Comparative Study of Exemplar based Image In-painting and fragment Based Image In-painting

Mr. Vijay Patil[1], Ms. Swati Pawar[2], Ms. Bhagawati Patil[3], Mr. Mayur Ingale[4]
[1, 2, 3, 4] Sandip Institute of Technology and Research Centre, Nashik

Abstract- *Image Inpainting, or image interpolation, is the process used to reconstruct missing parts of images. There have been several approaches proposed for the same. In this paper a comparative study of Exemplar based image inpainting and fragment based image inpainting is done. In past inpainting was categorized in two classes diffusion based inpainting and texture synthesis.*

Keywords- Exemplar, fragment, Image inpainting, isophotes, patch, region filling

I. INTRODUCTION

Image inpainting is a concept of to reconstruct the missing portion in an image or removing an unwanted object from the image to make it clearer. The word “inpaint” means to fill in the gaps. The main difference between denoising and inpainting is, in denoising information about the real data and the noise is known while in image inpainting information about the region that has to be inpainted is not known.

In Mathematical term, inpainting is describe as: for a sequence, say S, its subset, say X, can estimate the total S as S’, such that I(S’) = I(X) where I stands for information. For clarity we would like to explain it with an example. Suppose there exists a sequence S = {2, 4, X, 8, 10, 12}, where X is unknown. If X is derived as 6 then the sequence S = {2, 4, 6, 8, 10, 12}is a set of natural even numbers. But if X is derived as 15, then it seems that the sequence is not correct and needs some attention. In inpainting the plausible region gives a natural sequence, whereas for the region required to be inpainted, the sequence shows abnormality.

The principal of image inpainting:

Let $\Omega \in D$, where D is the image domain and Ω is the portion in D to be inpainted shown in figure 2, $\delta\Omega$ is the boundary of Ω. The objective is to interpolate data from the boundary region $\delta\Omega$ and fill the inpainting region Ω with the appropriate pixel value.

Image inpainting methodology:

- Select the image that needs attention.
- Manually select the portion to be inpainted i.e., the target region (Ω).
- Start filling the inpainted region by averaging the pixel value from the surrounding of the target region.
- To reconstruct a plausible image, the inpainting algorithm needs to continue isophote (a curve on a chart joining points of equal value) very smoothly inside Ω.
- Continue the above process till the all the pixel in the target region is inpainted.

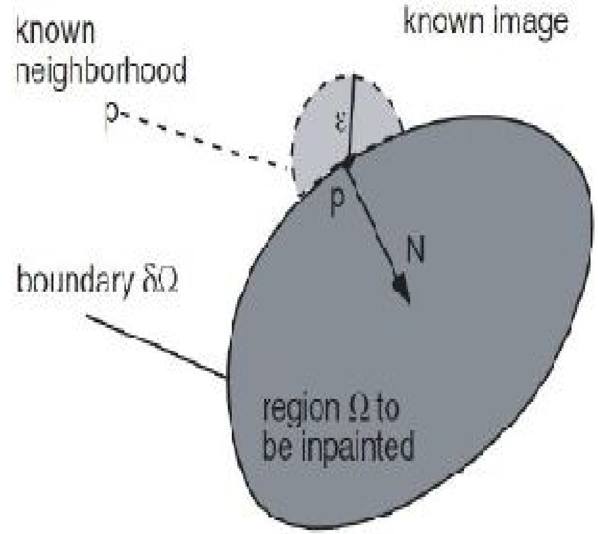

Fig.1. Principle of Inpainting

II. CRIMINISI'S ALGORITHM OR EXEMPLAR BASED IMAGE INPAINTING

Automatic digital inpainting was pioneered by Bertalmio [1] who proposed a PDE-based approach for inpainting. Partial Differential Equations (PDEs) can apply to automate image interpolation. The PDEs operate in similar way that trained restorers do: They propagate information from the structure around a hole into the hole to fill it in. In 2004 Criminisi et al. [2] developed a novel technique based on texture synthesis in which the filling order is influenced by the linear structures of the image. In other words, he combined the strength of both structural and textural synthesis to fill the missing regions of the image.

