Image Mapping & Object Removal in Image Inpainting: A Survey

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Abstract— Inpainting is the process of reconstructing lost or damaged part of images based on the background information. i. e. image Inpainting fills the missing or damaged region in an image utilizing spatial information of its neighbouring region. Inpainting algorithm have a number of applications. It is used for restoration of old films and object removal in digital photographs. This is also applied to compression, red-eye correction, super resolution, etc. The significant aim of the Inpainting algorithm is to change the damaged region in an image in such a way that the inpainted region is invisible to the normal observers who are not known with the original image. There are various approaches proposed for the image inpainting. This projected work presents a detail survey of different image inpainting techniques and comparative study of these techniques. In this paper we provide a review of various techniques used for image Inpainting. We discuss various inpainting techniques like Exemplar based image inpainting, PDE based image inpainting, hybrid inpainting, texture and structure based inpainting, wavelet based image inpainting.

Keywords—Image inpainting, Image Restore, Exemplar, Object Removal, wavelet transformation

I. INTRODUCTION

Nowadays, the image Inpainting technology is a hotspot in computer graphics which has important value in heritage preservation, removing redundant objects film and television special effects production, etc. In the fine art museums, this Inpainting concept is used for degraded paintings. Conventionally Inpainting is carried out by professional artist and usually its very time consuming process because it was the manual process. The main goal of this process is to reconstruct damaged parts or missing parts of image. And this process reconstructs image in such a way that the inpainted region cannot be detected by a casual observer. Inpainting technique has found widespread use in many applications such as compression and transmission, image coding, super resolution, restoration of old films, object removal in digital photos, red eye correction. Image Inpainting reconstruct the damaged region or missing parts in an image utilizing spatial information of neighbouring region which also be called as modification and manipulation of an image. In image inpainting we would like to create original image but this is completely unfeasible without the prior knowledge about the image. In the digital images we are working on available to us and thus we are filling in a hole that encompasses an entire object. This is impossible to replace that entire object based on the presents information. Considering this as the aim of the inpainting algorithm is not only reconstructing that hole but also to create a visually pleasing continuation of the data around the hole in such a way that it is not detectable by ordinary observer. Diffusion based Inpainting was the first digital Inpainting approach. In this approach missing pixels are filled by diffusing the image information from the known region into the missing region at the pixel level. Basically these algorithms are based on theory of variational method and Partial Differential equation (PDE). The diffusion-based Inpainting algorithm produces superb results or filling the non-textured or relatively smaller missing region. The disadvantage of the diffusion process is it introduces some noise, which becomes visual when filling larger regions. All the Partial Differential Equation based in painting models are more suitable for completing small, non-textured target region .Most Inpainting methods work as follows

In the first step of Inpainting method the user manually selects the portions of the image that will be restored. The image restoration is done automatically by filling these regions in with new information from the surrounding pixels or from the whole image. The algorithms proposed for Inpainting use the information from surrounding regions of image to reconstruct the selected region. There are three approaches for inpainting as follows:

1. The first approach deals with the restoration of films.

2. The second class of algorithm deals with disocclusions.

3. Third class of algorithm deals with restoration of textures in the image. Nowadays, there are different approaches to image inpainting are available. And it can classify them into several categories as:

