

Review and Potential of Various Approaches for Execution of Image Inpainting

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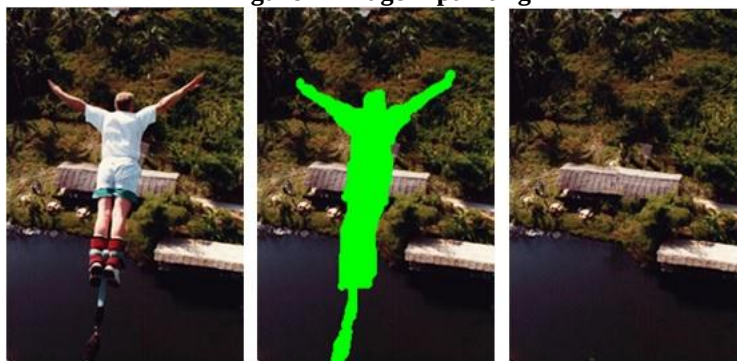
Abstract: Image in-painting is the art of restoring lost and selected parts of an image based on the background information in such a way so that the change is not observed by the observer. Image In-painting is very important and emerging field of research in image processing. Inpainting algorithm have numerous applications such as rebuilding of damaged photographs & films, heritage preservation, removal of superimposed text, removal/replacement of unwanted objects, red eye correction, image coding etc. The main goal of the Inpainting algorithm is to modify the damaged region of an image. The basic idea behind the technique is to automatically fill in lost or missing parts of an image using information from the surrounding/neighbouring area. There have been several techniques proposed for the image inpainting to restore the damaged image. In this paper, we provide a detailed review on different techniques used for image inpainting such as PDE based image inpainting, Exemplar based image inpainting, Texture synthesis based image inpainting, Hybrid inpainting, Semi-automatic and Fast inpainting.

Keywords: Inpainting; texture- synthesis; PDE; Exemplar; eye correction; restore

I.Introduction

Image in-painting is a hot spot in computer graphics and an active area in research in image processing. Image in-painting is also known as image disocclusion or completion. The main goal of this process is to fill the missing region/restoring lost part of an image based on the background information and this process reconstruct image in such a way so that the change cannot be noticeable by an observer. Image in-painting technique is used in so many fields like preservation of heritage films and television and for special effects production. It is used to restore old/damaged photographs, object removal from an image without affecting the image, image coding [1], [2] and transmission [3] (recovery of the missing blocks) etc. The mostly used in-painting methods are Geometry-based method and Exemplar-based method. We can also call Geometry based methods as structure in-painting methods. In the era of digital inpainting approach, Diffusion based Inpainting was the first one. In this method missing region is filled by diffusing the image information from the known region into the missing region at the pixel level. This type of algorithm is basically based on PDE (partial differential equation). Geometry-based inpainting methods shows good result in propagating smooth level line or gradients or filling the non-textured target region. This method is generally used when the inpainted region is small. The drawback of this method is, it introduces blurring artifacts in textured or when filling large missing region.

Figure 1 Image Inpainting



The second category is exemplar-base in-painting algorithm. It provides an efficient approach for reconstructing large target regions. Basically it consists of two main steps: The first step is of priority assignment and the second step consists of the selection of the best matching exemplar and updates all the priorities. Exemplar based in-painting iteratively synthesizes the target region, by the most similar patch in source region. They provide

good results in recovering textures or repetitive patterns. This algorithm overcomes the drawback of PDE based in-painting.

Most of the Inpainting methods work as follows: In the first step the user manually select the area of the image that is to be inpaint/restored. The image restoration is done automatically as you can see in Figure.1. In this step the region is filled in with new information coming from the surrounding/neighbouring pixels or from the whole image. After that the algorithm proposed for inpainting is used to inpaint the selected region of the image. This paper is organized as follows: Section-1 shows the Introduction of Image Inpainting problem. Section-2 describes the detailed review of different techniques for the image Inpainting which such as PDE based image inpainting, Exemplar based image inpainting, texture synthesis based image inpainting, Hybrid inpainting, Semi-automatic and Fast Inpainting. Finally concluding remarks are given in Section-3.