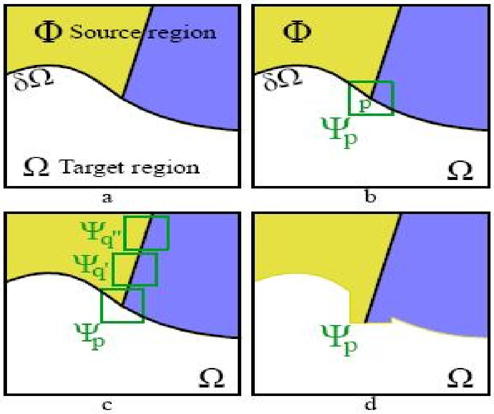

Fig.2. Structure propagation in Criminisi algorithm, (a) Original image with the target region Ω, filling front δΩ, and the source region Φ, (b) The patch φ_p Centered at point p that has to be inpainted, (c) The most similar candidate patches for the source region, (d) The best matched patch has been copied into φ_p [3]

'I' represents the original image. 'Ω' represents the target region, i.e. the region to be inpainted. 'Φ' represents the source region, i.e. the region from which information is available to reconstruct the image. Generally, Φ = I – Ω. δΩ to represent the boundary of the target region, i.e. the fill front. It is from here that we find some patch that is to be filled. Our algorithm is basically an extension to the algorithm proposed by Criminisi et al. [3]. Using this algorithm, we can inpaint large missing regions in an image as well as reconstruct small defects. Steps involved in an exemplar based inpainting algorithm:

i. Initialize the target region.

This is generally performed separately from the inpainting process and requires the use of an additional image processing tool. This is performed by marking the target region in some special color. Without any loss of generality, let us consider that the color that the target region will be marked in is green (i.e. R = 0, G = 255, B = 0).

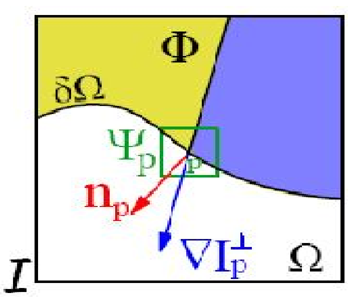

Fig. 3 Notation diagram, For patch φ_p Centered at point p, $\nabla I_p^{\perp}$ is the gradient vector at point p, and n_p is a unit vector normal to the filling front δΩ [3]

ii. Find the boundary of the target region.

It is a practice to first inpaint the region along contour by giving then a temporary higher priority. It is efficient way to do so because it is surrounded with edges that have high confidence value therefore, it makes the algorithm more reliable.

iii. Select a patch from the region to be inpainted.

The patch size should be a bit larger than the largest distinguishable texture element in the image. We have used a default patch size of 9 x 9 which can be changed with the knowledge of the largest texture element in the image. We denote the patch by ψp.

iv. Find a patch from the image which best matches the selected patch, ψp.

This matching can be done using a suitable error metric. We use the Mean Squared Error to find the best matching patch.

$$MSE = \sum \frac{(f_{x,y} - g_{x,y})^2}{N}$$

Where *fx,y* represents the element of the patch ψp and *gx,y* represents the elements of the patch for which MSE is to be calculated. N is the total number of elements in the patch.

v. Update the image information according to the patch found in the previous step.

As mentioned earlier, the result does depend considerably on the third step wherein a patch is selected to be inpainted. The result that we obtain would almost always depend on the selection order and thus there have been approaches that try to define this selection order so that the result is improved.

In Criminisi algorithm, the priority function used for selecting the best patch from the target region was defined in a multiplicative form

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

Where C(p) represents the confidence term for the patch and D(p) the data term for the patch.

$$C_{(p)} = \frac{\sum q \epsilon \varphi_p \cap (I - \Omega) C_q}{|\varphi_p|}$$

$$D_{(p)} = \frac{|\nabla I_p^{\perp} . n_p|}{\gamma}$$

where, |Ψp| is the area of Ψp, γ is the normalization factor (i.e, γ is 255 for a typical grey-level image), np is the unit vector orthogonal to the front δΩ in the point p, ⊥ denotes the orthogonal operator.

