESCRIPTION

Exemplar based Image inpainting is an efficient method for inpainting which preserves both structure and texture information during reconstruction of an image. This method is used to remove large object from an image in such a way that is not detectable by human and filling that region with the background information. An algorithm was proposed in [10] and it performs simultaneous structure and texture synthesis. In the proposed algorithm, the user selects the damaged portion of an image as the region to be filled. This region is considered as the target region and it is denoted by Ω. The source region is a region which contains the known information and it is denoted by Φ which is equal to entire image I minus the target region Ω. $(\Phi = I - \Omega)$. The boundary of the target region is detected and it is denoted by $\delta\Omega$. A patch is constructed for each pixel on the boundary by taking that pixel in the center.
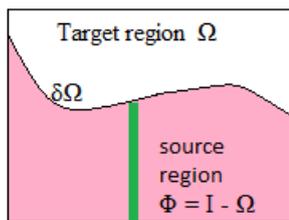

Fig-2: Input Image I

The priority is given to each patch on the boundary and it is equal to the product of confidence term C(p) and the data term D(p). The confidence term C(p) defines the number of pixels in a patch. The data term D(p) encourages the synthesis of the linear structure and it is propagated into the target region. The size of the template window Ψ is to be specified in the algorithm. The default window size is taken as 9 x 9 pixels. This value can be set slightly larger, if there is a larger element than this default window size in the source region. The order of filling in the target region is determined based on patch priority. The algorithm iterates following three steps, until all the pixels are filled in target region.

A. Computing priorities of patches on the boundary

The filling in the target region is carried out using the best-first filling strategy. In this strategy, the patch on the boundary is selected depending on its priority value. The priority of a patch is considered based on the following criteria, (i) if they are on the continuation of strong edges and (ii) they contain the more number of pixels which are already filled with known information. For a pixel p, where p ϵ $\delta\Omega$, the patch

priority P(p) for a patch Ψp , is calculated as the multiplication of confidence term C(p) and data term D(p).

$$P(p) = C(p) \times D(p) \qquad (1)$$

The confidence term C(p) and D(p) can be calculated as follows:

$$C(p) \quad = \frac{\sum_{q \in \Psi p \, \cap (I-\Omega)} c(q)}{|\Psi p|} \qquad (2)$$

$$D(p) \quad = \frac{|\nabla I p^{\perp}.n_p|}{\alpha} \qquad (3)$$

Where, $|\Psi_p|$ is the area of Ψ_p, α is a normalization factor, n_p is a unit vector orthogonal to the front in the point p. The patch priority P(p) is calculated for every patch with distinct patches for each pixel p on the boundary of the target region. The confidence term for the pixels belonging to the target region is set to zero and the confidence term for the pixels belonging to the source region is set to one. The confidence term C(p) is a measure of the amount of reliable information surrounding the pixel p [10]. The data term is a function of strength of isophotes hitting the front of the boundary at each iteration [10]. This term encourages the linear structure to be preserved first and then the texture information will be synthesized.

B. Filling in the texture and structure information

As the highest priority patch Ψp is obtained, one can fill that patch with the information from source region Φ. If the pixel value from the source region is propagated via diffusion, then blurring is noticeable in the reconstructed image. For filling in the patch, one can propagate image texture by direct sampling of source region [10]. Then search for the most similar patch in the source region to the patch Ψp.

$$\Psi q = \arg \min_{\Psi q \, \epsilon \, \Phi} d(\Psi p, \Psi q) \qquad (4)$$

Where the distance d(Ψp, Ψq) between the two generic patches is defined as the sum of squared differences of the already filled pixels in the two patches [10]. Once the source patch Ψq is found, the value of each pixel is copied from patch Ψq to patch Ψp. In this manner, the structure and texture information is propagated from source region to the target region with one patch at a time.

C. Modification of confidence values

Once the patch Ψp is filled with pixel values, the confidence term C(p) is updated as follows:

$$C(p) = c(\acute{p}) \qquad (5)$$

This simple update allows measuring the relative patch confidence. The confidence values decay as the filling

proceeds and it shows that the color values of pixels near the center of target region is less sure.
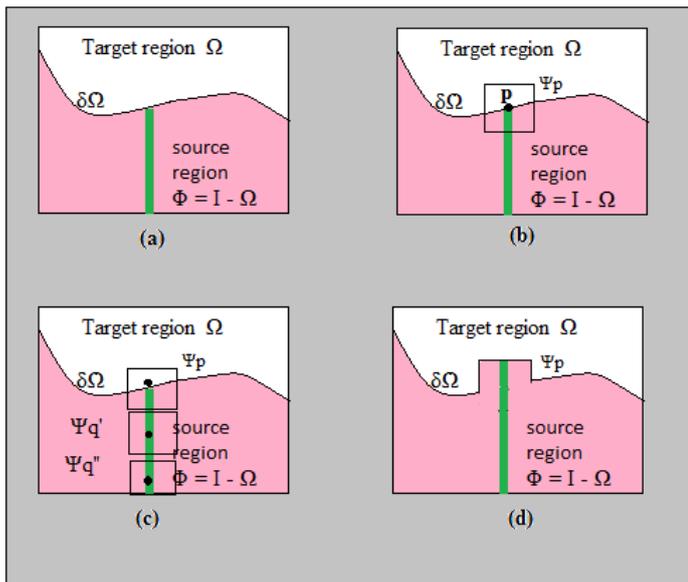

