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DIGITAL IMAGE INPAINTING: A SURVEY

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Abstract: ***Image inpainting also referred to as image restoration or completion is a technique used to fill-in the missing region or damaged region of an image by using the known information of an image. There are different approaches for image inpainting. First approach is diffusion based approach in which the target or missing region is filled in by diffusing the image information from the source region into the target region at the pixel level. For this it uses partial differential equations or total-variational approach. The second approach is the exemplar-based inpainting algorithm. Exemplar-based approach propagates the image information from the source or known region into the target or missing region at the patch level. This idea comes from the texture synthesis technique, in which the texture is synthesized by sampling the best match patch from the source region. Applications of this technique include the restoration of old photographs and damaged film; removal of superimposed text like dates, subtitles, or publicity; and the removal of entire objects from the image to give special effects.***

Keywords: **Inpainting; Texture synthesis; Exemplar; Sparse representation; Overcomplete dictionary.**

I. INTRODUCTION

Inpainting is a very old practice in art. In Renewal, artists updated medieval artwork by filling the gaps. This was called retouching or inpainting. This practice is traditionally carried out by restoration experts, such as museum art restorers, and it is commonly known as inpainting or retouching. Desired outcome of this technique is to make a damaged artwork more discernible, while restoring its unity. Inpainting is the art of restoring lost or damaged parts of an image using the background information. A large amount of research has gone into the development of new and better inpainting algorithms since the concept of digital inpainting was first introduced by Bertalmio et al. [1]. Inspired by the work done by Bertalmio et al. [1], Chan and Shen [2] proposed the Total Variational (TV). To solve the connectivity problem of TV model chan and shen [3] introduced curvature Driven Diffusion (CDD) based inpainting. The idea of patch-based image inpainting came from the texture synthesis techniques in [4]. Criminisi *et al.* [5] proposed an inpainting algorithm in which the target patch is inpainted with the best match patch from the known information. Wu and Ruan [6] modified data term and proposed the cross isophote exemplar based inpainting. Xu and Wang [7] gave a similar approach using p-laplace as a data term. Xu and Sun [8]

sparsely represented the target patch using multiple candidate patches from known region with local patch consistency. Zhidan Li *et. al.* [9] proposed another sparsity-based inpainting algorithm, which is basically modification of Xu and Sun's [8] algorithm.

II. DIFFERENT APPROACHES OF IMAGE INPAINTING

Before introduction to different inpainting algorithms, common terms, notations and few assumptions are described here.

Figure 1. Image Inpainting Problem [5].

Given an image, (Ω), the omega symbol will denote the inpainting domain or missing region, also referred to as the hole in the image. The known region or the source region is denoted by symbol (Φ). The task of image inpainting or image restoration is by using the information from the known region or the source region, to fill in the missing region or target region. The fill-front in the inpainting algorithm is the boundary of the missing or target region that is denoted by (δΩ).

Image inpainting algorithms can broadly categorized into the following groups:

A. Basic PDE-Based Inpainting Methods.
B. Texture Synthesis Approach.
C. Exemplar-Based Inpainting.

A. Basic PDE-Based Inpainting Methods

1) PDE-Based Inpainting:

The method that leads the way for modern digital inpainting was a PDE-based method, proposed by Bertalmio et al. [1]. Inspired by the concept of manually inpainting, this approach tries to translate the rules that are used in manual inpainting into mathematical and algorithmic language. The primary idea of this algorithm is to propagate the geometric and photometric information arriving at the boundary of the occluded area, into target area. This is accomplished by extending the isophotes lines that try to capture the minimal change direction. An important observation is that the angle of arrival of the isophotes at the boundary must be preserved for a successful inpainting. Thus, the information propagation is carried out in the direction of minimal change.