The priority P(p) is calculated for every pixel with distinct patch but patch that include the corner of the target region is inpainted first. As confidence term gives the measure of reliability so as data term D(p) is the function that is used to choose the patch with the maximum priority and then replace the patch with the best suitable and matching exemplar (patch) among all the candidate set from the source region and update the confidence value. That is C(p)=C(p̂), where, C(p̂) is the confidence value of the exemplar (patch) from the source region, C(p) is the confidence value of the patch in the target region that is inpainted.

This process continues till the entire pixel in the target region is completely inpainted. There are some points that we have noticed during the study and implementation of this algorithm such that in [3] the quality and reliability of the inpainted image is highly dependent on the order in which the filling process proceeds. The traditional concentric layer filling (commonly known as onion peel) process unexpectedly reconstructs curve at the horizontal line between the two different shades color of the image. But the edge driven achieves the artifact-free reconstruction. In [2] it is stated that, often the most appropriate patch lies very close to the patch selected for inpainting. So it is a good approach to restrict the search of the patch up to certain diameter surrounding the region to be inpainted. By doing so the performance of the inpainting algorithm is improved.

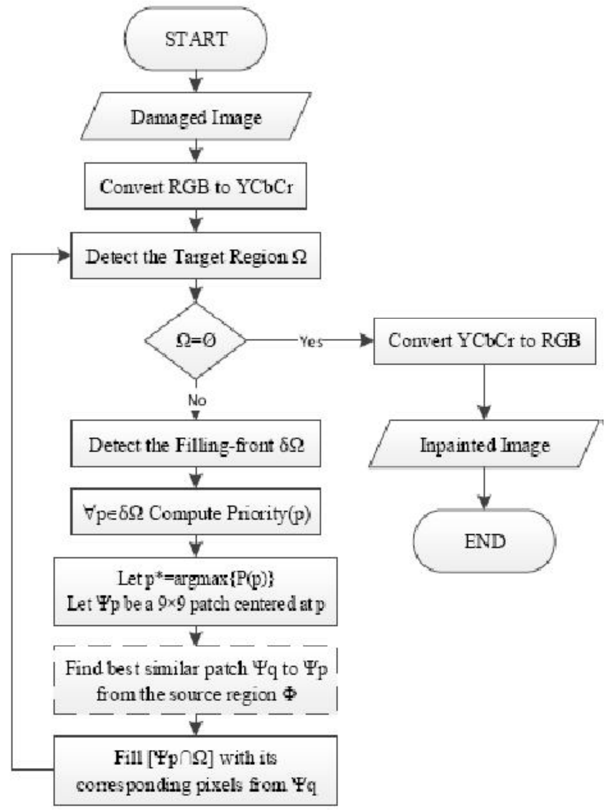

Fig. 4. Flowchart of the fast and simple exemplar-based image inpainting algorithm

III. FRAGMENT BASED IMAGE INPAINTING

In this technique to complete the image we have to remove the background and foreground elements from the image. The parts of the image which are seen with the naked eye can be used as spare parts to repair the image. In this method the first step is to select the region which we want to inpaint for that iterative process is used which selects the region approximately. After that we have to use composite image fragments to complete the image. To select the patch ,values of inverse matte is used which gives the high confidence pixels to complete the image and a level is set that provides the incremental approach to travel into the unknown region of image from high to low confidence. In each step we have to select the image fragment from frequently appearing examples. it processed to complete the image with this technique, the image fragments which is composited their probability rise with mean confidence of image.

Process:

Input: image C, inverse matte $\bar{a}$ (9 pixel with $\bar{a} < 1$)
Output: completed image, $\bar{a} = 1$

Algorithm:

1. For each scale from coarse to fine Approximate image

from color and coarser scale

2. Compute confidence map from ā and coarser scale
3. Compute level set from confidence map
4. while μ (b) < 1−e
   a. For next position p in level set Compute adaptive neighborhood N(p).
   b. search for most similar and frequent match N(q)
   c. composite N(p) and N(q) at p, updating color and ā
5. Compute approximation, confidence map and update level set

IV. DIFFERENT IMAGE INPAINTING TECHNIQUES

1. Image Inpainting Using PDE

In this algorithm first the area to be inpainted is selected and after that algorithm rebuilds the image by collecting the information available from the surrounding area of the source image. While filling this region this algorithm considers the way in which isophote lines arriving at the regions boundaries are completed inside. During completition of image one has no need to provide the surrounding information. This is automatically done, thereby allowing to simultaneously fill-in numerous regions containing completely different structures and surrounding backgrounds. By using the isophote direction this algorithm completed the image.

