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Image Enhancement and Restoration by Image Inpainting

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Abstract---
Inpainting is the process of reconstructing lost or deteriorated part of images based on the background information. i. e .it fills the missing or damaged region in an image utilizing spatial information of its neighboring region. Inpainting algorithm have numerous applications. It is helpfully used for restoration of old films and object removal in digital photographs. The main goal of the algorithm is to modify the damaged region in an image in such a way that the inpainted region is undetectable to the ordinary observers who are not familiar with the original image. This proposed work presents image inpainting process for image enhancement and restoration by using structural, texture and exemplar techniques. This paper presents efficient algorithm that combines the advantages of these two approaches. We first note that exemplar-based texture synthesis contains the essential process required to replicate both texture and structure; the success of structure propagation, however, is highly dependent on the order in which the filling proceeds. We propose a best-first algorithm in which the confidence in the synthesized pixel values is propagated in a manner similar to the propagation of information in inpainting. The actual color values are computed using exemplar-based synthesis. Computational efficiency is achieved by a blockbased sampling process.
Keyword--- Inpainting, Filling Region, Object Removal, Patch Propagation, structure Synthesis, Texture Synthesis, exemplar Synthesis.

I. INTRODUCTION

The filling of lost information is essential in image processing, with applications as well as image coding and Wireless image transmission, special effects and image restoration. The basic Ideaat the back of the algorithms that have been proposed in the literature is to fill-in these regions with available information from their environment. The alteration of images in a way that is non-detectable for an observer who does not be acquainted with the original image is a practice as old as inventive creation itself. Medieval Artwork started to be restored as early as the rebirth, the motives being frequently as much to bring medieval pictures "up to date" as to fill in any gaps. This practice is called inpainting.

The major objective of this procedure is to rebuild damaged parts or missing parts of image. Inpainting technique has set up an extensive use in many applications such as restoration of old films, object removal in digital photos, red eye correction, super declaration, compression, image coding and communication [1]. Image Inpainting restructure the damaged region or mislaid parts in an image utilizing spatial information of neighboring region. In image inpainting would like to create original image but it is absolutely not viable without the prior knowledge about the image.

An algorithm for the simultaneous filling-in of texture andstructure in regions of missing image information is presented in this paper [2]. The basic idea is to first decompose the image into the sum of two functions with different basic characteristics, and then reconstruct each one of these functions separately with structure and texture filling-in algorithms. The first function used in the decomposition is of bounded variation, representing the underlying image structure, while the second function captures the texture and possible noise.

Missing data in very high spatial resolution (VHR)optical imagery take origin mainly from the acquisition conditions [3]. Their accurate reconstruction represents a great methodological challenge because of the complexity and the ill-posed nature of the problem. In this letter, we present three different solutions, with all based on the inpainting approach, which consists in reconstructing the missing regions in a given image by propagating the spectrogeometrical information retrieved from the remaining parts of theimage. They rely on the idea to enrich the patch search process byincluding local image properties or by isometric transformationsorto reformulate it under a multi-resolution processing scheme, respectively.

II. IMAGE INPAINTING TECHNIQUES

Nowadays, there are different approaches to image inpainting are available. And we can classify them into several categories as follows:-

- Texture synthesis based inpainting.
- Structure synthesis based inpainting

- Exemplar based inpainting.
- Hybrid based inpainting.
- Semi-automatic and fast inpainting

2.1Texture synthesis based inpainting.

Texture synthesis based algorithms are one of the earliest methods of image Inpainting and these algorithms are used to complete the missing regions using similar neighborhoods of the damaged pixels [13]. This algorithm synthesizes 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. 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.

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 nature completion. Then after, this technique was extended to fast synthesizing algorithm.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 roottexture. And it does not appear simply as a tiled rearrangement of the root-texture.

Texture synthesis approaches can be categorized into
3 categories: Statistical, pixel-based and patch-based. Statistical methods are more likely to succeed in reproducing stochastic / irregular textures, but usually fail to reproduceStructured/regular textures .the 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.The texture synthesis 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.

2.2 Structure synthesisbased inpainting.

Structural inpainting uses geometric approaches for filling in the missing information in the region which should be inpainted [13]. These algorithms focus on the consistency of the geometric structure.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. the drawback of this method is that this method neither connects broken edges nor greats texture patterns.The above mentioned algorithms are very time consuming and have some problems with the damaged regions with a large size.Structure 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.

2.3 Exemplar based inpainting

The exemplar based approach is an important class of inpainting algorithms [13]. 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.