Fig-3: Propagation of structure using exemplar-based algorithm

III. IMPLEMENTATION DETAILS

The algorithm steps can be given as follows:

1. Initialize the confidence values for all the pixels in a given image. If the pixels belong to inpainting domain initialize confidence value to zero, else one.
2. Repeat the following steps until all pixels in target region are filled.
   (i) Identify the boundary of inpainting domain, if the boundary is empty set exit.
   (ii) Compute priority of all the patches on the boundary.
   (iii) Find the patch with highest priority. Presently assuming P.
   (iv) Find the best match patch (to the patch P) from the search window.
   (v) Copy the pixels of best match patch to the corresponding pixels of patch P, whose confidence term value is 0.
   (vi) Update the confidence values for the pixels of patch P.

The original image and the mask image are given as input to the computations. The mask image provides information about the target region that is to be filled with information from the background. The collection of pixels that have neighboring pixel in the target region is considered as contour or boundary. A vector is formed which contains the list of contour points.

A patch of appropriate size is formed using the boundary pixel as the center pixel. The highest priority patch is found from all these patches formed on the boundary. Then, a patch from the source region is searched which is most similar to the target patch based on the calculation of Sum of Square Difference (SSD) of color values of the pixels in both the patches. Information can be copied pixel by pixel from the source patch into the highest priority target patch. The target patch contains portion of source region and portion of target region, so while copying the pixels from the source patch; only those pixels which are part of target region need to be copied.

After the target patch is filled, the contour list is updated as follows:

(i) Those contour points will be removed from the list that fall into the boundary of the target region.
(ii) The pixels on the boundary of the target patch will be added to the contour list, if those pixels had not been filled yet.

Continue the selection of the patches which contain center point on the contour to be filled. Keep updating the contour list as filling proceeds. When the contour list is empty, the whole target region is filled and one can get an inpainted image as the output.

IV. EXPERIMENTAL RESULTS

The results obtained by performing exemplar-based image inpainting technique using MATLAB 7.5.0 are presented as follows.

(i) The image of an old book (fig. 4) is taken as an input image. This image is having horizontal resolution of 300 dpi and vertical resolution of 300 dpi. The dimension of the image is 324 x 243. The picture is taken using the Nokia X6 mobile phone camera of resolution 5MP.

Original Image   Inpainted Image

Fig-4: Scratch and the hole in the original image are reconstructed in inpainted image.

(ii) The same image of an old book is taken as an input image with different resolution. This image is having horizontal resolution of 72 dpi and vertical resolution of 72 dpi. The dimension of the image is 392 x 221. The picture is taken using the Sony Xperia Z mobile phone camera 13MP.
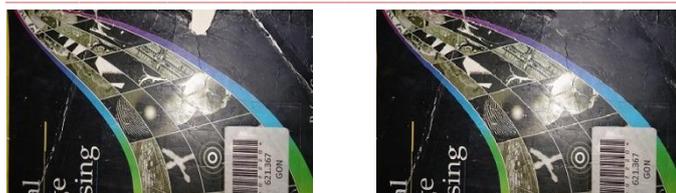
Original Image   Inpainted Image

Fig-5: Scratch and the hole in the original image are reconstructed in inpainted image with different resolution.

(iii) Another image having damage in the texture area is taken as input image. This image is taken using sony xperia z mobile phone camera with resolution 13 Megapixel. The result shows that the texture can also be synthesized properly.

Original Image   Inpainted Image

Fig-6: Results depicts that the textured area at bottom right corner is be synthesized properly.

The PSNR value for original image and inpainted image is calculated for the results shown in fig-4, fig-5 and fig-6 and they are given in table I.

Table-1: PSNR calculation for images

Sr. No.	Images	PSNR (values in decibel)
1	For original image and inpainted image (clicked using nokia) shown in fig-4	19.58
2	For original image and inpainted image (clicked using sony) shown in fig-5	14.63
3	For original image and inpainted image (depicting texture synthesis) shown in fig-6	17.58

V. CONCLUSION

In this paper, exemplar based Image inpainting is discussed. It is an efficient method for preserving both structure and texture information during reconstruction of an image. The simulation was performed on the image and the results are obtained for the various resolution and texture information. It is observed that the linear structure is preserved while reconstructing damaged portion of the original image. The qualities of the results are satisfactory while reconstructing the textured part of the image.

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