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Investigation of Optimal Image Inpainting Techniques for Image Reconstruction and Image Restoration Applications

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Abstract— People in today's society take a lot of pictures with their smartphones and also make an effort to keep their old photographs safe, but with time, those photographs deteriorate. Image inpainting is the art of reconstructing damaged or missing parts of an image. Repairing scratches in photographs or film negatives, or adding or removing elements like stamped dates or "red-eye," are all possible through inpainting. In order to restore the image many techniques have been developed, significant techniques include exemplar based inpainting, coherent based inpainting and method for correction of non-uniform illumination. The four main applications of these image inpainting techniques are scratch removal, text removal, object removal and image restoration. However, all the four image inpainting applications cannot be implemented using a single technique. According to the literature, there has been relatively less work done in the field of image inpainting applications. Investigation has been carried out to find the suitability of these three techniques for the four above mentioned image inpainting applications based on two performance metrics.

Keywords-— Object Removal; Text Removal; image restoration; Scratch Removal.

I. INTRODUCTION

Film and photo archives have become an essential component in the modern era. Numerous editing options are available in digital picture suites like Photoshop and Corel Draw. These methods require a significant amount of manual labor to complete. The term "inpainting" stems from the technique of recovering images, which is practiced today in places such as museums and art galleries all around the world. The information cannot be recovered by using a simple mathematical equation. The purpose of picture inpainting is not to restore the original image, but rather to produce a new image that is extremely similar to the original image. This task entails modifying the broken parts of the image or filling in the missing areas in such a way that a person who is not familiar with the original photographs would not be able to tell the difference. Image inpainting has many applications, including restoration of artworks, movies, and pictures and the elimination of occlusions in images caused by text, stamps, subtitles, and advertisements. In addition to that, inpainting can also be used as a tool for the special effects creation.

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The outline of paper contains introduction regarding applications of inpainting in Section-I, brief knowledge about previous work in the field of different image inpainting applications in section-II, Discussion about applications methodology with the help of flow charts in section-III, the observations and experimental results under section-IV and conclusions in section V.

II. LITERATUE REVIEW

There have been earlier ideas in the scholarly literature addressing possible spatial restoration techniques for missing data. They each tackle the problem of filling the incomplete information and treating the situation in a distinct manner. Following is a succinct overview that is divided into categories and examines the most often used strategies.

In [1], Masnou and Morel provide an easy yet effective approach for filling in unfilled sections. This strategy is based on linking levels with identical values along the artifact's shape. More advanced variational techniques are provided by Bertalmio et al. and Ballester et al. in [2]-[3]. Using Euler's elastica, curvature-driven diffusions and the total variation models. Chan et al. propose a variety of inpainting techniques in [4] –[5]. Bertalmio et al. significantly enhance the approaches described in [6] and [7] by trying to merge many interpolation techniques for structure and texture into a single algorithm. You may find these two documents here and here. We use explicit edge information to restore artefacts spatially in reference [8]. Straight edges are the most critical assumption. Knutsson and Westin [9] presented a thorough, data-only approach to multi-dimensional data interpolation using convolutions.

Therefore, Efros and Leung [10] provide a non-parametric method for generating textures using Markov random fields. This method is used in texture-based image restoration. A neighbourhood is selected at random from the potential neighbourhoods, and the centre pixel value of that neighbourhood is copied and inserted into the current location. In [11], Criminisi et al. expand Efros and Leung's technique by giving pixels near edges greater restoration priority. Thus, the technique preserves the continuity and edge sharpness better than Efros and Leung's. In their article [12], Jia and Tang characterize a brand-new tensor-based method. This step begins with the recreation of the edge structure, accompanied by the synthesizing of the texture. Hirani and Totsuka [13] integrate both frequency and spatial information to reconstruct a lost image's structure or texture by combining spatial and frequency information.

F.D. Beulah David [14] et al outlined a technique for inpainting that employs spatial contextual correlation. The inpainting process is concluded when the hole region is selected fully or partially automatically. In order to reduce noise and distortion, this approach preprocesses the picture to be inpainted using the Gaussian filter. A growing region's surface area is divided with max-difference technique using a merge split.