***2)* Total Variational Method**

Inspired by the work done by Bertalmio et al. [1], Chan and Shen [2] proposed the Total Variational (TV) Inpainting model This approach uses anisotropic diffusion based on the strength of the isophotes and Euler-Lagrange equation. This inpainting approach performs plausibly well for small regions. The major drawback of TV-based image inpainting approach is that this method neither connects broken edges nor greats texture patterns. Then the total variational approach extended to Curvature Driven Diffusion (CDD) [3] model. In

which it included the curvature information of the isophotes to handle the curved structures in a better manner.

In almost all PDE based algorithms, blurring artifacts may be produced when the missing regions are large and purely textured. To fill in large regions with pure textures, texture synthesis techniques were proposed.

B. Texture Synthesis Approach

The texture synthesis approach is slightly different from image inpainting or image restoration. The goal of texture synthesis approach is to create a texture from a given sample in such a way that the created texture is larger than the source sample with a similar visual appearance. This problem is also called sample-based texture synthesis.

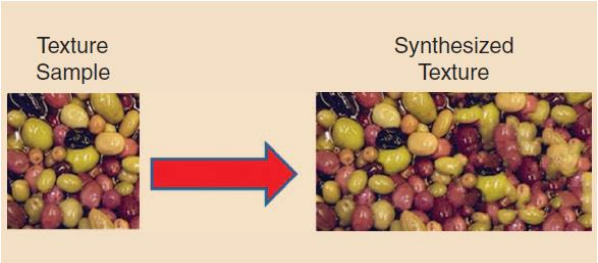

Figure 2. Example of Texture Synthesis [10]

Texture synthesis methods can be divided into two categories. First is single pixel based, in which one pixel is synthesized at a time. Clearly these methods are more time consuming. Second category is patch based methods, improving drawback of pixel based methods, in which blocks of texture images are being used to estimate blocks of pixels rather than one pixel at a time [10]. While handling natural images these algorithms faces difficulty as they are composed of texture and structures in form of edges.

Texture synthesis methods directly apply to the inpainting problem where the source part or known part of the image can be seen as the input texture sample from which the missing pixels can be learned.

C. Exemplar-Based Inpainting

The exemplar-based image inpainting approach is a key class of inpainting algorithms. Exemplar-based image inpainting algorithms have proved to be very successful. Basically exemplar-based approach consists of two fundamental steps: priority assignment is done in the first step and the second step consists of the selection of the sparse linear combination of several top similar patches or selection of best matching patch. The exemplar-based approach selects the sparse linear combination of several top similar patches or a best matching patch from the source region, whose similarity is measured by certain criterion, and pastes into the target patches in the target region.

1) Best Match Patch

One of the algorithms frequently given as a reference when discussing exemplar based inpainting methods is the one proposed by Criminisi et al. [5], an algorithm that has been designed for removing large objects from an image, while filling in the gaps with visually plausible information from the background, as the authors state. Criminisi et al.[5] proposed an exemplar-based inpainting approach to propagate the known patches (i.e., exemplars) into the target region by the synthesizing process. According to the target patch priority, the algorithm fills patches in the target region using spatial information of surrounding regions. For reconstructing large missing regions, this algorithm is an efficient method.

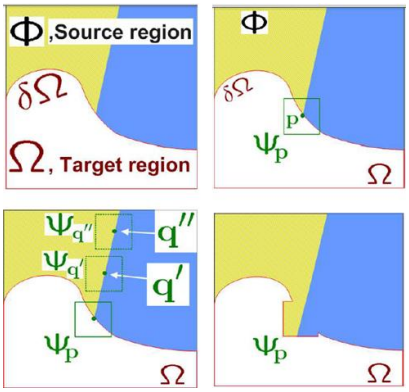

Figure 3. Criminisi's Algorithm [5]

An exemplar-based Inpainting algorithm includes the following four steps:

1. Initializing the Inpainting Region, in which the missing patches are extracted.
2. Computing Filling Priorities, at the beginning of each filling iteration the priority of target patches at the boundary of the target region is calculated.
3. Searching for Best Match Example, in this step the best match patch is searched for the target patch from the known region.
4. Updating Target Patch Information, in this step the target patch is updated by the selected best match patch.

