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An Overview of Image Inpainting

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ABSTRACT: Image Inpainting is an art of restoring the lost or deteriorated part in an image. Previously it was performed by artists and even today missing part in an image can be recovered by same means but at the cost of time. In today's era of automation, same can be mimicked digitally taking benefits of advances in digital image processing which is much more time saving than doing the same manually. Many algorithms and methods have proved their effectiveness for digital image Inpainting. This paper gives overview of some effective image Inpainting techniques.

KEYWORDS: Image Inpainting, Exemplar-based Image Inpainting, Super pixel-based depth map Inpainting, Partial Deferential Equation (PDE), Wavelet based Image inpainting.

I. INTRODUCTION

The image inpainting is the process of filling in the missing details in an image to restore details in it. The restoration and modification of images in not detectable way is a very old practice, right from the time of the manual restoration of by filling in any gaps that damaged the artwork over the years. Traditionally, artists performed image inpainting manually which was a very tedious and time consuming process. In modern times, the digitizing of analog images often results in undesirable defects like scratches, etc. which should be removed. This practice is known as inpainting. The aim of inpainting is to recover the damaged portions of the picture. The necessity of image restoration extends from paintings to photographs and films for recondition any deterioration like cracks or scratches in paintings and photographs , or to modify image by adding or removing elements .The goal is to produce a modified image which is similar to original image and merged inpainted region cannot be distinguished from modified image. [1], [2], [3]

The applications of image completion including recovery of lost blocks in wireless image transmission, objects removal as special effects in image forgery, removal of scratches in historical image restoration, removal of occlusions like text-subtitle, and logos, stamps. Applications also include removing remarks like orientation and location from medical, aerial and military images. It is one of the vital step in cinema post production. Post production films companies has significant budget allocated for visual story modification which saves cost since it is more expensive to reshoot the scene. Furthermore, they can also be observed in applications like image compression and super resolution.

In this paper various effective image inpainting techniques are discussed including inpainting based on exemplar method, Exemplar based Inpainting with search region prior, Partial Deferential Equation (PDE), Wavelet based Image inpainting.

II. IMAGE IN-PAINITNG APPROACHES

The Inpainting algorithms can be divided into three categories of 2D image. The first is structural inpainting, the second one is texture inpainting and the third approach is to use combination of these two techniques. Structural inpainting uses knowledge of consistency of the geometric structure for filling in the missing information in the region to be inpainted. Texture has a pattern which is repetitive and can be used for filling a missing portion. A combined approach performs filling in regions of missing image information using both textural and structural information simultaneously. All these inpainting methods use the information of the undamaged image areas in order to fill the gaps.

In the paper [4], structure propagation for image inpainting is performed. Structure propagation is formulated enforcing structural continuity.

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In the paper [5] by Geeta K.Sarpate et al., an algorithm is proposed for removing target objects from image. Actual color values computed using exemplar based texture synthesis and region filling technique. The 'blur' and unevenness in texture in inpainted image is removed.

In the paper [6] by Somayeh Hesabi, a new approach by combining structure inpainting method and texture synthesis technique is presented. The combination of these two approaches enables us to simultaneously recover texture and geometric information. They established result that the quality of the results obtained by combined approach is better than individual approaches [6].

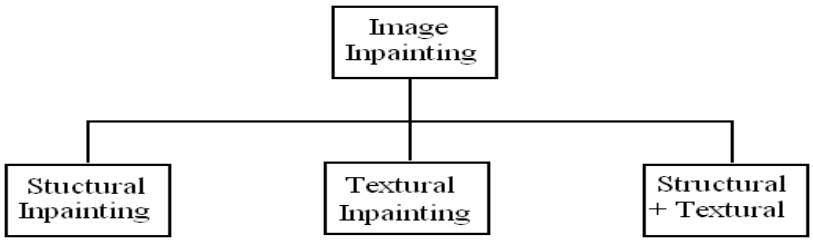

Fig 1. Image in-painting approaches

III. OVERVIEW OF IMAGE INPAINTING TECHNIQUES

Lot of work in done in image processing with the aim of inpainting. Different algorithms have proved their effectiveness for predicting missing area in a damaged image including, Exemplar based inpainting, inpainting using Partial differential equation, wavelet based image inpainting. In this section all these techniques are discussed in detail.

A. *Exemplar based Inpainting*

This method is very frequently used Inpainting and texture synthesis technique proposed by Criminisi et.al [7]. In this algorithm priority based region filling is done to decide order of region to be filled. This technique work very good for removing large images [8]. Exemplar-based image inpainting try to make the replica of texture and structure. It fills depleted region in the image by searching for comparable patches in a nearby source region of the image and copying the pixels from the most related patch into the hole. By performing the fill at the patch level as divergent to the pixel level, the algorithm reduces blurring artifacts.

The algorithm given by Criminisi et.al [7] proceeds by taking inputs from user namely a target region, Ω, to be removed and filled and the source region, Φ which can be defined as the complete image minus the target region ($\Phi = I-\Omega$), or it may be manually specified by the user. The default window size of the template window Ψ is of 9×9 pixels.

Ones region to be filled is defined; patches along the fill front are assigned a momentary precedence value, which determines the filling order.