The item and the actual photographs are then compared. Ultimately, image matching is accomplished by employing context - specific correlation and the information about self-data. In the semi-automatic technique, the process is identical to that of the fully automatic method; the only variance would be that segmentation is managed manually using the drag shape method. The boundary information is progressively shifted into the centre, and the disregarded area is filled by correlation information provided by the neighbour's. With the aid of this method, it is feasible to repaint single or multiple areas.

The technique presented in Xiaowei shao [15] involves dissecting the picture to be repainted into its structural and textural components before applying fixes depending on the characteristics of these parts. In order an Exemplar-based technique is utilized to repair the damaged texture image. The Laplacian operator is employed for the purposes of improving and repairing the structure. An Exemplar-based technique is then utilized to inpaint this same Laplacian image, which is followed by a Poisson equation-based reconstruction. Ultimately, the inpainted image is created by combining the two images that required repair. This method provides these visual effects for large regions of inpainting.

In 2012, Qing Zhang [16] created an innovative technique for assigning priorities and completing instructions. The author has given priority using a unique technique based on the color distribution analysis, as opposed to the conventional isophote-driven method. This approach emphasizes structure over texture, making it more sturdier. This method maintains texture consistency and continuity at the borders, improving visual quality.

K.sangeetha[17] introduced Exemplar-based Image inpainting using extended wavelet transform. The method is divided into two stages: the first is the process of breaking down of the sub bands and the second seems to be the directional transform.

Discontinuities at discrete points are first captured using a Laplacian filter bank, and then the direction of the discontinuity is determined using a directional filter bank. The results of this algorithm's enhancements to the edges of natural images are indeed very promising.

Detailed analysis and comparison of image inpainting applications their merits and demerits have not been presented in literature. This study attempts to analyze and compare various inpainting techniques so as to provide clear understanding of the image inpainting methods and their applications.

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III. APPLICATIONS OF IMAGE INPAINTING

The challenge of image inpainting consists in bringing back an original image after it has been altered or degraded in some way. Specular reflections that appear during the photo capturing process, stains, and cracks can degrade the quality of photographs. Depending on the application, the cause of the deteriorations that need to be dealt with might vary. For instance in digital photography, it could be the text overlay, the removal of objects, or scratches; in images taken of old paintings, it could be the ageing of the paint.

1.Image Restoration

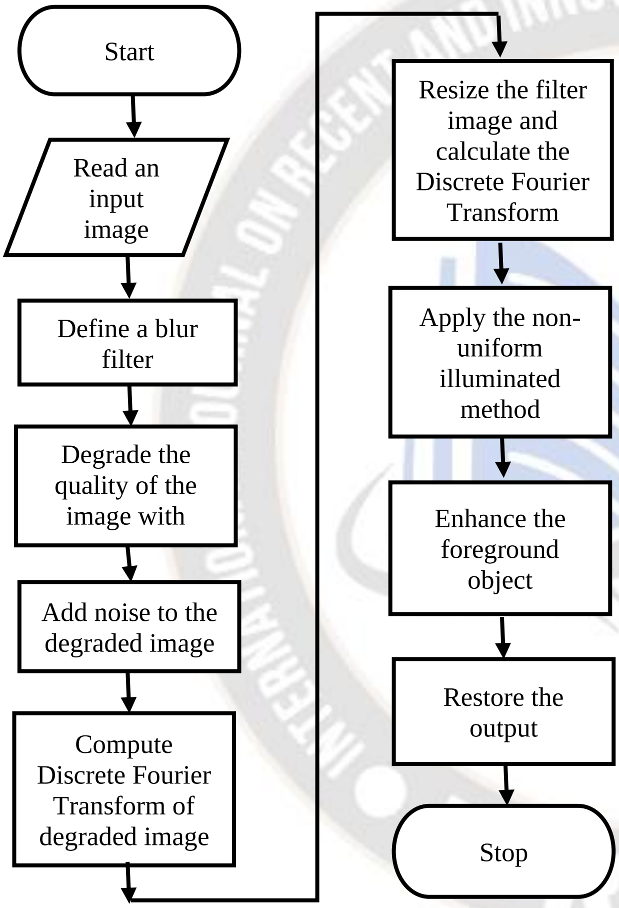

Fig1. Flow chart of image restoration application

Restoring a damaged image involves fixing the problems that caused the image to deteriorate in the first place. There are many different manifestations of degradation, such as motion blur, noise, and misfocus in the camera. In case of motion blur, it is feasible to "undo" the blur in order to restore the original image by coming up with a very good estimate of the actual blurring function and applying that estimate to damaged image. In situations where the image is ruined by noise, the most that we can hope to achieve is to make up for the quality loss that was brought on by the noise. In the course of this work, a number of the picture restoration techniques that are currently in use in the field of image processing are implemented and discussed with the help of flow chart (fig.1).