2. Multiresoultion Image Inpainting

In this approach the damaged image block is divided into equal number of blocks of equal size. After dividing the image, the three threshold values were consider first for the threshold of variance of pixel colors, second and third- for the threshold of percentage [5]. Variance of color pixels has strong indication of containing the details of the image. By using this value we can able to rebuild the image. While rebuilding the image the percentage of damaged pixel was consider. In case the damaged pixel percentage is high, then to inpaint the image we have to consider the global average color. If the percentage is low, in that case we have to consider the information available from the image. After completition of image it evaluates the image with the help of PSNR value. This multilevel PSNR value decides how good the image is inpainted.

3. Completition Of Images With Natural Scenes

This method used to done the completion of images of natural scenery, where the removal of a foreground object creates a hole in the image. In this technique to select a patch from the image we limit the search into the horizontal direction only for that purpose we have to use Fourier transform which gives the distinct vertical line at center , by using this approach we gets the more promising pixels in horizontal direction only [6]. This whole process reduces the effort of searching the portion of image which we require to complete the image. We are able to locate the patch that imposed into the rest of image horizontally. During this method if we are trying to recover the area of slopes then privileges also provided for that image. The grid algorithm is used to complete the image in which the image first completed from the left region and then completed from right side. We fill-up the unknown regions of the matte with grid blocks from the source image.

4. Graph cut Patch Algorithm

Zhang [7] introduced a method to inpaint the image which divided into the three steps, First step is spatial range model is decided to get the direction of selecting the patch from the image. In second step source patch is selected by matching the dimensions of the source patch with target patch and if the dimensions don't match in that case we have to adjust the dimensions and then we have to enforce the searching areas into the neighborhood around the previous source patch. Third, to guarantee about the non-blurred result graph cut patch updating algorithm is designed. The quality of result corresponds to the human image recognition after image is completed.

5. Image Inpainting Using Wavelet Transform

Dongwook Cho [8] presented the technique with the help of the wavelet transform. Here we expect the best global structure estimation of damaged regions in addition to shape and texture properties. If we consider the fact of multiresoultion analysis, data separation, compaction along with the statistical properties then we have to consider the wavelet transform due to its good image representation quality. Wavelet transform try to satisfy the human visual system (HVS). In this algorithm decomposition of incomplete image is done with the help of wavelet and after that wavelet and scaling coefficients is found. The image inpainting process is applied in the wavelet domain by considering both scaling and wavelet coefficient from coarse to fine scales in the target region.

6. Image Inpainting Using MCA

Holes present in an image are filled with texture by a new image inpainting technique. Same process applied in cartoon image layer. This algorithm is a direct extension of a recently developed sparse-representation-based image decomposition method called MCA (morphological component analysis), designed for the separation of linearly combined texture and cartoon layers in a given image. Our method is based on the ability to represent texture and cartoon layers as sparse combinations of atoms of predetermined Dictionaries. So if we want to fill simultaneously the image of texture which has unknown regions and image which consist of the cartoon image layer in that case we have to consider the MCA method to get the desired reconstructed image which providing the more promising result. The confidence pixels are going to help in both the cases to fill the incomplete image and reconstruct the both texture and cartoon image layer.

7. Multiscale Image Modeling

If one considers the non separable filter banks and direction based filter banks then we have to think differently because for this purpose it is not good idea to fully resemble on wavelet transform. To extend and to add this detail we have to consider the contourlet transform [9]. It can efficiently take control over the edges of image along with small number coefficient one dimensional contour because of its multiscale and directional properties. Contourlet transform region and its advantages helps author to inspect the image. The Detail study of contourlet coefficient makes clear idea about non-Gaussian trivial statics and strong dependencies. Contourlet coefficient is calculated about the Gaussian by considering the difficulty of neighboring coefficient magnitude. Technique is applied on the images which are affected by noise and the image where we have to retrieve the texture. While recovering the texture it shows too much improvement and additional things than wavelet transform and performance is also better.