2.4 Hybrid based Inpaintig.

Hybrid inpainting technique is also called as Image Completion and it is used for filling large target (missing) regions [13]. And also preserves both structure and texture in a visually possible manner. The hybrid approaches combine both texture synthesis and PDE based Inpainting for completing the holes. The idea behind these approaches is to decompose the image into two separate parts, Structure region and texture regions. The corresponding decomposedregions are filled by edge propagating algorithms and texture synthesis techniques and these algorithms are computationally intensive unless the fill region is small. One important direction 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 completionfollowed by texture synthesis. In this stage, segmentation, using the algorithm of, isperformed basedonthe inobservant geometry, color and texture information onthe input and then the partitioning boundaries are extrapolated to generate a complete segmentation for the input using tensor voting. The second step consists of synthesizing texture and color information in each segment, again using tensor voting.

2.5 Semi-automatic and fast 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 favor with researchers [13]. 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. In the second-step, 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.

For multiple objects, the optimization is great deal more difficult and theproposes approximated the answer by using belief propagation. To speed up the conventional image Inpainting algorithms, new classes of fast Inpainting techniques are being developed. Oliviera et.al 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 to propagate image information has been proposed by Telea in. These fast techniques are not suitable in filling large whole regions as they lack explicit methods to inpaint edge regions. This technique results in blur effect in image.

III. PROCESS AND ALGORITHM STEPS

This approach is applicable for simple and easy region filling. Exemplar-based inpainting technique has to follow these steps:

Fig.1 Data flow diagram of inpainting process

- Input : Masked target region
- Initialize confidence values
- Find boundary of the target region
- Calculate patch priorities
- Choose the patch with maximum priority and find best Exemplar
- Replace the patch with exemplar and update the confidence values
- Repeat the steps till all pixels mask becomes zero
  (Inpainted region filled out).
- Display the inpainted image.

Fig.2Original image, with the target region its contour and the source region clearly marked.

It is basic figure showing the Target region Ω, which is the information less region of an image which needs to filled from the surrounding region Φ. Here the region boundary is indicated with δΩ. δΩ is a small part of whole boundary of target region considered for patching process.

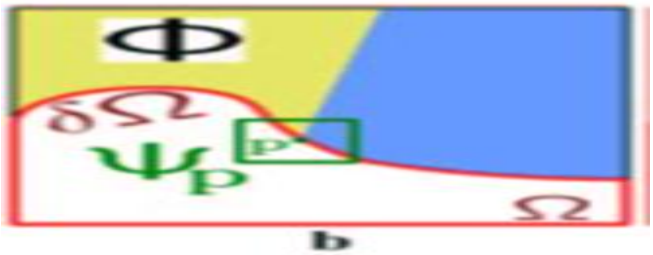

Fig.3 synthesizes the area delimited by the patchcentered on the point p.

We consider a point 'p' of this region boundary δΩ. Here, weare considering a small region ψ_p around the center pixel 'p'. This region needs to be filled out with source regions. Filling process starts with identifying the nearer regions which has highest amount of probability to be a continued structure or a edge of any structure.

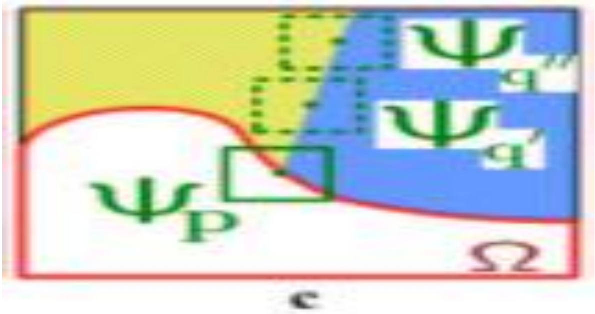

Fig.4 the most likelyCandidate matches for$\psi_p$lie along the boundary between the two textures in the source region.

In this figure we has depicted as region ψ_p To be filled by the patches identified from the source region Ω. We has considered two regions $\psi_{q'}$ and $\psi_{q''}$Here we have considered two small regions this regions are identical and hence we can conclude that this region should also be extended till the target region boundary. Thus, we can copy and paste the region $\psi_{q'}$ at location ψ_p.

Finally all that is required to propagate the isophote inwards isa simple transfer of the pattern from the best-match source patch. Notice that isophote orientation is automatically
preserved. In the figure, despite the fact that the original edge is not orthogonal to the target contour δΩ. The propagated structure has maintained the same orientation as in the source region.