2) Sparse Linear Combination of Exemplars.

Many image imprinting algorithms proposed image inpainting by using the sparse linear combination of top similar known patches. In this approach, an image is represented by a sparse linear combination of an overcomplete set of dictionary, and then by adaptively updating the sparse representation the target pixels are inferred. This approach has two fundamental steps: 1. Patch selection and 2. Patch inpainting. Priority assignment is done in the first step and the second step consists of the selection of the sparse linear combination of several top similar patches.

Exemplar-based image inpainting by using sparse patch representation is proposed by Xu and Sun [8]. The algorithm proposed the idea of sparse patch representation, in which the target patch could be inpainted by sparse linear combinations of several top similar known patches. Xu and Sun's [8] image inpainting algorithm usig sparse linear combination of candidate patches is shown in the FIG. 4.

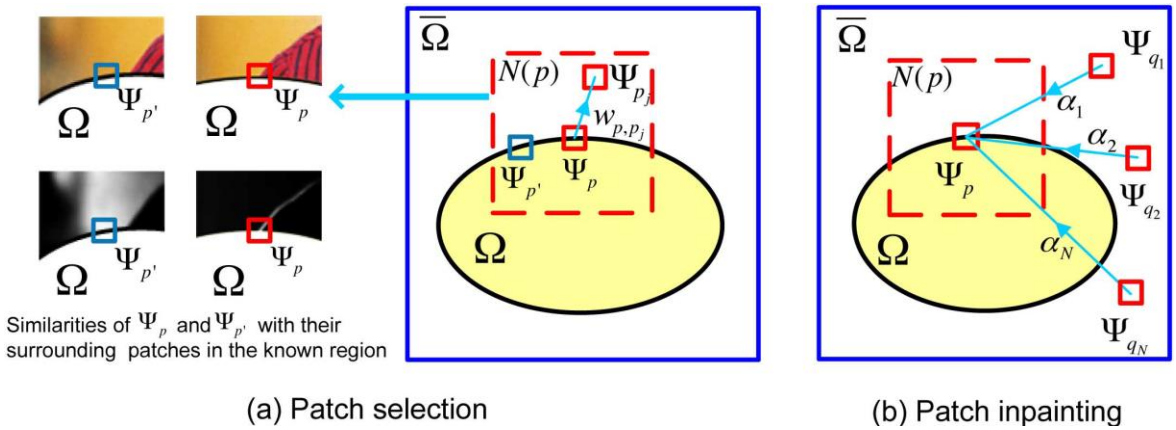

Figure 4. Xu's Algorithm for Image Inpainting.

Zhidan Li *et. al.* [9] proposed another sparsity-based inpainting algorithm, which is basically modification of Xu and Sun's [8] algorithm. Differing from the Xu and Sun's [8]

exemplar-based inpainting approach in which only color information is used, this algorithm Considers both gradient and color information, which ensures a better maintenance of texture clarity, structure coherence and neighborhood consistency. Takahiro Ogawa and Miki Haseyama [11] an image inpainting method based on sparse representations optimized with respect to a perceptual metric. Another sparsity based image inpainting algorithm is introduced by Elad et. al. [12] that uses an overcomplete DCT dictionary using to find an estimate of target region using sparse coding technique.

III. CONCLUSION

- Different image Inpainting techniques such as PDE based Inpainting, texture synthesis based Inpainting, Exemplar based Inpainting are studied.
- The performance of different techniques is compared based on the size of area to be inpainted.
- Most of the algorithms work well for small scratch regions or small regions to be inpainted.
- The theoretical analysis proved that compared with PDE based approach exemplar based approach produces better result. In exemplar based approach instead of using best match patch, sparsity based approach uses linear combination of several top similar patches, due to more samples are utilized it can more robustly estimate missing information and produces better result.

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