8. Image Completition with Patch Propagation

This author described the necessities of semi-automatic image inpainting techniques. To complete this research the user plays the role of guide to help in the complete the structure and he found as favorer of the image [10]. This process works in two steps. In which first step user defined the region to be inpainted by drawing the object area border and physically specifies the missing information in the image. The border defined for that object move from the known region to unknown region. The patches are used to complete the texture in case of texture based synthesis. Author consider this problem as worldwide problem were he has to optimized the variety of structural and constancy constraints in that case the misplaced image patches produced all along the user defined curve. If we found the single curve in attendance then to get the optimum result we have to perform the dynamic programming. To produce the result with great accuracy dynamic programming importance is increased in this technique. The dealing with this propagation will decide the approximation of the result and how close is the result. In this way this technique are designed to complete the image which are damaged due to cracks, noise in the image , superimposed text, unknown object and each and every image inpainting techniques produces the good result or approximate result.

V. RESULTS

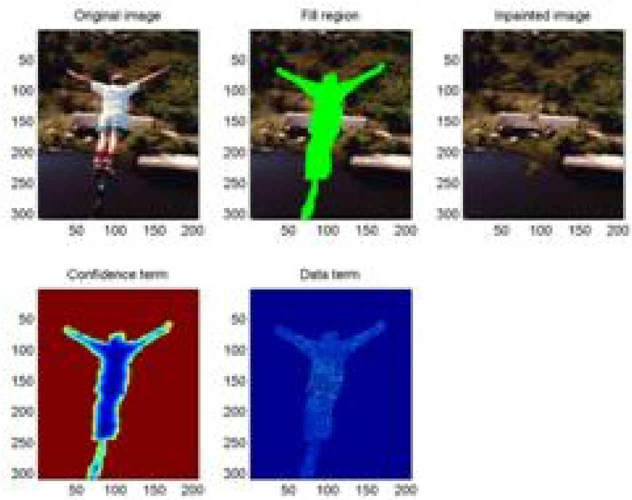

Fig. 5. Image inpainting using Exemplar based algorithm.

Author	Proposed Method	Time Efficiency
M. Bertalmio	Image inpainting	85%
Timothy K. Shih	Multiresoultion Image Inpainting	90%
Iddo Drori	Fragment-Based Image Completion	88.8%
Siddharth Borikar	Completion of Images With Natural Scenes	92.7%
Zhang	Region Completion in single image	87.9%
Criminisis	Exemplar Based Inpainting	96.2%
Dongwook Cho	Image Inpainting Based On Wavelet Transform	93.2%
M. Elad	Image Inpainting Using MCA	87.4%
Duncan D.K.	Image Inpainting Using Contourlet Transform	94.9%
Jian et.al	Image Inpainting By Patch Propagation	97%