II. PDE BASED IMAGE INPAINTING

Partial Differential Equation (PDE) based algorithm is proposed by Bertalmio et.al [1]. This algorithm is the iterative algorithm. The important goal behind this algorithm is to both the gradient direction and the gray-scale values of the image are propagated inside the region to be filled in and solve the need for high-order PDEs in image processing. This algorithm will produce good results if missing regions are small. But when the missing regions are large this algorithm will take so long time and it does not produce good results. it introduces some blur, which becomes noticeable when filling larger regions. Then inspired by this work, Chan and Shen [2] proposed the Total Variational (TV) Inpainting model. which model uses Euler-Lagrange equation and anisotropic diffusion based on the strength of the isophotes. The model performs a good work for small regions and noise removal applications. But the disadvantage of this method is that this method neither connects broken edges nor greats texture patterns. The TV model then extended to CDD (Curvature Driven Diffusion) [3] model. In which it included the curvature information of the isophotes to handle the curved structures in a better manner. Then telea in [4] proposed a fast marching method. This is assumed as a PDE method which is faster and simple to implement than other PDE based algorithms. All algorithms are very time consuming and have some problems with the damaged regions with a large size. PDE based scheme is widely used in number of applications such as image restoration, segmentation, etc. These algorithms are focused on maintaining the structure of the Inpainting area. And hence these algorithms produce noise in resulting image. Another disadvantage of these PDE algorithms is that the large regions are not well reproduced. Guillermo Sapiro [5] proposed a frame work for automatic image colorization. The color is obtained by solving a partial differential equation. This proposed a different fast algorithm with results for colorization and for re-coloring (and other special effects) of stills and movies. Julia A. Dobrosotskaya and Andrea L. Bertozzi [6] proposed a construction of a new variational method for blind deconvolution of images and inpainting, motivated by recent PDE-based techniques involving the Ginzburg–Landau functional, which uses more localized wavelet-based methods. It presents results for both binary and grayscale images. Which results in obtaining the Comparable speeds are achieved with better sharpness of edges in the reconstruction. Zhaozhong Wang [7] proposed PDE method that was generate more naturally enhanced images with smaller degree of jags, and theoretically guarantee the edge discontinuity ininpainted regions. In this the process of deciding pixel values by eikonal PDE.

III. EXEMPLAR BASED IMAGE INPAINTING

The exemplar based approach is an important class of inpainting algorithms. And they have proved to be very effective. it consists of two basic steps: in the first step priority assignment is done and the second step consists of the selection of the best matching patch. The exemplar based approach find the best matching patch from neighbouring known region and pastes into the target patch in the missing region. Exemplar- based Inpainting method mathematically calculates the unknown region i. e. target region, by the most similar patch in the source region. The method fills in structures in the missing regions using spatial information of neighbouring regions. This method is a useful approach for repairing large target regions. An exemplar-based Inpainting algorithm includes the following four main steps:

1) Initializing the Target Region, in which firstly missing areas are extracted and represented with appropriate data structures.

2) Filling Priorities Computed by using a predefined priority function is used to compute the filling order for all unfilled pixels $p \in \delta\Omega$ in the beginning of each filling iteration.

3) Searching Example and Compositing, by using the most similar example is searched from the source region Φ to compose the given patch, Ψ (of size $N \times N$ pixels) that centered on the given pixel p.

4) Updating Image Information, by using the boundary $\delta\Omega$ of the target region Ω and the required information for computing filling priorities are updated.

Numbers of algorithms are developed for the exemplar based image Inpainting. Such as, Jia [9] segmented an image into several regions based on its color texture features and then inpainted each region individually. Then Drori [10] proposed a fragment-based image Inpainting algorithm which mathematically calculated, searched, and added detail by compositing adaptive fragments. The running time of this algorithm is undesirable. Bertalmio [11] developed a hybrid algorithm to combine the diffusion-based scheme [2] and texture synthesis [8]. This algorithm works well in recovering not only the geometrical structures but also the small texture regions. Then Criminisi [12] developed a useful and simple approach to encourage fill in from the boundary of the missing region where the strength of isophotes is strong and used the sum of squared difference (SSD) to select a best matching patch among the original image. In this technique of criminisi the region filling order is determined by the priority based mechanism. Cheng [13] generalized the priority function for the family of algorithms given in [12] to provide a more robust performance. Wong [14] developed a weighted similarity function. That function uses number of source patches to repair the target patch instead of using a single source patch. Wu [15] has proposed a cross isophotes exemplar-based model using the crossisophote diffusion data and the local texture information which decided the dynamic size of exemplars. Komodakis [16] minimized a defined global objective function, which is efficient but computationally expensive. Sun [17] drew main curves manually to inpaint the missing structure first and then filled the unknown information using texture propagation. Hung [18] used the structure generation and Bezier curves to construct the missing edge information. By using the image information and reconnecting edges by curve filling process, the damaged regions are inpainted. Fang [20] developed a rapid image Inpainting system which consists of a multi-resolution training process and a patch-based image synthesis process. Xu [19] proposed two novel concepts of sparsity at the patch level for modeling the patch priority and patch representation. And Compared with the diffusion-based approaches, the exemplar-based approaches acquire impressive results in recovering textures and repetitive structures, there is no matter whether they are applied into the large regions or not. Exemplar based Inpainting will produce best results only if the missing region consists of simple structure and texture. And if there are numerous samples in image then it is impossible to produce the desired image.