II. Mathematical Representation of Inpainting Problem

We can define Inpainting problem in terms of Mathematical point of view, In a sequence say S , given only a subsequence of it, X estimate the whole S as S' such that $I(S')=I(X)$, where I denotes the information. Let us take a simple example to explain it more clearly. Suppose there is a sequence $\{1,2,3,X,5,6\}$ where X is the unknown element. If X is derived as 4, the whole sequence looks very natural i.e., $\{1,2,3,4,5,6\}$ it takes the exact value as we expected. However, if X is derived as 15, i.e. $\{1,2,3,15,5,6\}$ then the whole sequence does tell us something unexpected. In case of inpainting, the generated plausible regions are commonly looks so natural which indicates that no additional information can be reproduced out of nothing related.

III. Different Approaches of Image Inpainting Techniques to Restore Image

So many methods have been proposed for image inpainting so far and we can classify them into several categories as follows:

1. PDE based image inpainting
2. Exemplar based image inpainting
3. Texture synthesis based image inpainting
4. Hybrid Inpainting.
5. Semi-automatic and Fast Inpainting.

Let us first describe the basic terminologies used in inpainting:

1. Image is represented as ' I '.
2. The target region or the region to be inpainted is represented by omega ' Ω '.
3. Source region ($I-\Omega$) that is the region which is not to be in-painted and from where the information is extracted to fill the target region is represented by Φ .
4. Boundary of the target region is represented by: $\delta\Omega$

Figure 2 Image Inpainting



A. PDE Based Image Inpainting

Partial Differential Equation (PDE) is a differential equation contains one or more variables, relating the values of the function itself and its derivatives of various orders. Consequently, a PDE is a differential equation that uses partial derivatives. Bertalmio et.al (2000) [4] proposed Partial Differential Equation based algorithm. It is iterative algorithm. The main idea behind this algorithm is to continue geometric and photometric information that arrives at the border of the occluded area into area itself. This is done by propagating the information in the direction of minimal change using "isophote lines". This algorithm will produce good results for small inpainted regions. And if the missed regions are large this algorithm will take so long time and it will not produce good results. Then inspired by this work, Chan et al [5] (2001) proposed the Total Variational (TV) Inpainting model. This model uses Euler-Lagrange equation and anisotropic diffusion based on the strength of the isophotes. This TV model performs well for small regions and even for noise removal applications. This algorithm also encounter with some problem, the main drawback of this method is that it is neither suitable for large texture regions nor it connects broken edges i.e. imitation of large texture regions is difficult. The TV model then extended to CDD (Curvature Driven Diffusion) [6] model. In which it included the curvature information of the isophotes to handle the curved structures in a better manner. Then telea in [7](Telea, et

al,2004) propose a fast marching method which is considered as a PDE method, faster and simpler to implement than other PDE based algorithms. PDE based technique has been widely used in various applications such as image segmentation, restoration etc. All of the above mentioned algorithms are very time consuming and have some problems with the damaged regions with a large size. The main disadvantage of this algorithm is that it produces blurring artifacts and creates problem in the reproduction of large texture regions. This algorithm also fails to recover Partially Degraded Image.

B. Exemplar Based Image Inpainting

It is an important class of inpainting algorithms. It overcomes the drawback of PDE based inpainting and it is used for reconstructing large target regions. Basically it consists of two basic steps: priority assignment is the first step and the second step consists of the selection of the best matching patch. The exemplar based approach samples the best matching patches from the known region and pastes into the target patches in the missing region. According to the filling order, the method fills structures in the missing regions using spatial information of neighboring regions. Generally, an exemplar-based Inpainting algorithm includes the following four main steps:

