International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-2, December 2018

An Exploration of Digital Image Inpainting Techniques

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Abstract*: *This paper gives an overview of different digital Image Inpainting techniques used contemporarily for image restoration and enhancement process. Inpainting, dis-occlusion, image completion, retouching and filling-in are different terms for the same task: if an image is given with a missing section, the values in the missing area has to be restored by its values in an undetectable way. The patches are filled in from the neighbouring pixels. Inpainting can be used for removal of objects from an image also. Inapainting techniques are made more sophisticated by applying Neural Network and Fuzzy logic for fast and accurate filling of patches.

Index Terms*: *Image Inpainting, Partial Differential Equation, Curvature Driven Diffusion, Examplar- Based, MAP, SOM.

I. INTRODUCTION

Digital images are becoming an important part of everyones life. Some of our great memories lie in photographs, some in videos. They make us laugh and weep. Like someone aptly mentioned, "a picture is worth more than ten thousand words". Photographs freeze present day remarkable moments and store them for years and we often value our home videos more than blockbuster movies. We take great measures to protect them. What if something did happen? In the past we depend on skilled artists for photo restoration. In today's world new and sophisticated methods appear every other day. Here comes the significance of digital Inpainting techniques. Automatic digital inpainting is a method that convalesce spoiled images and videos by implementation of spatial / temporal interpolation and other methods. The techniques adopted in photo restoration like zooming, scratch elimination, and coding of images. The errors caused by information loss effect old media as well as the present ones. The latest types of medias are also effected by alike issues. Packet losses while broadcast and streaming digital video (specifically live or other transmissions everywhere retransmission is imaginable) results in ruined image pixels, or even the whole loss of more than one successive frames, wireless image broadcast like recuperating missing blocks and specialized effect like elimination of objects and removal of red eye from photographs.

Manuscript published on 30 December 2018.
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II. LITERATURE SURVEY

Lot of works are being done in the area of image inpainting, the stepping stone being laid by Bertalmio et al.[1] in the year of 2000. During the past few years many algorithms were developed in connection with inpainting techniques by researchers from various fields. Even though software are available in the market for object removal, the algorithms presented in Inpainting techniques gives better result. There are different Inpainting techniques available. Some of the techniques are given in this paper. PDE is a parametric smoothness preserving algorithm. In the Partial Differential Equation (PDE) category, there are different approaches; some are discussed in this paper as follows: Simple isophote connection is proposed by Bertalmio et. al.[1]. In this method the person has to mark the regions to be inpainted. The marked areas are automatically packed with the arrangement of their surroundings. The elementary notion is to efficiently spread information from the immediate areas in the position of isophotes. The applications of isophote are to restore old and damaged photographs and films, removal of overlaid texts, and exclusion of particular objects. But, the method required PDE solution so it is complex and reproduction of large text is difficult and time consuming because of the number of iterations. The smoothness information is spread in the direction of isophote. Total Variational (TV) model suggested by Chan et.al [2] after seeing the disadvantages of lines of equal gray value (isophote method). It is designed for local inpainting. PDE or variational inpainting models are used in diffusion method to fill missing areas in images by spreading linear structures into the marked region using isophotes technique. Thermo diffusion equation is applied in PDE method to diffuse the information of the regions around the damaged regions. The advantage of TV model is that there is a comparatively fast and easy to implement fixed point method. Curvature Driven Diffusion (CDD) [3] model is an extension of TV model. It was suggested to realize the connectivity principle which will not hold in Total Varaitoinal model. The conduction coefficient of TV model depending on the isophotes curvature and it satisfies "the holistic and connection principle". And there for TV model can recover big damaged regions as well as the tiny edges. PDE based CDD can link some damaged edges, however the resulting interpolated segments generally looks burry and very slow explicit time marching. All the above approaches have a disadvantage that they incline to present smooth effect in the textured region and filling of bigger regions are difficult. These are the PDE based inpainting techniques.

