Image Restoration using Digital Inpainting and Superresolution

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ABSTRACT
This paper introduces combination of two image processing techniques i.e. Inpainting and Super resolution. It consist of performing inpainting on input image using Enhanced Exemplar based algorithm and then converting it into high resolution using Single frame super resolution algorithm. Enhanced exemplar based algorithm fills selected target region with suitable patches from the surrounding image area. Once the input image is inpainted, it is then converted to high resolution using single frame super resolution algorithm. The single frame super resolution algorithm used in this approach does not require a predefined training set thus increasing its performance for its practical use.

General Terms
Image Processing, Image restoration

Keywords
Inpainting, superresolution, single frame superresolution, exemplar algorithm.

1. INTRODUCTION
There are various factors that affects the quality of image like degradation, scratches, and defects or degradation during acquisition or transmission. In order to remove these defects, image restoration and image enhancement techniques were developed. Image restoration is a process in which a degraded image is restored to its original appearance. This technique is widely used in restoration of damaged painting, digital photographs to improves visual appearance [4] [5].

Ages ago, people used to preserve their visual work carefully. As time passes, photographs get damaged & scratched. People then used inpainting to remove scratches from degraded images. Inpainting is an ancient art of restoring images in which damages from an image are removed so that they appear to be visually plausible. It can also be used to remove unwanted objects, overlaid text from images, scratches, stains etc. from the input image.

Once the image has been inpainted, superresolution technique is applied to improve visual quality of image. Superresolution can only be applied if input image is of low resolution. Superresolution is a technique to convert low resolution image into high resolution image. Superresolution can be classified as: Single Frame Superresolution & Multi Frame Superresolution [4] [7].

Multi Frame superresolution uses multiple low resolution images of same scene from different perspective to generate high resolution output. Single Frame on the contrary, uses single low resolution image to produce high resolution image [10]. It may or may not require collection of training data of low & high resolution patches. Our approach uses single frame super resolutions which do not require training set with high and low resolution patches, which may limit its use. The algorithm used here, uses SVR models to convert input low resolution image to super resolved version.

2. RELATED WORK
Various Digital Image Processing Techniques have been invented since years ago. Two of the image processing techniques are Inpainting and superresolution. Many Inpainting algorithms have been developed over the years and Bertalmio was first to introduce image inpainting.

The basic idea of digital inpainting is to fill correct patches from the neighboring region into the selected region to be inpainted. Bertalmio used partial differential equation and Chan and Shen used a Total Variation Inpainting model, yet such algorithms fails to inpaint large regions.

Another approach of Inpainting was developed by Criminisi known as Exemplar based Inpainting which is an isophote driven image sampling process. In order to fill the region, Criminisi used SSD (sum of squared differences) to find the best matching patch which was then filled in the targeted region. SSD criteria may generate an error match in the targeted region and as a result it may give inaccurate output. In this paper, variation in the selection of best matching patch is used [2] explained in section 3.1.

In most digital image processing applications, high resolution image is required for later image processing and analysis. Image Superresolution technique is one which produces a high resolution image from one or more low resolution images. The basic idea behind superresolution is to generate high resolution image by combining non-redundant information present in multiple low resolution frames.

The theory of super resolution was first proposed by Tsai and Hunag in the year 1984. They considered the problem of developing a high quality image from several downsampled and transactionally displaced images. Their training dataset consisted of geographical images taken from Land satellites. They used the shift property of Fourier transform for obtaining a set of equations in the frequency domain. Optical Noise and Blur were not considered in this method. Later the Tsai-Hunag theory was extended by Tekalp, Ozkan and Sezan which contains the point spread function for imaging system and observation of noise.

Basically, there are two approaches for superresolution based on the number of input images. First, Single Frame super resolution in which a single input image is used to produce a high resolution image. A dictionary of high resolution patches are used in [7]. Second is Multi frame super resolution which has multiple frames of an image as an input, which gives a high resolution output.

In this approach a single frame super resolution algorithm is used, which is more convenient than multiframe super resolution.

3. PROPOSED METHOD

The proposed method combines two techniques of image processing for enhancing the image from the perspective of its visual quality. The algorithm can be explained in the steps given below:

Step 1: Input an image which the user wishes to inpaint.

Step 2: This steps performs inpainting using enhanced exemplar based algorithm which is explained in section 3.1

Step 3: Once the image is inpainted, super resolution of this image is done using single frame super resolution as explained in section 3.2.

Step 4: if the result is satisfactory, user can save the result or can again process it for inpainting.

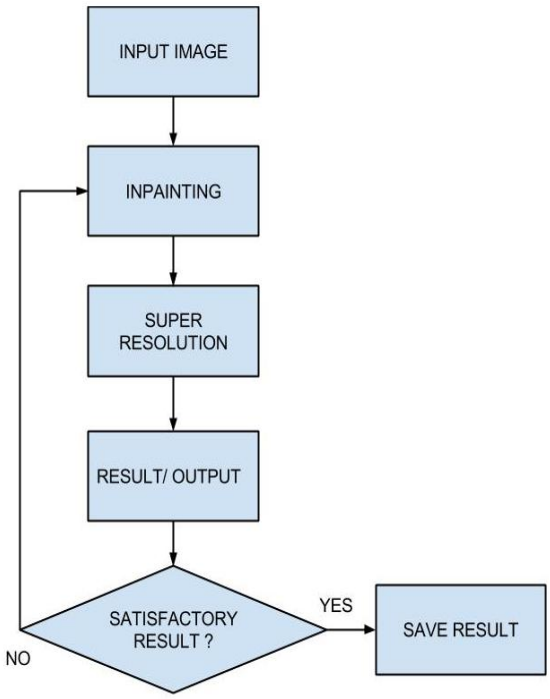

Fig 1: Flow chart of proposed method.

