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Analysis of Exemplar Based Image Inpainting

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Abstract-Image Inpainting is an art of modifying the digital image in such a way that the modifications /alterations are undetectable to an observer who has no idea about the original image. Image Inpainting is technique in which it mainly used to filling the region which are damaged and want to recover from unwanted object by collecting the information from the neighboring pixels. In this paper here they provide an analysis of different Exemplar based techniques used for image Inpainting. This proposed work presents a brief comparative study of different Exemplar based image Inpainting techniques.

Keywords-*Keywords are your own designated keywords which can be used for easy location of the manuscript using any search engines.*

1. Introduction

There are lots of advantages multimedia instruments in today's world peoples are clicking lots of Picture or images of theirs and also trying to preserve their past pictures. And as the time goes on those pictures got damaged (cracks, starches, image data loss, unwanted etc.) Inpainting is the art of restoring lost parts of an image and reconstructing them based on the background information. In real world, many people need a system to recover damaged photographs, designs, drawings, art works etc. damage may be due to various reasons like scratches, overlaid text or graphics etc.

Inpainting technique has many applications such as, object removal in digital photos, removal of occlusions (date ,stamps ,logo etc.), such as large unwanted regions, red eye correction, super resolution, restoration of old films and paintings etc.[2].

Another use of image inpainting is in creating special effects by removing unwanted objects from the image. Unwanted objects may range from microphones, ropes, some unwanted person and logos, stamped dates and text etc. in the image. During the transmission of images over a network, there may be some parts of an image that are missing. These parts can then be reconstructed using image inpainting. Many works on Inpainting have been proposed these recent years. The image is to decompose the original image into a structure and a texture image. Reconstruction of each image is performed separately. The missing information in the structure component is reconstructed using a structure Inpainting algorithm, while the texture component is repaired by an improved exemplar based synthesis technique.

2. Inpainting Algorithms

The survey contains several inpainting algorithms that has have been developed. They may roughly be divided into two categories:

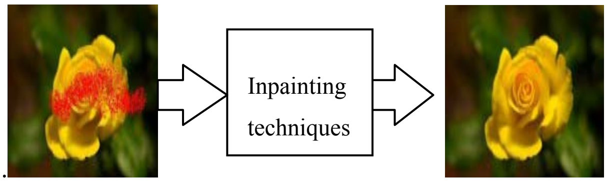

Fig 1: Inpainting method

1. Usually PDE based algorithms are designed to connect edges (discontinuities in boundary data) or to extend level lines in some adequate manner into the Inpainting domain, see [4][5].They are targeted on extrapolating geometric image features, especially edges. Most of them produce disturbing artifacts if the inpainting domain is surrounded by textured regions.
2. Texture synthesis algorithms use a sample of the available image data and aim to fill the inpainting domain such that the color relationship statistic between neighbored pixel matches those of the sample, see[4][5].They aim for creating intra region details. If the inpainting domain is surrounded by differently textured regions, these algorithms can produce disturbing artifactsAll paragraphs must be indented.

Nowadays, there are different techniques of image inpainting are available. So we can easily understand the methods and classify them into several categories as follows. Texture Synthesis based Inpainting, PDE based Inpainting, Exemplar based Inpainting, Hybrid Inpainting and Fast semi-automatic inpainting.

2.1 Texture synthesis based image inpainting

In this method, holes are filled by sampling and copying neighboring pixels [1,21]. Main difference between different texture based algorithms is how they maintain continuity between hole's pixel and original image pixels. This method is only work for selected number of images, not with all. Yamauchi et.al presented algorithm which generate texture under different brightness condition and work for multi resolution [2]. Fast synthesizing algorithm presented in [21], uses image quilting (stitching small patches of existing images). All texture based methods are different in terms of their capacity to generate texture with different color intensity, gradient and statistical characteristics. These methods not handle edges and boundaries well. In some cases user need to enter which texture to replace with which texture. So these methods are used for small area of inpainting. These algorithms have difficulty in handling natural images as they are composed of structures in form of edges.

2.2 *PDE based Inpainting.*

Partial Differential Equation (PDE) based algorithm is proposed by Bertalmio et.al [1]. This algorithm is the 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 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 [4] proposed the Total Variational (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 applications. But the drawback 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) [4] model. In which it included the curvature information of the isophotes to handle the curved structures in a better manner. Then telea in [23] propose a fast marching method. This is considered as a PDE method which is faster and simpler to implement than other PDE based algorithms. All of the above mentioned algorithms are very time consuming and have some problems with the damaged regions with a large size. PDE based technique has been widely used in number of applications such as image segmentation, restoration etc. These algorithms were focused on maintaining the structure of the Inpainting area. And hence these algorithms produce blurred resulting image. Another drawback of these algorithms is that the large textured regions are not well reproduced.