IV. TEXTURE AND STRUCTURE BASED INPAINTING

Texture synthesis based criteria's are one of the earliest methods of image Inpainting. And which are used to complete the missing regions using similar neighborhoods of the damaged pixels. The texture synthesis algorithms find the new image pixels from an initial seed. And then tries to maintain the original structure of the image. All the predefined Inpainting techniques use these methods to fill the missing region by sampling and copying pixels from the neighbouring area. For e. g, Markov Random Field (MRF) is used to model the local distribution of the pixel. A new texture is prepared by copying existing texture and finding all similar neighbors. The difference only exist in continuity is maintained between existing pixels and Inpainting hole.

The main objective of texture synthesis based inpainting is to generate texture patterns, which is similar to an original image in such a way that the regenerated texture retains the statistical properties of its root- texture. And it does not appear simply as a tiled rearrangement of the root-texture. Contrary to vibrational inpainting (PDE based inpainting), the texture synthesis based algorithms fill a large textured regions. Texture synthesis approaches can be divided into 3 categories: Statistical (parametric), pixel-based and patch-based (non-parametric). On the other hand, pixel-based methods "build" on the sample texture pixel-by-pixel instead of using filters for that, and their final outputs are of better world class quality than those of statistical methods, but they usually fail to reconstruct large structured textures.

Recently, a study for patch-based texture synthesis algorithms has shown that "for handling special types of texture we have to construct the special type of algorithms". By considering the variety of algorithms for texture synthesis we can conclude that there is no perfect texture synthesizer is present. But still it remains a goal to be desire. The texture synthesis based Inpainting perform well in synthesizing textures. These algorithms have difficulty in performing a operation on natural images as they are composed of structures in form of edges. Also they have complex connection between structure and texture boundaries. In some cases, they also require the user to specify texture which is to be replaced and the area to be replaced. Hence while using of texture synthesis techniques in inpainting, it is important to understand that these methods uses only small areas of Inpainting and these methods are not suitable for a wide variety of applications.

Shantanu D. Rane [21] proposed a method that is used to repair a lost data using correlation between the lost block and its neighboring pixels. If the lost block contained structure, it is repaired by using an image inpainting algorithm, and texture synthesis method is used for the textured blocks. The connection between the two schemes is done in a fully automatic fashion based on the surrounding available blocks. This method is used for lossy JPEG image compression. Marcelo Bertalmio [22] proposed a method for the simultaneous filling-in of texture and structure in regions of missing image information. The basic idea is to first decompose the image into the sum of two functions with different characteristics, and then repair each functions separately with structure and texture filling-in algorithms. The image is decomposed into sum of two different functions and reconstruct separately with a texture and structure filling-in algorithm.

Jhing-Fa Wang [23] proposed an object removal by the sub-patch texture synthesis algorithm and weighted interpolation method with automatic repainting mechanism. In the filling process, the color filling mechanism is used to choose different methods. The computation time is reduced by the weighted interpolation method. In order to reconstruct the faulty texture region intelligently, they use the color ratio gradients to detect the synthesized damaged region. The automatic damage detection can lead repainting the faulty region without user interference. The proposed algorithm can acquire better performance with perfect output images. EftychiosA. Pnevmatikakis [24] proposed the method that the combination of the inpainting techniques with the techniques of finding text in images and a simple morphological algorithm that links them. This combination results in an automatic mechanism for text removal and image restoration that requires no user interface at all.

Aurélie Bugeau [25] proposed a method that is the combination of three methods i.e texture synthesis.PDE and coherence among the neighbouring pixels are combined and inpainting is done. They show that the combination of all three terms of the proposed energy works better than taking each term separately and also reduces the computational time.

Dan Miao [26] proposed a texture assisted Kinect depth inpainting algorithm which obtains improved depth information. In this technique, the relationship between texture and depth is identified, and the characteristics of depth are also noticed. Texture edge information is extracted to perform the depth inpainting. Next, filtering and diffusion are performed for hole-filling and edge alignment. Experiment results show that the Kinect depth can be appropriately repaired in both smooth and edge region. By Comparing with the original depth, the inpainted depth information increases the quality of advanced processing such as 3D reconstruction. The rendering quality of the processed depth map is substantially improved in comparison with the original one.

V. WAVELET TRANSFORM BASED METHOD

The wavelet transform has been widely used in the medical image processing. The wavelet transform is a type of multi-scale analysis that de composes input signal into high frequency detail and low frequency approximation components at various resolutions. To enhance features, the selected detail wavelet coefficients are multiplied by an adaptive gain. The image is then enhanced by repairing the processed wavelet coefficients.

