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Review paper on Various Techniques of Image Inpainting

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Abstract

Image inpainting is the art of restoring lost parts of an image and reconstructing them based on the background information. This has to be done in an undetectable way. This technique have numerous applications such as rebuilding of damaged photographs and films, removal of superimposed text like dates, subtitle and removal of objects, scratches and red eye. In this paper we have analysis review of different techniques used for image inpainting such as PDE based image inpainting, Texture synthesis based image inpainting, Exemplar based image inpainting, Hybrid inpainting.

Keywords: Inpainting, Texture Synthesis, PDE, Exemplar.

Introduction

Inpainting is the process of reconstructing lost or deteriorated parts of images and videos based on the background information. The modification of images in a way that is non-detectable for an observer who does not know the original image is a practice as old as artistic creation itself. Medieval artwork started to be restored as early as the Renaissance, the motives being often as much to bring medieval pictures "up to date" as to fill in any gaps. [1]. This practice is called retouching or Inpainting. The object of inpainting is to reconstitute the missing or damaged portions of the work, in order to make it more legible and to restore its unity [2]. Inpainting technique has found widespread use in many applications such as restoration of old films and painting, object removal in digital photos, compressions, image coding, transmission, removal of occlusions, such as large unwanted regions, red eye correction, super resolution etc.

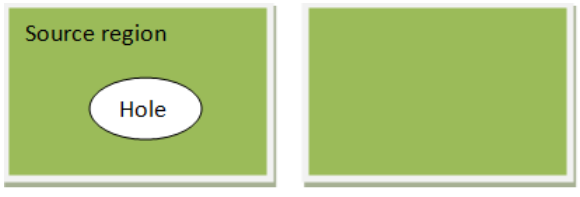

Figure 1: Idea of image inpainting

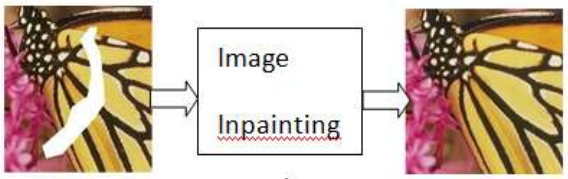

Figure 2: Image Inpainting Process

In Figure 1 The basic idea of image inpainting, to fill the hole in image from the source region. The image inpainting techniques fill the holes in image by propagating linear structure in to the mask region [3]. This paper is structured in the following way: Section 1 gives introduction to image inpainting. Sections 2 contain different inpainting techniques. In Section 3 contain comparison of various techniques. In Section 4 Contain conclusions.

Image inpainting techniques

Image Inpainting algorithm can be classified in to the following way.

i. Partial Differential Equation (PDE) based inpainting
ii. Texture Synthesis based inpainting
iii. Exemplar based inpainting
iv. Hybrid Inpainting

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Partial differential equation (PDE) inpainting

Partial Differential Equation (PDE) based algorithm for Image Inpainting is proposed by Bertalmio et al [4]. This algorithm is the iterative algorithm. The 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 if missed regions are small one. But when 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 and shen, (2001) proposed the Total varitional (TV) Inpainting model. This model uses Euler Lagrange equation and anisotropic diffusion based on the strength of the isophotes. This model performs reasonably well for small regions and noise removal application. But drawback of this model is neither connects broken edges nor greats texture patterns. The TV model than extended to CDD (Curvature Driven Diffusion) model. Which is added to curvature information, but it take so time than QCDD (Quick Curvature-Driven Diffusions) algorithm takes so much less computation time compare to other algorithm. QCDD model is developed by the Curvature-Driven Diffusions (CDD) model which improves the roundness and effectiveness which is represented in [4]. 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 [6, 7]. This algorithm also fails to recover Partially Degraded Image.

Texture synthesis based inpainting

Texture synthesis based algorithms are used to complete the missing regions using similar neighborhoods of the damaged pixels. The texture synthesis algorithms synthesize the new image pixels from an initial seed. And then strives to preserve the local structure of the image [5]. All the earlier Inpainting techniques utilized these methods to fill the missing region by sampling and copying pixels from the neighbouring area. Markov Random Field (MRF) is used to model the local distribution of a pixel and new texture is synthesized by querying existing texture and finding all similar neighbourhoods. Their differences exist mainly in how continuity is maintained between the inpainted hole and the existing pixels. These synthesis based techniques perform well only for a select set of images where completing the hole region with homogenous texture information would result in a natural completion. Then later, this technique was extended to fast synthesizing algorithm. This technique works by stitching together small patches of existing images referred to as image quilting. Basically this method can fill big textured regions, however depends on operator selections on sampling position and content.

Texture synthesis approaches divided into three categories [5]:

1) Statistical (parametric)
2) pixel-based (non-parametric)
3) patch-based (non-parametric)

Statistical methods are mostly succeed in reproducing stochastic / irregular textures, but usually fail to reproduce structured/regular textures.

Pixel-based approaches build on the sample texture pixel-by-pixel instead of applying filters on it. Their final results are of improved quality than those of statistical methods, but they usually fail to grow large structured textures. Patch-based [5] methods build on a sample texture patch-by-patch as opposed to pixel-by-pixel; therefore they yield faster and more plausible regular textures. The texture synthesis based inpainting perform well in approximating textures [3]. 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 [10]. 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.