VI. CONCLUSION

In this paper different image inpainting algorithms are studied. In PDE algorithm due to Isophote driven approach one can find the line of equal gray scale values which contains the more promising information and this used to complete the image with less time. But the main problem with this algorithm is reproduction of large texture regions and it also unable to recover Partially Degraded Image. In multiresolution image inpainting the single resolution approach produces the blurred result that overcome by this approach. It also covers the different level of details. The issue with this technique is that there is no friendly environment is provided to mark the region which we have to rebuild. In fragment based image inpainting Image completed with composition of similar fragment is used which iteratively fills the missing regions. One can apply any method like scaling, transformation to composite the fragment. The limitation of this technique is that the building blocks are required to complete the image from unknown regions to the known regions. In completion of image with natural scenes method saves lots of time with the help of Fourier transform by limiting the search in horizontal direction only. But his Method does not apply the computation over all levels and also search is applied to small regions only not at different levels. In Graph cut Patch Algorithm divided into three steps the blurring of images is greatly reduced in this image. But in this algorithm one need to take care of filling order as well as patch matching and finally the patch updating. The Criminisi or exemplar based Algorithm can be applied with the large scale image but this algorithm does not handle the depth of ambiguities. If this algorithm does not found similar patches for synthesis, we can’t get desirable result. Image Inpainting Using Wavelet Transform utilizes inter and intra scale dependency to maintain image structure and texture quality using Wavelet Transform. But in this algorithm mask for regions are defined manually. In Image Inpainting Using MCA method is fusion of variation and regularization of the image that allows missing data and also automatically filling the missing holes in texture and also in the cartoon image layer. But in this method there is necessity to consider the numerical solution to extend this approach. If the object has sparse representation then it creates the problem for this technique. In Multiscale Image Modeling in denoising process the contourlet transform provides the better result than wavelet transform and in comparison to other technique it provides the good result in terms of human visual quality (HVS) and peal signal-to-noise ratio (PSNR). But it is complex than the wavelet transforms and it also found difficulty to find the neighboring coefficient. In Image Completition with Patch Propagation Dynamic programming helps to complete the image from single level to multilevel. If the single curve in this image is found then one can complete the image quickly and can also get the optimum result which is closely resembled with original image. But For multiple objects the difficulty level is increased to optimize the result one has to propagate the technique to get approximate result.

ACKNOWLEDGMENT

	**First Author** (Mr. Vijay P. Patil) M.Tech in Digital Communication. Working as Assistant Professor at Sandip Institute of Technology and Research Centre, Nashik
	**Second Author** (Ms. Swati Pawar) ME in Electronics and Telecommunication. Working as Assistant Professor at Sandip Institute of Technology and Research Centre, Nashik
	**Third Author** (Ms. Bhagawati Patil) ME in Digital Communication. Working as Assistant Professor at Sandip Institute of Technology and Research Centre, Nashik
	**Fourth Author** (Mr. Mayur Ingalel) ME in Electronics and Telecommunication. Working as Assistant Professor at Sandip Institute of Technology and Research Centre, Nashik

REFERENCES

[1] M. Bertalmio, G. Sapiro, V. Caselles, and C. Ballester, "Image inpainting," in Proceedings of the 27th annual conference on Computer graphics and interactive techniques, 2000, pp. 417-424.

[2] Bertalmio, M., Sapiro, G., Caselles, V., Ballester, C.,: Image inpainting. In: Proceedings of SIGGRAPH 2000, pp.417-424. ACM Press, New York (2000).

[3] A. Criminisi, P. Perez, and K. Toyama, “Region Filling and Object Removal by Exemplar- Based Image Inpainting,” IEEE Transactions on Image Processing, 13(9), 1200-1212, 2004.

[4] D. Iddo, C. O. Daniel, and Y. Hezy, "Fragment Based Image Completion," ACM Transactions on Graphics, 2003, 22(3) 303-312.

[5] Timothy K. Shih,Liang-Chen Lu, Ying-Hong Wang and Rong-Chi Chang, “Multi-resolution Image Inpainting” IEEE Transactions on Image Processing, 2003.

[6] S, Borikar, K. K. Biswas, and S. Pattanaik, "Fast Algorithm for Completion of Images with Natural Scenes,"

[7] Dongwook cho and Tien D. Bui “Image Inpainting Using Wavelet-Based Inter-and Intra-Scale Depedency” IEEE Transactions on Image Processing, 2008.

[8] M. Elad, J.L. Starck, P. Querre, and D.L. Donoho, “Simultaneous Cartoon and texture image inpainting using morphological component analysis (MCA) ,” Journal on Applied and Computational Harmonic Analysis, 340-358, 2005.

[9] Po, Duncan D K, “Directional multiscale modeling of images using the contourlet transform”, Statistical Signal Processing, 2003 IEEE Workshop on 28 Sept.-1 Oct. 2003.

[10] Z. Xu and S. Jian, “Image inpainting by patch propagation using patch sparsity,” IEEE Transactions on Image Processing, Vol. 19, Pp. 1153-1165, 2010.

[11] R.C. Gonzalez, and R.E. Woods, Digital Image Processing, 2nd ed. Pearson Education, 2002.