2.3 Exemplar based Inpainting.

The exemplar based approach is an important class of inpainting algorithms. And they have proved to be very effective. Basically 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 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. According to the filling order, the method fills structures in the missing regions using spatial information of neighboring regions. This method is an efficient approach for reconstructing large target 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 each 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, 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 [22] segmented an image into several regions based on its color texture features and then inpainted each region individually. Then Drori [8] 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 [2] developed a hybrid algorithm to combine the diffusion-based scheme [1] and texture synthesis [8]. This algorithm works well in recovering not only the geometrical structures but also the small texture regions. Then Criminisi [13] developed an efficient and simple approach to encourage filling in from the boundary of the missing region where the strength of isophote nearby was strong, and then used the sum of squared difference (SSD) to select a best matching patch among the candidate source patches. In this algorithm of criminisi the region filling order is determined by the priority based mechanism. Cheng [9] generalized the priority function for the family of algorithms given in [13] to provide a more robust performance. Wong [15] developed a weighted similarity function. That function uses several source patches to reconstruct the target patch instead of using a single source patch. Wu [16] has proposed a cross isophotes exemplar-based model using the cross-isophote diffusion data and the local texture information which decided the dynamic size of exemplars. J. WU [19] 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. 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.

2.4 Hybrid Inpainting

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, Structure region and texture regions [3]. The corresponding decomposed regions are filled by edge propagating algorithms and texture synthesis techniques. These algorithms are computationally intensive unless the fill region is small. One important direction we believe is more natural to the inpainting process is by structure completion through segmentation. This technique uses a two-step approach: the first stage is structure completion followed by texture synthesis. The second step consists of synthesizing texture and color information in each segment, again using tensor voting.

2.5 Fast semi-automatic inpainting

Semi-automatic image inpainting requires user assistance. And it 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 [11] 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. 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. Oliviera [21] 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 [23]. 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.

It is observed that the PDE based image Inpainting algorithms cannot fill the large missing region and it cannot restore the texture pattern. The theoretical analysis proved that exemplar based Inpainting will produce good results for Inpainting the large missing region 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. The Exemplar based technique combines the strengths of both approaches into a single, efficient algorithm. As with inpainting, we pay special attention to linear structures. But, linear structures abutting the target region only influence the fill order of what is at core an exemplar based texture synthesis algorithm. The result is an algorithm that has the efficiency and qualitative performance of exemplar based texture synthesis, but which also respects the image constraints imposed by surrounding linear structure. Here we can briefly survey on Exemplar based Image Inpainting.

3. EXEMPLAR BASED INPAINTING

As it was shown in above that PDE based Inpainting algorithms are not sufficient for faithfully reconstructing textured images, nor images with large missing areas. Thus, when Inpainting is done with an image restoration purpose in mind, more complex techniques are required, as paintings are composed of both structures and textures. Exemplar-based Inpainting methods can overcome this drawback, being able to provide reasonably good quality results, even for large gaps, by combining the isophotes driven Inpainting with texture synthesis. The reconstructed visual quality and the reasonability of the filled image are mainly influenced by the filling order. So, we conclude that better performance is obtained using developing a robust priority function. Exemplar based Inpainting iteratively synthesizes the target region, by the most similar patch in the source region [3]. According to the filling order, the method fills structures in the missing regions using spatial information of neighboring regions. This method is an efficient approach for reconstructing large target regions. Generally, an exemplar-based Inpainting algorithm includes the following three main steps:

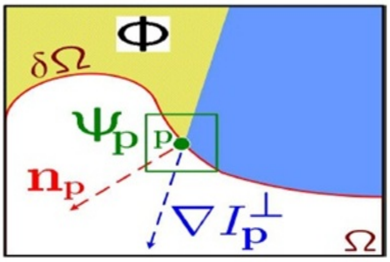

Fig.2. Notation diagram. Given the patch Ψ_p, n_p is the normal to the contour $\delta\Omega$ of the target region Ω and $\nabla I_p^{\perp}$ is the isophotes (direction and intensity) at point p. The entire image is denoted with *I*.