Application of Navier Stokes equation in image inpainting practices ideas from standard fluid dynamics to spread isophote lines continuously from the outward into the region to be inpainted.[4]

The intensity of image is considered to be stream function for a 2D in-compressible flow. This algorithm is intended to continue the motion of isophotes during matching gradient vectors at the frontier of the inpainting region. The technique is unswervingly constructed on the Navier-Stokes equations for fluid dynamics. This is a fresh methodology for presenting concepts from Computational Fluid Dynamics (CFD) into complications in image analysis and computer vision. [4] Navier Stokes' fluid viscosity, fluid velocity, vorticity, Stream Function corresponds to anisotropic diffusion, isophote direction, smoothness, image intensity respectively.

Multi – echelon Gabor filters were introduced [5] for morphological Inpainting. Based on the morphological erosion the damaged regions are filled in synchronization with image feature replication. It gives a result with less iteration and stronger edges.

Expectation Maximization (EM) algorithm gives the idea that based on sparse representations missing samples can be recovered. The Expectation Maximization algorithm permits investigating the merging behaviour of the inpainting process. It validates the idea of substituting the lost data by estimated ones from coefficients of the former iteration, and then reestimate the fresh expansion coefficients from the whole data, and iterate the procedure up to convergence. Comparing to the other algorithms, EM algorithm permits greater grade of tractability to improve various structural component in the images like piecewise texture, even and curvilinear. [6] The Parametric Framework, Fields of Experts was proposed for image restoration and thus to fastens inferences, Bayseian Framework is one of it.

Feature based approach uses different edge property to recreate lost structure and filled regions amongst reconstructed edges by even extension of surrounding information of the image[7]. The problem of texture synthesis and texture inpainting is connected. The image is usually exhibited as a Markov Random Field and texture is synthesized in a pixel by pixel manner, by selecting existing pixels with similar neighborhoods in a random manner. Markov Random Fields is a nonparametric approach. Hidden Markov Tree model presented for signal denoising is now used with continuous wavelet model in image Inpainting. Primal Sketch (Combination of Sparse Coding (Generative model) and Markov Random field model (Geometric Structure) were introduced in the paper. Simultaneous structure and texture image inpainting [8] is done, first by decomposing the image into texture image and structure images. The two reconstructed inpainted image is then combined back. Structure is defined as the key part like object of an image, in which surface is homogeneous without having any detail. [9]Texture is defined as the details on the surface of the object which make the image more lifelike. The image can be inpainted using Poisson equation [10] the image to be inpainted is filtered and divided into the structure image and the texture image, and then they are processed according to their image characteristics. The texture image is repaired by the exemplar-based method is used to repair texture contents of an image. Laplacian operator is used to enhance the structure information of the image. The Laplacian image thus obtained is inpainted using exemplar-based algorithm. Then the image is reconstructed with the help of Poisson equation. The final inpainted result is attained by adding back the two sub-images.

MAP (Maximum a posteriori) centred algorithm [11] is used for destriping aa well as inpainting problems. In destriping technique, the image is processed with a low-pass filter in frequency domain using the discrete fourier transform. In Adaptive Digital Inpainting technique [12] different damaged pixel is processed differently. Algorithm uses a pseudo window. The window helps to estimate whether there exist adequate information to inpaint a damaged pixel. The surrounding pixels which are not damaged are used for estimation. An adaptive tool, which is based on a colour interpolation mechanism, is proposed. The restoring process checks the surrounding information of a damaged pixel and selects the range of references which can be used to compute an interpolated colour.