2.Text Removal

In order to remove undesirable text from images, a two-step framework has been implemented: the first stage involves detecting text inside the image, and the second stage involves removing that text using a method known as inpainting. In order to detect the text, it first needs to be localized and then extracted. After that, inpainting is used to fill in the gaps formed in the image by making use of the area around it. Smoothing is the appropriate method for increasing the effectiveness of text detection. Text detection is carried out by employing techniques such as feature extraction, stroke filtering, and centroid processing. Processing based on color histograms is done so that text components can be filtered out more clearly from other image components. In the final stage, the text holes that were formed are filled with relevant information that is already present in the same image by employing the inpainting technique of the nearest matching neighborhood. Then smoothing operation is performed on the selected filled patches in order to provide visually believable results. The Fig.2 gives a detailed flow chart of text removal application.

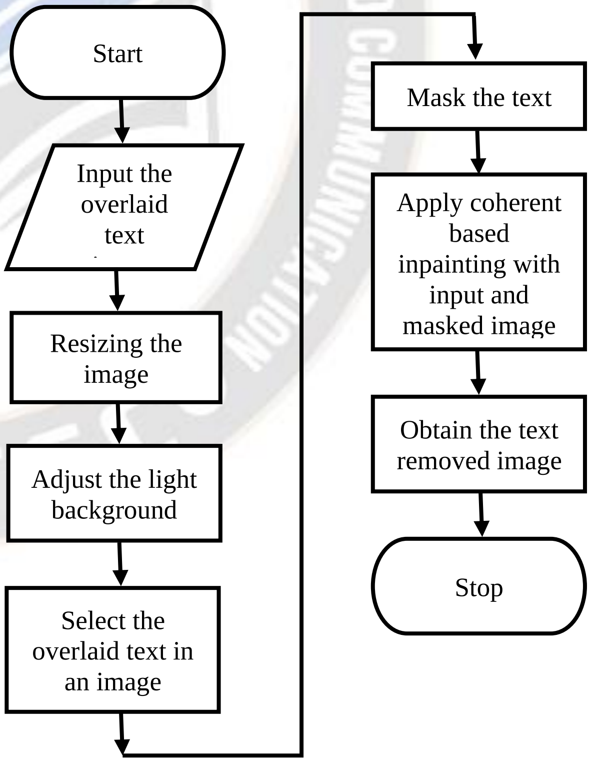

Fig.2 Flow chart of text removal in an image

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3.Object Removal

The technique of exemplar-based inpainting evolved as a direct result of the application of many of the ideas discussed in the texture synthesis. The process of removing objects from large target regions involves assigning priorities and selecting the patch that is the greatest possible match with the target region. The exemplar is helpful in this process, which is based on selecting the patch that has the highest possible degree of similarity. After all of the priorities have been computed, the pixel with the highest priority is selected as the target pixel to rebuild, and the missing part is filled in pixel by pixel with the linear combination of neighborhood patches. Once this has been done, the image reconstruction is complete. The exemplar is used to assist in selecting the patch from the source region that provides the best possible match, and the order in which patches are filled is determined by priority. This is done in order to differentiate the structure from the texture of each patch, and the degree of similarity between patches is calculated using metrics such as peak signal to noise ratio (PSNR) and mean square error (MSE).