First, given an input image, the user selects a target region, Ω, to be removed and filled. The source region, Φ, may be defined as the entire image minus the target region (Φ = I-Ω), as a dilated band around the target region, or it may be manually specified by the user. We provide a default window size 9 X 9 pixels, but in practice require the user to set it to be slightly larger than the largest distinguishable texture element, in the source region. Once these parameters are determined, the region-filling proceeds automatically.

In our algorithm, each pixel maintains a *colour* value (or "empty", if the pixel is unfilled) and a *confidence* value, which reflects our confidence in the pixel value, and which is frozen once a pixel has been filled. During the course of the algorithm, patches along the fill front are also given a temporary *priority* value, which determines the order in which they are filled. Then, our algorithm iterates the following three steps until all pixels have been filled:

1) Computing patch priorities.

Filling order depends on the priority values that are assigned to each patch on the fill front. Given a patch Ψ_p centered at the point p for some $p \in \delta\Omega$ (see fig.2), we define its priority *P* (p) as the product of two terms:

P (p) =C (p) D (p).

We call *C* (p) the *confidence* term and *D* (p) the *data* term, and they are defined as follows:

$$C(p) = \frac{\sum_{q \in \Psi_p (I-\Omega)} C(q)}{\Psi_p}, \quad D(p) = \frac{|\nabla I_p^{\perp} . n_p|}{\alpha}$$

Where $|\Psi_p|$ is the area of Ψ_p, α is a normalization factor (*e.g.*, α= 255 for a typical grey-level image), n_p is a unit vector orthogonal to the front $\delta\Omega$ in the point p and $\perp$ denotes the orthogonal operator. The priority *p* (p) is computed for every border patch, with distinct patches for each pixel on the boundary of the target region. During initialization, the function *C* (p) is set to *C* (p) = 0 $\forall_p \in \Omega$ and C (p) =1 $\forall_p \in I - \Omega$.

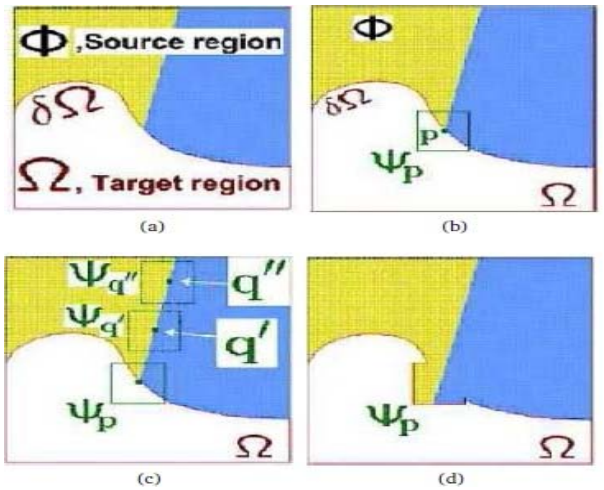

Figure 3: Visualisation of exemplar-based inpainting process. [10](a) Original image shows sources and target region as well as the boundary contour (b)Patch that was given the highest priority (c) Candidate patches $\Psi_{q'}$ and $\Psi_{q''}$ (d) The patch $\Psi_{q'}$ is filled in with the best matching patch.

2) Propagating texture and structure information

Search the source region to find the patch which is most similar to $\Psi_{\hat{q}}$

$$\Psi_{\hat{q}} \;=\arg min_{\Psi_{q\in\Phi}} d\,(\Psi_{\hat{p}}, \Psi_{q})$$

Where the distance *d* (Ψ_a,Ψ_b) between two generic patches is simply defined as the sum of squared differences (SSD) of the already filled pixels in the two patches.

3) Updating Confidences values

In which the boundary $\delta\Omega$ of the target region Ω and the required information for computing filling priorities are updated.