Computing patch priorities is performed through a best-first filling. Those patches which are on the continuation of strong edges and which are surrounded by high-confidence pixels are assigned high priority .The confidence term is a measure of the amount of reliable information surrounding the pixel. Patches having most of the pixels already filled, with additional preference to pixels those were never part of the target region s higher priority.

Once all priorities have been computed, the patch with highest priority is found and is filled with data extracted from the source region Φ.

Image texture is propagated by direct sampling of the source region. The source region for that patch which is most similar to patch to be filled is searched. Best matching patch is the one with minimum sum of squared differences (SSD) between the already filled pixels in the two patches. After finding best matching source exemplar, the value of each pixel to be filled, is copied from its corresponding position from source region into target region.

These steps are iteratively performed till whole target region is predicted.

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Limitation of this method is, curved structure is not handled properly and biasing in due to incorrect selection of patches.

B. *Exemplar based Inpainting with Search Region Prior*

In the paper[9] by Jae Hyeok Choi published in 2013, exemplar-based inpainting with search region prior is introduced .In this method, source patch searching in the region with more consistent color or texture is performed by partitioning source region of input image by color or texture before exemplar-based inpainting and generate region index map. The region index map generation is then followed by selective choice of search region of given target patch improving search performance.

Traditionally in Exemplar based inpainting method, best patch using Sum of Squared Difference between target patch and candidate patch within fixed size of search area is calculated.

But in this method of Exempler inpainting based on search region prior, input image is Partition using color or texture. It is followed by Generation of region index map by setting unique index to all pixels in each region patch. Patch priorities for all patches are computed whose center is located along the boundary. Patch with maximum priority value is chosen. Within search region, the best match patch is found such that it has minimum Sum of Squared Difference (SSD) with known pixel point in target patch under the provision that only candidate patches in search area which has the same region indices with target patch are considered.

Pixel data from best patch is copied, to unknown pixel point in target patch. Data term values from best patch are copied to unknown data term point in target patch, 6. Finally confidence term of unknown pixel point in target patch is updated

C. *PDE based inpainting*

Image inpainting by Partial Deferential Equation (PDE) was first presented by Bertalmio et.al [10]. Method is based on the principle of transferring the image details like intensity in the direction of the level lines of constant gray value. Technique requires no user intervention in inpainting algorithm but only selection of area to be inpainted.

The region to be inpainted is first selected by user and it is followed by iteratively transmission of information from the outside area using the concept of isophotes i.e. linear edges of surrounding area and diffusion process. The angle of arrival should be maintained.

Limitation of this method is that due to blurring effect caused by diffusion process, duplication of big texture is not performed well. Pixels on edges are also not reconstructed efficiently. Thus method works well for only small and structurally damaged region.

In a paper by Wei Yao [11], a new image inpainting algorithm is given which combines PDE and texture synthesis which initially separates the damaged region into structure region and texture region is presented. Damaged region pixels are divided into two categories as texture pixels and structure pixels. These pixels are then processed for inpainting with related algorithms. Texture classification to the known image to reduce the texture search region is performed. In this algorithm the image is divided into structural part and textural part. Then texture segmentation and damaged area classification is performed with the aim of reducing the pixels to be synthesized and reducing the region to search for similar texture blocks. Texture area is segmented from the known image part with the purpose of reducing the texture search region and the damaged texture region is estimated to reduce the pixels for texture synthesis. Inpainting of the structural part is done by diffusion or PDE based methods. Synthesizing texture for the textural part and recombining the two inpainted parts together.

D. *Wavelet based Image inpainting*

Hongying Zhang et al. in their paper [12], presented an image inpainting algorithm based on wavelet decomposition for damaged image with missing structural and textural information.

In this method, the damaged image is decomposed into sub-image of structural and textural information using the wavelet transformation to obtain the corresponding four wavelet coefficient matrix. Then applying inverse wavelet transform to each wavelet coefficient matrix four images are obtained including one texture image, one horizontal

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structure image, one vertical structure image and one diagonal structure image. These three structure image overlay as one structure image

Then, the sub-image containing the region of missing information is reconstructed by image inpainting using Curvature Driven Diffusion (CDD) algorithm. The same region in the texture sub-image is filled-in with texture synthesis based on exemplar algorithm. The restored image is obtained by recombining the structure and texture

In the paper [13], by Yongsheng Xu et al., similar inpainting method is followed. In this technique, after wavelet decomposition, the structural image is be reconstructed by TV model .The main concept is to locate functional extreme.

On the other side, the texture image can be reconstructed by the sample synthesis method. The main concept is to calculate the priority of all target blocks. Then reconstruction of blocks takes place according to priorities until target area is repaired wholly.

IV. CONCLUSION

Digital image inpainting has very wide application as well as research area. It plays important role in recovering lost or deteriorated areas in an image and removing undesirable or unwanted part from the image. There are many techniques invented for same purpose with corresponding merits and demerits. In this paper different image inpainting techniques are studied. Different steps adopted for image inpainting in different techniques are explained. Their qualities and demerits are discussed in brief. For different techniques, researchers performed experiments on pictures of different environmental. The achievement of the inpainting formula depends on texture and structure. A combined approach of synthesizing target patch using textural as well structural information gives better results as compared to only structural or textural synthesis.

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