Exemplar based image inpainting

The exemplar based consists of two basic steps **1.** Priority assignment is done and the 2. The selection of the best matching patch [10]. The exemplar based approach samples the best matching patches from the known region, whose similarity is measured by certain metrics, and pastes into the target patches in the missing region. Exemplar- based Inpainting iteratively synthesizes the unknown region i.e. target region, by the most similar patch in the source region [2]. The method fills structures in the missing regions using spatial information of neighboring regions. This method is an efficient approach for reconstructing big target regions. Normally, an

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exemplar-based Inpainting algorithm includes the following main steps:

I. Initializing the Target Region:, in which the initial missing areas are extracted and represented with appropriate data structures.
II. Computing Filling Priorities: in this a predefined priority function is used to compute the filling order for all unfilled pixels p∈δΩ in the beginning of each filling iteration.
III. Searching Example and Compositing: in which the most similar example is searched from the source region Φ to compose the given patch, Ψ (of size N × N pixels) that centered on the given pixel p.
IV. Updating Image Information: in which the boundary δΩ of the target region Ω and the required information for computing filling priorities are updated.

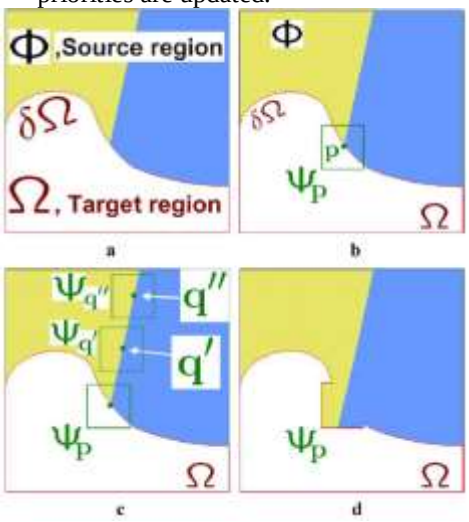

Figure 3: Structure propagation by exemplar-based texture synthesis, (a) Original image, with the target region Ω, its contour δΩ and the source region Φ clearly marked. (b) We want to synthesize the area delimited by the patch ψp centred on the point p €δΩ (c) The most likely candidate matches for ψp lie along the boundary between the two textures in the source region, e.g., ψq' and ψq". (d) The best matching patch in the candidates set has been copied into the position occupied by ψp therefore achieving partial filling [2].

For the better quality of image the algorithm checks the boundary area for Sharpe changes like edges and assigns more weights to the unknown pixels nearest to the edges. This algorithm also gives more weights to the pixels near the boundary. These are obtained by calculating the edge factor E(p) and known pixels factor K(p) for a patch Pp centered at the pixel P, as given equation 3.1 and 3.2 respectively.

$$E(p) = \frac{\sum_{q \in \emptyset \cap Pp} e(q)}{|Pp|} \qquad (3.1)$$

$$K(p) = \frac{\sum_{q \in \emptyset \cap Pp} k(q)}{|Pp|} \qquad (3.2)$$

Where, e(q), k(q) represents the edges and known pixels in the known area of the patch Pp., |Pp| represents the cardinality of the patch. The K values of the known and unknown areas are initialized to 1 and 0 respectively. The overall weight is taken as a product of these two terms as in equation 3.3. The pixels with more weight are considered first for filling.

$$P(p) = E(p)*K(p) \qquad (3.3)$$

Once a patch is filled the boundary (δΩ) and weights are recomputed before the next filling. The process is repeated until all pixels of Ω are complete in. [9]

The Exemplar-based algorithms adopt the greedy strategy, so these algorithms suffer from the common problems of the greedy algorithm, being the filling order is very critical. Exemplar based Inpainting will produce good results only if the missing region consists of simple structure and texture [6]. And if there are not sufficient samples in image then it is impossible to synthesize the desired image.

Hybrid based image inpainting

Hybrid inpainting technique is also called as the image completion. These approaches combine both texture synthesis and PDE based inpainting for completing the hole [10]. The main idea behind these approaches [3] is that it decomposed the image into two separate parts, Structure region and texture regions. The corresponding decomposed regions are filled by edge propagating algorithms and texture synthesis techniques in [2]. It is used for filling large target (missing) regions. And also preserves both structure and texture in a visually plausible manner. It requires more computational time for large holes.

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Comparison of techniques

Table 3.1 Comparative study of various image inpainting techniques shown in below table.

Image Inpainting Methods	Advantages	Disadvantages
PDE based image inpainting	It is perform well for smaller inpaint region and noise removal application.	It cannot fill the large missing region. This method is that due to blurring effect of diffusion process replication of large texture is not perform well. Pixel on edges are not handle properly.
Texture Synthesis based image inpainting	The structure reconstruction good for selected set of image.	This method not perform well for natural image. It is not handle edges and boundaries well.
Exemplar based image inpainting	This method will prouce good result for inpainting the large missing region also these algo can inpaint both structure and textured image as well.	Curved structure are not handle properly and biasing in due to incorrect selection of patches. This algorithm generate staircase effect in image inpainting.
Hybrid based image inpainting	In this technique the tensor voting method is good for maintaining curvature.	Tensor voting method is not perform well on complex structures and image segmentation of natural image.

Conclusion

This review results that existing techniques of image inpainting. Here we have provided detailed description of these techniques. The performance of different techniques is compared based on the area to be inpainted. Most of the algorithm work well for small area to be inpainted such as PDE based inpainting algorithm. It cannot fill 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 and also can inpaint both structure and textured image as well.

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