$$\mathbf{C(p)=C(\hat{}P)}\ \forall_p \in \Psi p \cap \Omega.$$

Numbers of algorithms are developed for the exemplar based image Inpainting. Such as, Bertalmio, (2) developed a hybrid algorithm to combine the diffusion-based scheme and texture synthesis. This algorithm works well in recovering not only the geometrical structures but also the small texture regions. Then Drori,(8) proposed a fragment-based image Inpainting algorithm that iteratively approximated, searched, and added detail by compositing adaptive fragments. Exemplar based Inpainting (10) 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. In(2) first decomposing the original image into the sum of two images, one capturing the basic image structure and the other capturing the texture. The first image (structure image) is inpainted following the work by Bertalmio et al. [1], while the other one is filled-in with a texture synthesis algorithm following the work by Efros et al. [12]. The algorithm works well enough for well designed structures in the image, but in case of natural images the structures do not have well defined edges so the results might not be correct. Also for large unknown regions the algorithm might not give plausible results. This approach still remains limited to the removal of small image gaps, however, as the diffusion process continues to blur the filled region. In(13)inpainting techniques fill holes in images by propagating linear structures (called isophotes in the inpainting literature) into the target region via diffusion. They are inspired by the partial differential equations of physical heat flow, and work convincingly as restoration algorithms. Their drawback is that the diffusion process introduces some blur, which becomes noticeable when filling larger regions. The technique presented here combines the strengths of both approaches into a single, efficient algorithm. In this paper the author proposed an exemplar-based image completion algorithm. Their method computes the priorities of patches to be synthesized through a best-first greedy strategy which depends upon the priority assigned to each patch on the filling-front, where the patch filling order is determined by the angle between the isophotes direction and the normal direction of the local filling front. This algorithm works well in large missing regions and textured regions. The technique is capable of propagating both linear structure and two-dimensional texture into the target region with a single, simple algorithm.In (14) instead of creating a new inpainting scheme, they try to generalize the priority function for the family of algorithms given in [13] to provide more robust performance. And the generalized algorithms can be applied to any image contents with different characteristics. In this paper present, the new priority function is able to resist undesired noises and robust to the aforementioned over amplified phenomenon. The computational complexity of the proposed algorithm is dominated by two tasks: exemplar search and component weight selection. Therefore, limitation of this paper will focus on the investigation of efficient searching scheme and on the automatic discovery of component weights for different kinds of images. In (15) paper author introduce newer approaches to the problem of image inpainting have focused on the concept of exemplar-based synthesis [12][16]. In these techniques, a best match sample from the source region is found and copied directly into the target region. The main benefit of techniques based on exemplar-based synthesis is that they can utilize nonlocal information. The main drawback of this technique is that the nonlocal information is used in a very limited way. By using only the best match sample, the method runs the risk of choosing a sample that is corrupted, or not a perfect match. In [17] they extend the exemplar-based method in [13] to a local setting, where candidate image patches for a selected location on the boundaries of the missing regions are chosen following a list of factors aimed at preserving image sharpness and detail. The proposed method delivers results whose inpainted regions are in better qualitative accordance with the image than those yielded by other alternatives. In (18) they develop the proposed algorithm is basically an extension to the algorithm proposed by Criminisi et al. [13]. Using this algorithm, we can inpaint large missing regions in an image as well as reconstruct small defects. These approach used a priority count based on defines a way of differentiating between patches that have the same minimum mean squared error with the selected patch. This technique can be used to fill small scratches in the image/photos as well as to remove larger objects from them. It is also computationally efficient and works well with larger images.In (19) a new hybrid image inpainting method based on Bezier curves which combines the exemplar-based inpainting pixel-based interpolation, while the second phase fills holes for preserving texture information with patch-based inpainting method. It improves the limitation of the edge-based restoration approach which approximates incoming edges method solve the disadvantage of Exemplar based approach for handle ambiguities in which the missing region covers the intersection of two regions and achieves better results than the conventional edge based restoration method. with only lines and circle arcs which preserves successfully the curvature structures in the damaged image also these technique and the edge-based image restoration algorithm. For restoring image structures, we first use the segmentation result with iterative Otsu's thresholding to obtain the information of edges. Bezier phases: the first phase restores the image structure by In [20] a robust exemplar- curves are then used to reconstruct the image skeletons in missing areas. The inpainting process is divided into two based image in-painting algorithm is proposed. The algorithm uses a novel priority function to determine the in-painting order. Structure tensor is adopted in the priority function. Structure tensor contains the transformation direction of the image and the size of transformation along these directions. Therefore, a patch along a strong geometric structure has a higher in-painting priority and would be completed prior to other patches to preserve the linear structure.

4. CONCLUTION AND FUTURE WORK

In this comparative study, we review the existing techniques of Exemplar based image Inpainting. We Also we have provided a concept and description of the different Exemplar based techniques for image Inpainting. From this analysis, we also highlighted a number of shortcomings and limitations of these different techniques.

Future study also focused Most of the new exemplar based-algorithms.

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