1. Initializing the Target Region in which the initial missing areas are extracted and represented with appropriate data structures.
2. Computing Filling Priorities: in this a predefined priority function is used to compute the filling order for all unfilled pixels $p \in \delta \Omega$ in the beginning of filling iteration.
3. Searching Example and Compositing: in which the most similar example is searched from the source region Φ to compose the given patch, say Ψ (of size $N \times N$ pixels) that centered on the given pixel p .
4. Updating Image Information, in which 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 [8] segmented an image into several regions based on its color texture features and then inpainted each region individually. Then Drori [9] proposed a fragment-based image Inpainting algorithm that iteratively approximated, searched, and added detail by compositing adaptive fragments. The computation time of this algorithm is intolerable. Bertalmio [10] proposed a hybrid algorithm for the simultaneous filling of texture and structure in regions of missing part of the image. They decompose the two image into structure and texture components respectively & perform in-painting separately on them. The result is the combination of these two methods. This algorithm works well in recovering not only the geometrical structures but also the small texture regions. Then Criminisi [12] proposed a single efficient algorithm for Region filling and object removal by exemplar based image in-painting. Exemplar based Texture synthesis modulated by a scheme for determining the fill order of the target region. They used patch based filling approach. Pixels maintain a confidence value. They fill the hole of the target region according to the priority order & this order is determined by the strength of the incoming edges and a confidence value. This technique is capable of propagating linear structures. The limitation of this paper is that the algorithm is not designed to handle curved structures and also they do not handle depth ambiguities. 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 several source patches to reconstruct the target patch instead of using a single source patch. Wu [15] has proposed a cross isophotes exemplar-based model using the cross-isophote diffusion data and the local texture information which decided impressive results in recovering textures and repetitive structures no matter whether they are applied into the large regions or not. Most of the new exemplar-based algorithms adopt the greedy strategy, so these algorithms suffer from the common problems of the greedy algorithm, being the filling order (namely priority) is very critical. Exemplar based Inpainting will produce good results only if the missing region consists of simple structure and texture and if there are not enough samples in image then it is impossible to synthesize the desired image. There are some approaches formulate image in-painting as a discrete global optimization problem, where the images are modeled using a Markov Random Field (MRF) with pair-wise interactions. In [16], the objective function is minimized using belief propagation, which is efficient but computationally expensive. Sun-et-al [17] proposed a technique of structure propagation. They first propagate the structure and after structure propagation, they fill the remaining unknown regions using a patch based texture synthesis. In this approach, the user manually specifies the curves, the most salient missing structures. Hung [18] used the structure generation and Bezier curves to construct the missing edge information. Using the structure information and reconnecting contours by curve filling process, the damaged regions will be inpainted. Fang [19] developed a rapid image Inpainting system which consists of a multi-resolution training process and a patch-based image synthesis process. Xu [20] proposed two novel concepts of sparsity at the patch level for modeling the patch priority and patch representation. Compared with the diffusion-based approaches, the exemplar-based approach achieve impressive results in recovering textures and repetitive structures no matter whether they are applied into the large regions or not.

C. Texture Synthesis Based Image Inpainting

Texture Synthesis based Image Inpainting algorithms are used to complete the missing regions using similar neighborhoods of the damaged pixels. These algorithms synthesize the new image pixels from an initial seed. And then strives to preserve the local structure of the image. All the earlier Inpainting techniques utilized these methods to fill the missing region by sampling and copying pixels from the neighboring area. For e. g, Markov Random Field (MRF) is used to model the local distribution of the pixel. And new texture is synthesized by querying existing texture and finding all similar neighborhoods. Their differences exist mainly in how 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 a given sample pattern, in such a way that the reproduced texture retains the statistical properties of its root texture.