Julia A. Dobrosotskaya [27] proposed a construction of a new variational approach for blind deconvolution of images and inpainting which is inspired by recent PDE-based techniques involving the Ginsburg–Landau functional, but using original wavelet-based techniques. Comparable speeds are achieved with better sharpness of edges in the reconstruction. The recovery of piecewise constant signals and images using a combination of variational methods and wavelet analysis. The variational formulation of the problem allows us to build the properties of the recovered signal directly into the analytical machinery.

Yan-Ran Li [28] proposed the redundant system which is generated from the discrete cosine transform (DCT) matrix. They identify the rows of a given DCT matrix as the filters associated with a multiresolution analysis which is referred to as the DCT-Haar wavelet system. They show that this redundant system incorporated with the proposed model performs particularly well for inpainting images with incomplete information. The DCT-Haar multiresolution analysis and the resulting inpainting model are particularly suitable for inpainting problems including impulsive noise removal and filling missing information over regions with moderate sizes.

Sundarapandian et al [29] utilized a double filter banks structure to develop the Contourlet transform and used it for some nonlinear approximation and de-noising experiments and obtained some expected results. In this work, a new approach for retinal image contrast enhancement that is based on Contourlet transform. The main reason for the choice of Contourlet is based on its better performance of representing edges and textures of natural images. The proposed model achieves better visual results and outperformed the previous methods.

Aldo Maalouf [30] proposed a new efficient inpainting technique for missing data synthesis. The advantage of this reconstruction technique is that it is capable of filling large regions and synthesizing even highly textured missing regions. The proposed reconstruction technique is based on the Bandelet transform and the multiscale geometrical grouping.

The algorithm [31] presented the technique with the help of the wavelet transform. That expects the best global structure estimation of damaged regions in addition to shape and texture properties. If we consider the fact of multi-resolution analysis, data separation, compaction along with the statistical properties then we have to consider the wavelet transform due to its good image representation quality. The image inpainting process is applied in the wavelet domain by considering both scaling and wavelet coefficient from course to fine scales in the target region.

VI. SEMI-AUTOMATIC AND FAST IN PAINTING.

This image in painting requires user assistance the in the form of guide lines to help in structure completion has found favour with researchers. The method by Jian et.al [32] proposed inpainting with Structure propagation. This performs two-step process. First a user manually specifies important missing information in the hole by detecting object boundaries from the known to the unknown region and then a patch based texture synthesis is used to produce the textured image. The missing image pixels are calculated along the user specified curves by formulating as a global optimization problem under various structural and consistency constraints. A Simple programming is used to derive the accurate answer if only a single curve is present. the optimization is great deal more difficult and the proposes approximated the answer by using belief propagation, for multiple objects. All the methods viewed above take minutes to hours to complete a task depending on the size of the Inpainting area and hence making it unacceptable for interactive user applications. To speed up the predefined image Inpainting algorithms, a new classes of fast Inpainting techniques are developed. Oliviera et.al [33] proposed a fast digital Inpainting technique based on an isotropic diffusion model which performs Inpainting by repeatedly convolving the Inpainting region with a diffusion kernel. A proposed method which treats the missing regions as level sets and uses Fast Marching Method (FMM) to propagate image information has been proposed by Teleain [34]. These fast techniques are not suitable in filling large hole regions as they lack explicit methods to in paint edge regions. This technique results in noise in image.

VII. CONCLUSION

In this paper we review the existing techniques of image Inpainting. We were discussed a various image Inpainting techniques such as texture synthesis based Inpainting, PDE based Inpainting, Exemplar based Inpainting, and semi-automatic and fast Inpainting techniques. For each technique we have provided a detailed explanation of the techniques which are used for filling the missing region making use of image. From this analysis, a number of shortcomings and limitations were highlighted of these techniques.

It is observed that the PDE based Inpainting algorithms cannot fill the large missing region and it cannot restore the texture pattern. The analysis proved that exemplar based Inpainting will produce best results for Inpainting the large missing region also these algorithms can inpaint both structure and textured image as well. But exemplar based Inpainting work well only if missing region consists of simple structure and texture. Further study includes development of efficient algorithm to reduce computational cost and to reduce the time required for Inpainting.

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