3.1 Region filling algorithm

First, a user selects the target region Ω, to be removed and filled by nearest pixel values [1]. The source region Φ may be defined as the entire image minus target region i.e.

$$\boldsymbol{\Phi} = \boldsymbol{I} - \boldsymbol{\Omega} \quad (1)$$

Where, I = Entire image, Φ = Source region, Ω = Target region

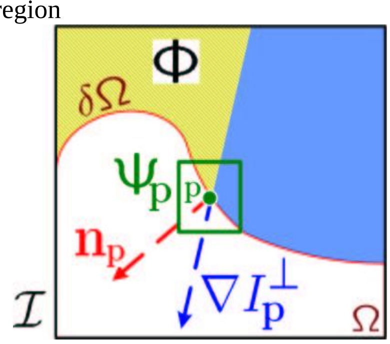

Fig 5 Notation diagram

The fig 5 is annotation diagram where at given patch location ψ_p, n_p is normal to the contour δΩ of the target region Ω and $\nabla I_p^{\perp}$ is the isophote (direction and intensity) at point P, and the entire image is denoted by I .

In this algorithm, each pixel maintain the color value (or "empty" if the pixel is unfilled) and a confidence value, which reflects our confidence in the pixel value, and it is frozen once a pixel has been filled [1]. 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.

3.1.1 Computing patch priorities:

This algorithm perform this task through a best-first filling algorithm that depends entirely on the priorities values those are assigned to each patch on the fill front [1]. The priority computation is biased towards those patches which are on continues of the strong edges and which are surrounded by high-confidence pixels.
In the fig 4.5, the given patch ψ_p at the point P for some $P \in \delta\Omega$ its priority $P_{(p)}$ is defined as the product of two terms:

$$\boldsymbol{P}_{(\boldsymbol{p})} = \boldsymbol{C}_{(\boldsymbol{P})} . \boldsymbol{D}_{(\boldsymbol{p})} \qquad (2)$$

Where, $C_{(p)}$ is confidence value and $D_{(p)}$ is the data term, and they are defined as follows:

$$\boldsymbol{C}_{(p)} = \frac{\sum_{q \in \psi p \cap \Omega} \boldsymbol{C}_{(q)}}{|\boldsymbol{\psi p}|} \boldsymbol{D}_{(p)} = \frac{|\nabla \boldsymbol{I}_{\boldsymbol{p}}^{\perp} \ . \boldsymbol{n}_{\boldsymbol{p}}|}{\boldsymbol{\alpha}}$$

Where |ψp| is the area of ψp, α is a normalization factor(e.g.. if value is 255 then it is typically gray-level image), and n_p is a unit vector orthogonal to the front $\delta\Omega$ in the point P.
During the initialization, the function $C_{(p)}$ is set to,

$$\boldsymbol{C}_{(\boldsymbol{p})} = \boldsymbol{0} \quad \forall_{\boldsymbol{p}} \in \boldsymbol{\Omega}, \text{ and} \qquad (3)$$
$$\boldsymbol{C}_{(\boldsymbol{p})} = \boldsymbol{1} \quad \forall_{\boldsymbol{p}} \in \boldsymbol{I} - \boldsymbol{\Omega} \quad (4)$$

The confidence term $C_{(p)}$ may be thought as a measure of amount of reliable information surrounding the pixel P [1]. At a coarse level, the term $C_{(p)}$ of (1) approximately enforces the desirable concentric filled order. As the filling proceeds, pixels in the outer layers of the target region will be characterized by greater confidence values, therefore be filled earlier; pixels in the center of the target region will have lesser confidence values.

The data term $D_{(p)}$ is a function of the strength of isophote hitting the front $\delta\Omega$at each iteration [1]. This term boosts the priority of the patch that an isophote "flows" into. This factor is important because it encourages the linear structures to be synthesized first, and then propagated securely in the target region and broken lines tend to connect.

3.1.2 Propagating texture and structure information:

Once all the priorities on the fill front have been computed, the patch ψpthe highest priority is found, then fill it with data extracted from the source region Φ [1]. In the traditional inpainting techniques, pixel-value information is propagated via diffusion. Diffusion necessarily leads to image smoothing, which results in blurry-filled in especially on large object.

On this algorithm, we propagate the image texture by direct sampling of the source region [1]. We search in the source region for that patch which is most similar to target region $\psi_{p.}$ Formally,

$$\boldsymbol{\psi_q} = \mathbf{arg\,min}_{\psi_q \in \emptyset}\ \boldsymbol{d}(\boldsymbol{\psi_p}, \boldsymbol{\psi_q}) (5)$$

Where the distance $d(\psi_p, \psi_q)$ between two generic patches ψ_p and ψ_q is simply defined as a sum of square differences (SSD) of the already filled pixels in the two patches.