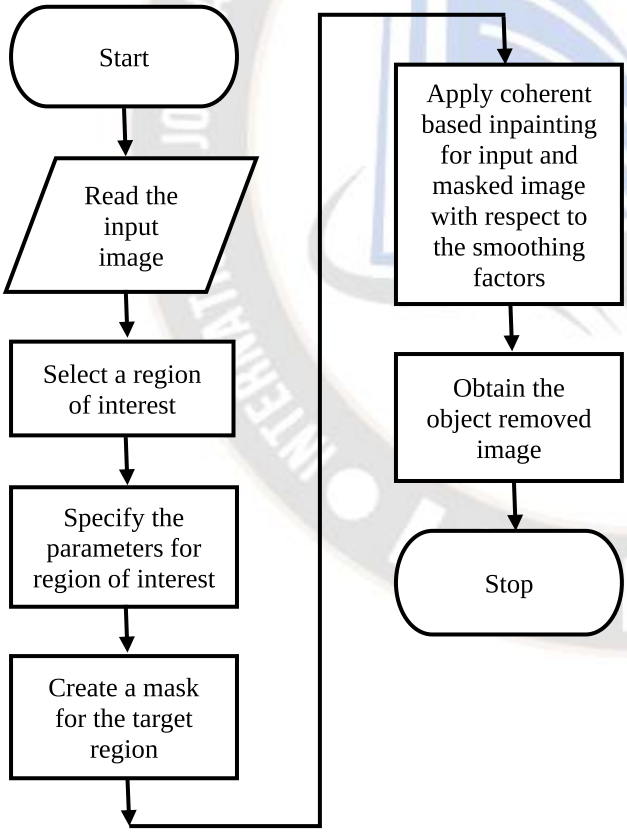

Fig3. Flow chart of object removal in an image

The detailed flowchart of object removal application is given in Fig.3.

4.Scratch removal

The picture can be thought of as a 2D function where the amplitude of the image at any point is referred to as the intensity or grey level of the image at that point. Scratches are flaws that appear on older films and photographs. These flaws reduce the quality of the images they appear on. Scratches are a type of anisotropic interference that appears as a shared vertical orientation. Images that have been scratched can be recognized by the presence of vertical lines that, in comparison to the pixels surrounding them, have an intensity that is either bright or dark. Therefore, the scratches are classified according to their length and the amount of light that they reflect. In accordance with the length of the scratch, it is possible to divide it into two distinct categories i.e., the principal Scratch and the secondary Scratch. Scratches that are considered to be principal scratches have a length that is greater than 95% of the height of the image. Secondary scratches, when compared to major scratches, are quite minor and take up very little space. The scratches are further divided into positive and negative based on their relative brightness. Positive scratches are located in an area of high intensity and a while negative scratch is the one that is located in an area of low intensity. The flow diagram of scratch removal application is shown in Fig.4.

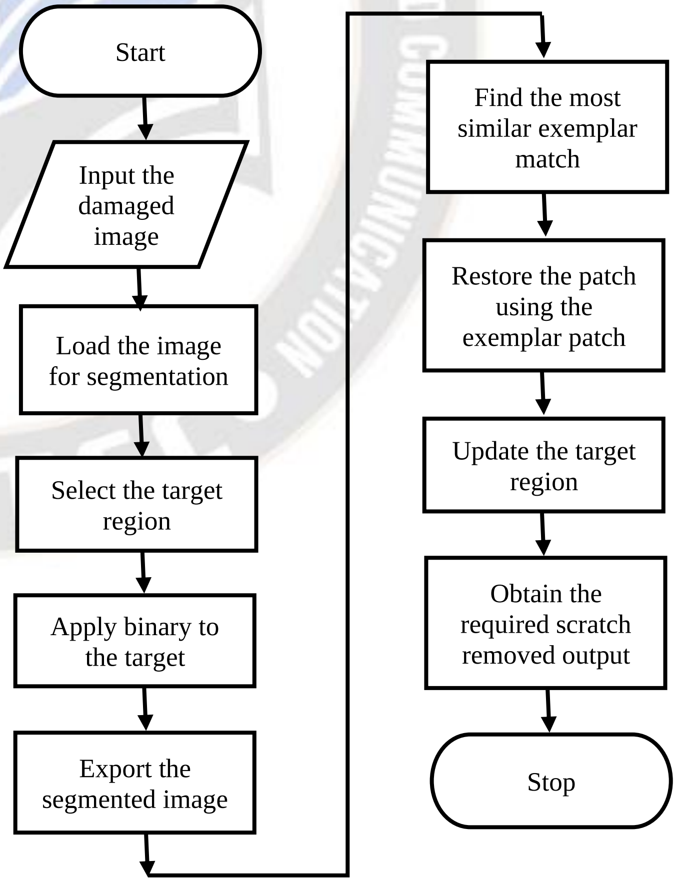

Fig.4 Flow chart of scratch removal in an image

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Table1: A Quantitative report of different image inpainting applications