Texture synthesis approaches (Efors et al.1999) [21] can be categorized into three categories: Statistical (parametric), pixel-based and patch-based (non-parametric). Statistical methods are more likely to succeed in reproducing stochastic/irregular textures, but usually it fails to reproduce structured/regular textures. On the other hand, pixel-based methods “build” on the sample texture pixel-by-pixel instead of applying filters on it, and their final outputs are of better quality than those of statistical methods, but they usually fail to grow large structured textures. Finally, patch-based methods “build” on a sample texture patch-by-patch as opposed to pixel-by-pixel, thus they yield faster and more plausible regular textures. A comparative study for patch-based texture synthesis algorithms has shown that “for handling special types of texture we have to develop the special purpose algorithms”. Taking this aim and the variety of algorithms for texture synthesis into consideration, we can conclude that there is no universal texture synthesizer is present. Still it remains a goal to be desire. The texture synthesis is (Rane et al. 2002) [22] based Inpainting perform well in approximating textures. These algorithms have difficulty in handling natural images as they are composed of structures in form of edges. Also they have complex interaction between structure and texture boundaries. In some cases, they also require the user to specify what texture to replace and the place to be replaced. Hence while appreciating the use of texture synthesis techniques in Inpainting, it is important to understand that these methods address only a small subset of Inpainting issues and these methods are not suitable for a wide variety of applications.

D. Hybrid Based Image Inpainting

Hybrid inpainting technique is also known as Image Completion. It is used for filling large target (missing) regions. It also preserves both structure and texture in a visually plausible manner. The hybrid approaches combine both texture synthesis and PDE based Inpainting for completing the holes. The main idea behind these approaches is that it decomposed the image into two separate parts, one for Structure region and another for texture regions. The corresponding decomposed regions are filled by edge propagating algorithms and texture synthesis techniques. One important direction we believe is more natural to the inpainting process is by structure completion through segmentation. This technique uses two step methods: First a texture based segmentation on the input image and extrapolating the boundary regions by tensor voting to generate a complete image segmentation and second by using tensor voting missing colors are synthesized. Tensor voting method is good for maintaining curvature, but cannot perform well on complex structures and image segmentation of natural images is also a difficult task to perform.

E. Semi-automatic and Fast Image Inpainting

Semi-automatic image inpainting requires user assistance and it requires user assistance in the form of guide lines to help in structure completion has found favor with researchers. The method by Jian et.al [20] proposed inpainting with Structure propagation. This technique follows a two-step process. In the first step a user manually specifies important missing information in the hole by sketching object boundaries from the known to the unknown region and then a patch based texture synthesis is used to generate the texture. The missing image patches are synthesized along the user specified curves by formulating the problem as a global optimization problem under various structural and consistency constraints. Simple dynamic programming can be used to derive the optimal answer if only a single curve is present. For multiple objects, the optimization is great deal more difficult and the proposes approximated the answer by using belief propagation. All the methods discussed above take minutes to hours to complete depending on the size of the Inpainting area and hence making it unacceptable for interactive user applications. To speed up the conventional image Inpainting algorithms, new classes of fast Inpainting techniques are being developed. Oliveira et.al [23] 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 new method which treats the missing regions as level sets and uses Fast Marching Method (FMM) to propagate image information has been proposed by Telea in [7]. These fast techniques are not suitable in filling large hole regions as they lack explicit methods to inpaint edge regions. This technique results in blur effect in image.

IV.Conclusion and Future Scope

In this paper we review the existing techniques of image Inpainting. We discussed a variety of image Inpainting techniques such as PDE based Inpainting, Exemplar based Inpainting, Texture synthesis based Inpainting,

Hybrid Inpainting, and semi-automatic and fast Inpainting techniques. For every technique we have provided a detailed explanation which is used for filling the missing region based on the surrounding information of the image. From this study, a number of advantages and disadvantages were highlighted of these techniques. Image inpainting is very important research area in the field of image processing. The performance of different techniques is evaluated on the basis of area to be inpainted. Most of the algorithms work well for small scratch regions or small regions to be inpainted such as PDE based Inpainting algorithms. It cannot fill the large missing region and also it cannot restore the texture pattern. The theoretical analysis proved that exemplar based Inpainting will produce good results for the large missing regions & also these algorithms can inpaint both structure and textured image as well. But they work well only if missing region consists of simple structure and texture.

We have observed that all these image inpainting algorithm require more time to implement. So we would like to improve these algorithms and would like to propose a new inpainting algorithm for inpainting large regions. Advance study includes growth of efficient algorithm to reduce computational cost and to decrease the time required for Inpainting.

V. References

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