Now, having found the source exemplarψ_q, the value of each pixel has to be filled. The $P' \in \psi_{p\cap\Omega}$ is copied from its corresponding position inside ψ_q [1]. This suffices are used to achieve both structure and texture information from the source to the target region.

3.1.3 Updating the confidence value:

After the patch has been filled up with the new pixel values, the confidence $C_{(p)}$ is updated in the area delimited by ψ_p as follows:

$$\boldsymbol{C}_{(\boldsymbol{q})} = \boldsymbol{C}_{(\hat{\boldsymbol{p}})} \quad \forall \boldsymbol{q} \in \boldsymbol{\psi}_{\hat{\boldsymbol{p}}} \cap \boldsymbol{\Omega} \qquad (6)$$

The simple update rule allows us to measure the relative confidence of the patch in the fill front, without image specific parameters [1]. As the filling proceeds, confidence values decrease, indicating that we are less sure of color values of pixels near the center of the target region.

IV. CONCLUSION

This paper has presented analgorithm for removing large objects from digital photographs. The result of object removal is an image in which the selected object has been replaced by a visually possible background that mimics the appearance of the source region.

Our approach employs an exemplar-based texture synthesis technique modulated by a unified scheme for determining the fill order of the target region. Pixels maintain a confidence value, which together with image isophotes, Influence their fill priority.

The major novelty of this work is that an improved patch priority term and an appropriate search region for best patch match are introduced into the exemplar based inpainting algorithm. The technique is capable of propagating both linear structure and two-dimensional texture into the target region, but the limitation is the quality of performance drops as the mask size increases but the time is reduced. Exemplar based methods perform well for larger mask size but fails in larger structure propagation.

REFRENCES

[1] A. Criminisi, P. Perez and K. Toyama, "Object Removal by Exemplar-Based Inpainting", in .Proc. MicrosoftResearch Lab, vol. 2, pp. 721-728, 2003.
[2] M. Bertalmio, L. Vese, G. Sapiro, and S. Osher, "Simultaneous Structure and Texture Image Inpainting" in proc. IEEE-CVPR 2003.
[3] Luca Lorenzi, Student Member, IEEE, FaridMelgani, Senior Member, IEEE, Grégoire Mercier, Senior Member, IEEE, "Inpainting Strategies for Reconstruction of Missing Data in VHR Images" in proc. IEEE September-2012
[4] Image Replacement through Texture Synthesis, Homan Igehyand Lucas Pereira, Stanford University, Appears in the Proceedings of the 1997 IEEE International Conference on Image Processing
[5] Peterson, Ivars (11 May 2002). "Filling in Blanks".Science News (Society for Science &#38) **161** (19): 299–300.doi: 10.2307/4013521. JSTOR 4013521.Retrieved 2008-05-11.
[6] M. Bertalmio, G. Sapiro, V. Caselles, and C. Ballester "Image Inpainting", in Proc. SIGGRAPH, pp. 417–424. , 2000.
[7] J. C. Huang, C. H. Hwang, Y. C. Liao, N. C. Tang, and T. J. Chen, "Exemplar-based image inpainting base on structure Construction," Journal of Software, Vol. 3, 2008, pp. 57-64.
[8] Gunamani Jena, "Restoration of Still Images using Inpainting techniques", International Journal of Computer Science & Communication, Vol. 1, No. 2, Pp. 71-74, July- December 2010.
[9] J. C. Huang, C. H. Hwang, Y. C. Liao, N. C. Tang, and T. J. Chen, "Exemplar-based image inpainting base on structure Construction," Journal of Software, Vol. 3, 2008, pp. 57-64.
[10] RajulSuthar, Mr. Krunal R. Patel "A Survey on Various Image Inpainting Techniques to Restore Image" in proc. IJERA February-2014.
[11] Komal s Mahajan, Prof. M. B. Vaidya,"Image in Painting Techniques: A survey", in proc. IOSR Journal of Computer Engineering (IOSRJCE), Sep-Oct. 2012.
[12] Seema Dixit and Saranjeetsingh, "Exemplar-Based Image Inpainting Technique using Image Partitioning (Search Region Prior) Method", in proc. IJSTE, October-2014
[13] RajulSuthar, Mr. Krunal R. Patel "A Survey on Various Image Inpainting Techniques to Restore Image" in proc. IJERA February-2014.