	Image restoration	Text removal	Object removal	Scratch removal
PSNR (dB)	6.64	16.4	29.6	30.0
MSE	1409	1418	69.68	63.94
METHOD	Correction of non uniform illumination method	Coherent based inpainting	Coherent based inpainting	Exemplar based inpainting

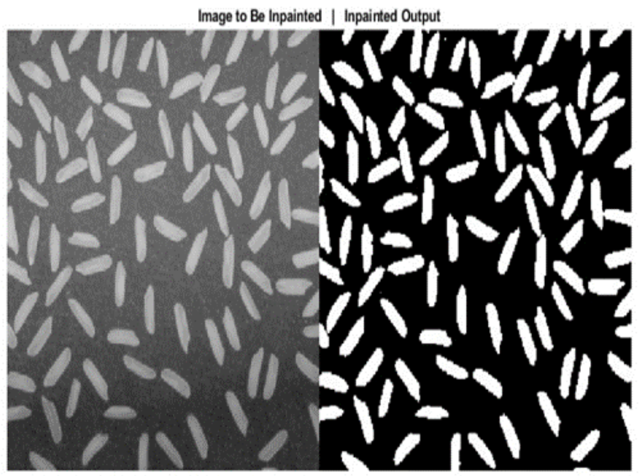

Fig.5 Result of Image restoration application. Damaged image on left side and reconstructed image on right side

IV. EXPERIMENTAL RESULTS

The experiment is about repairing the damage images. With the proposed techniques the experimental result of the different image inpainting applications are achieved.

The performance measures used are MSE and PSNR.

a) The term "mean square error" (MSE) refers to the average squared deviation that exists between the values that are estimated and the values that are really present. MSE may be determined by the use of a formula,

$$\text{MSE} = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \quad \textbf{(1)}$$

Where m represents the total number of rows and n represents columns. I_1 is the gray value of the corresponding pixel in the original picture and I_2 is the gray value of the current pixel in the inpainting image.

b) The peak signal-to-noise ratio (PSNR) is the ratio of the greatest possible signal power to the maximum possible noise power that degrades the accuracy of the signal representation. The formula for determining PSNR is as follows

$$\text{PSNR} = 10\log_{10}\left(\frac{\boldsymbol{R}^2}{\boldsymbol{MSE}}\right) \quad \textbf{(2)}$$

R represents the amount of variation that may be found in the supplied picture data type. Using these formulae performance can be measured, if the PSNR value is high then the errors in

that is very less and vice versa.

The implementation of the different applications had been tested on MATLAB R2022a. Table 1 presents the experimental results of different applications. It has been observed that mean square error is very less in scratch removal application. while comparing with other methods exemplar based method gives high peak signal to noise ratio. The results of image restoration, text removal, object removal and Scratch removal applications are presented in Fig.5, Fig.6, Fig.7and Fig.8 respectively.

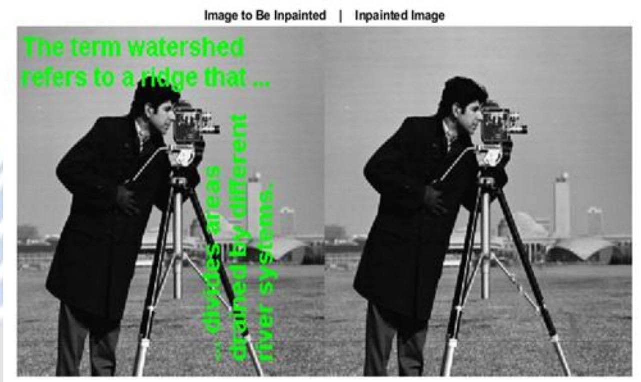

Fig.6 Result of text removal application. Damaged image on left side and reconstructed image on right side

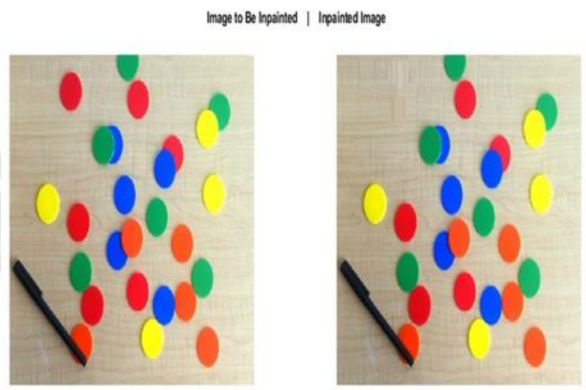

Fig.7 Result of object removal application. Damaged image on left side and reconstructed image on right side