In Examplar-based algorithm[13],[14] the image information is propagated from the recognized area into the omitted area at the patch level. The advantage of exemplar grounded Inpainting over diffusion grounded inpainting algorithm is that it gives good result for inpainting larger missing region. Exemplar-based methods address this issue by using nonlocal information from the image to seal in the omitted region. Exemplar based patch propagation using patch sparsity [15],[16] is done with the help of two steps, first by identifying the sparsity of the patch to be inpainted and then filling in the areas by checking the neighbourhood. Sparse linear combination of exemplar is used for inpainting. The linear combinations of examplars gather the information about the patches in a particular frame of sparse representation. Its advantage is that inpainted patches are extra unfailing with their neighbouring surfaces and structures because of the local patch consistency constraint. Exemplar-based image inpainting method by including Bezier curves to reconstruct missing edge information was introduced by Jason C Hung et al [17]. Mean shift segmentation is used to comprehend colour segmentation in damaged images. Bézier curve is also used to connect the missing contour lines to reconstruct main structure in damaged areas. A best matching patch from other source region which contains original information is found finally and merged it into corresponding area. Exemplar- based compressed/ive sensing algorithm [19] introduced a new inpainting algorithm which is capable of reconstructing texture and structure image contents. The algorithm is an extension of the MCA (Morphological Component Analysis). MCA is designed for the separating an image into different components based on semantics. The global optimization approach, patches image along the user specified curves in a omitted region. It is synthesized by means of patches designated along the curvatures in a source region. Structural propagation can be expressed by imposing structure and consistency constrictions.

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Compression of image framework for visual superiority compared to pixel-wise fidelity is considered in the paper[19].

An image coding framework in which newly established vision methods are integrated with old-fashioned transform-based coding methods to exploit visual redundancy in images. Some areas in the images are intentionally removed automatically at encoder end and are repaired obviously by image inpainting technique at the decoder end.

Self organizing Map (SOM) relatively new techniques [19] introduced to fill the occlusions using the concept of Neural Network. Neural network has the ability of solving nonlinear problems. It is implemented in multilayer image Inpainting also [21]. Comparing TV model and SOM technique, SOM gives a better result for filling in the missing regions. The aim of TV algorithm is to inpaint texture boundary pixels without blurring.

For video restoration temporal properties like motion vectors need to be considered. [22] Combining object tracking and image completion will help the objects in video to be detached or substituted. Spikes - bright or dark intensity and long vertical lines - dark intensity and in large length, are the most commonly seen defects in old films. Inpainting in video is a research area where many algorithms are tried.

Inorder to estimate the pixel values for inpaintng accurately wavelet-based Inpainting is used [25]. The inter and intra scale dependeny is checked using wavelet coefficient. It is a multiresolution analysis for data separability and sparsity features. Bandlet transform with wavelets is implemented inorder to inpaint remoltely sensed images from noise as clouds, they also make use of multiscale grouping and spectrotemporal relationship. [26] Inorder to improve the magnification property of inpainted image , watershed guided Inpainting technique is used and it gives better result when compared to the interpolation techniques that are commonly used. Works are carried out in search of substituting Inpainting algorithms in place of compression and decompression.

For motion-state prediction[23] video Inpainting of moving human in a still background, the following steps are used. I) Background inpainting: damaged background regions are repaired. 2) Motion State Estimation: the feature points of moving human is detected from the undamaged frames and based on the feature points motion state vector is computed. 3) Motion State Classification: from the undamaged frames the motion state vectors are clustered and then labelled with the cluster indices. 4) Motion State Prediction: A motion-state transition model is constructed and it is used to foretell the motion state of the damaged frame. 5) Moving Human Inpainting: According to the predicted motion states the moving human of each damaged frame is copied from other undamaged frames. Graph cut model image inpainting is used for this. Based on patch and Bayseian approach, motion-related information is embedding into the relationship among video patches and develops a nonlocal sparsity-based prior for typical video sequences. [24] Rectangular or 3D patches are used in this method. Patch based video model can be applied into III processing steps—Inpainting, de-noising and de-interlacing. For video sequences, contrasting to prevailing model established on motion estimation, motion related temporal dependency is indirectly set into the bonding among video patch and a generic sparsity centred algorithm.

III. CONCLUSION

Various existing methods for Inpainting are discussed in this paper. Various applications, merits and demerits are briefed in this paper. On comparison of the various methods shows that Exemplar based approach and SOM have better inpainting results. The algorithms are faster and can be used for Inpainting larger missing blocks. Work is being carried out to find better methods in the area of Inpainting with the idea of improving features of video images by Inpainting the missing blocks caused during transmission of signals.

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