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Fig.8 Result of Scratch removal application. Damaged image on left side and reconstructed image on right side

V. CONCLUSION

The inpainting procedure will be successful if the image information (photometry), color, shape, and geometric structure are successfully restored into the areas that is missing. Each image inpainting technique has good picture restoration capabilities; however, the issue lies in the exact reproduction of the source images. The edges are where the majority of the problems are. The sharp edges are responsible for a higher number of errors overall. All of the algorithms that have been described in this article come with their own unique set of benefits as well as drawbacks. A large number of distinct ways have been presented, each of which has a different level of application in terms of repairing damage, removing objects, and filling up gaps. The findings of this work imply that error is significantly reduced and peak signal to noise ratio is improved in exemplar based inpainting.

REFERENCES

[1] "Image sequence restoration in the presence of pathological motion and severe artifacts," presented at the IEEE ICASSP, Orlando, FL, USA, May 2002
[2] S. Masnou and J.-M. Morel, "Level-lines based disocclusion," presented at the IEEE Int. Conf. Image Processing, Chicago, IL, 1998.
[3] C. Ballester et al., "Filling-in by joint interpolation of vector fields and gray levels," IEEE Trans. Image Process., vol. 10, no. 8, pp. 1200–1211, Aug. 2001
[4] M. Bertalmio, A. Bertozzi, and G. Sapiro, "Navier-stokes, fluid-dynamics and image and video inpainting," presented at the IEEE CVPR, 2001.
[5] T. Chan and J. Shen, "Mathematical models for local nontexture inpainting," SIAM J. Appl. Math., vol. 62, no. 3, pp. 1019–1043, 2001
[6] T. Chan, S. H. Kang, and J. Shen, "Euler's elastica and curvature based inpainting," SIAM J. Appl. Math., vol. 63, no. 2, pp. 564–592, 2002.
[7] M. Bertalmio, L. Vese, G. Sapiro, and S. Osher, "Simultaneous structure and texture image inpainting," IEEE Trans. Image Process., vol. 12, no. 8, pp. 882–889, Aug. 2003.
[8] S. Rane, M. Bertalmio, and G. Sapiro, "Structure and texture filling-in of missing image blocks for wireless transmission and compression applications," IEEE Trans. Image Process., vol. 12, no. 3, pp. 296–303, Mar. 2002.
[9] H. Knutsson and C.-F. Westin, "Normalized and differential convolution: Methods for interpolation and filtering of incomplete and uncertain data," presented at the IEEE CVPR, New York, 1993.
[10] A. A. Efros and T. K. Leung, "Texture synthesis by nonparametric sampling," presented at the ICCV, 1999.
[11] A. Criminisi, P. Pérez, and K. Toyama, "Object removal by exemplarbased inpainting," presented at the IEEE CVPR, 2003.
[12] J. Jia and C.-K. Tang, "Image repairing: Robust image synthesis by adaptive ND tensor voting," presented at the IEEE CVPR, 2003.
[13] A. N. Hirani and T. Totsuka, "Combining frequency and spatial domain information for fast interactive image noise removal," in Proc. ACM SIGGRAPH, 1996, pp. 269–276.
[14] F. D. Beulah David and Dorai Rangaswamy "Image Completion by Spatial-Contextual Correlation Framework Using Automatic and Semi-Automatic Selection of Hole Region" Ictact Journal On Image and Video Processing, August 2015, Volume: 06, Issue: 01
[15] Xiaowei Shao,Zhengkai Liu,Li Houqiang "An Image Inpainting approach Based on Poisson equation" Document Image Analysis for Libraries, 2006. DIAL '06. Second International Conference, April 2006.
[16] Qing Zhang and Jiajun Lin "Exemplar-Based Image Inpainting Using Color Distribution Analysis" Journal of Information Science and Engineering 28, 641-654 (2012).
[17] K. Sangeetha, Dr.P. Sengottuvelan and E.Balamurugan "Extended Wavelet Transform Based Image Inpainting Algorithm For Natural Scene Image Completion" Computer Science & Information Technology (CS & IT) .