This section aim to trace the methods used for inpainting and superresolution.

3.1 Inpainting Algorithm

Enhanced Exemplar based algorithm uses the core Exemplar based algorithm [1] with a variance in the process of selecting best matching patch.

As shown in the figure 1 below, I is the input degraded image and Ω is target region to be inpainted. Φ is the entire image excluding target region Ω (Φ =I-Ω).-Ω). ∂Ω denotes the boundary of Ω and Ψ_p is the patch we wish to fill in the targeted region , centered at p [1][2].

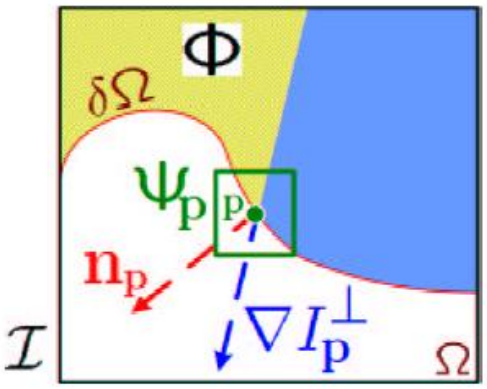

Fig 2: Notation diagram showing source region and target region [2].

The proposed Enhanced Exemplar based algorithm as described in [2] has following steps:

3.1.1 Computing patch Priority for filling in target region.

Computation of patch filling priority is based on patches which are located along the strong edges and are surrounded by high confidence pixels. The confidence term represent the texture characteristics. For selecting the best matching patch Criminisi [1] in his approach used SSD, which is difference between current patch and corresponding pixel of matching patch. Thus patch with minimum SSD value will be selected as best matching patch. However, correlation between damaged area of current patch and corresponding pixel of matching patch is not taken into consideration, which may generate error match resulting in inaccurate output.

Instead [2] uses a variation in SSD criteria to make correct patch selection. Variance can be expressed as a mathematical expectation of the average squared deviation. In order to maintain stability of image patch, variance is used. The proposed method compare variance to select the best matching patch from current patch and candidate patch, which avoids error match.

3.1.2 Filling in target region with computed best patch.

Once the variance is calculated, the best patch will be selected. This patch is then copied in the target region that is more similar to the selected patch [2].

3.1.3 Updating the information

After the patch has been filled in the target region the confidence is updated and the process is repeated till the target region is completely filled [1].

3.2 Super resolution Algorithm

This section describes single frame super resolution algorithm as in [10] [11]. In this approach of super resolution, collection of training data is not required. Predefined training data limits its practical application and also affects its performance.

3.2.1 Learning of Sparse Representation

Low Resolution (LR) image is synthesized into its high resolution (HR) using Bicubic Interpolation. Once the input LR image is up-sampled, all 5×5 patches are extracted from this HR image. Now from these extracted patches proper patches are selected to represent image features. To represent the image features sparse representation is used. Sparse representation can be determined by learning the extracted patches. The resulting sparse coefficient for each patch will be the feature of interest [10].

3.2.2 Support Vector Regression (SVR)

Support vector regression is an extension of Support vector machine which is powerful function used for classification and regression. SVR has the ability to fit data in high dimensional feature space. In this approach the mean value of each patch is subtracted from its pixel value and then sparse coefficient is calculated. The same value is then subtracted from the corresponding pixel in high resolution image. Once the training set of SVR is complete, it can be used to predict the final super resolved output. To refine the HR image to final SR image, sparse representation is used for each patch and the center pixel value of each patch is updated using SVR models [11].

The above explained process of super resolution can be summarized; first the input low resolution images are up-sampled to produce high resolution images with different scales using Bicubic interpolation. After getting the HR images, sparse representation is applied to the patches and using SVR models final SR output is generated [10].

4. RESULTS

An extended version of the core exemplar based Inpainting algorithm in [1] is used for removing defects or objects from the input image, which uses a variance in the patch selection step for Inpainting. Conventional super resolution methods uses a dictionary of low and high resolution patches; but instead the method used in this paper [10] do not require a predefined training data and uses the single input low resolution image instead of multiple frames of the same scene. The proposed algorithm works for variety of colored images and give a satisfactory result.

Table 1 shows time estimated by this project and time estimated by [6] on images with different resolutions.

Table 1: Computational time comparison

Image	Resolution	Total Time from [6]	Total Time by our system
Elephant	480×320	2m 30s	1m 48s
Cow	600×400	2m 51s	2m 05s

Figure 2 shows original image to be inpainted [6] and figure 3 shows selected region. Figure 4 shows result using [6] and figure 5 shows result using our approach.

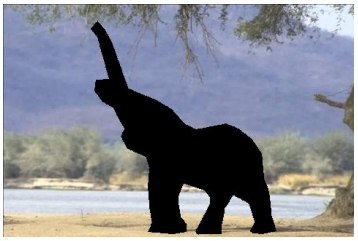

Fig 2: Original Image

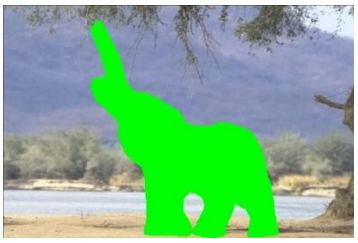

Fig 3: Selected region

Fig 4: Result by [6]

Fig 5: Result using proposed method

Similarly, Figure 6 shows original image to be inpainted [6] and figure 7 shows selected region. Figure 8 shows result using [6] and figure 9 shows result using our approach.

Fig 6: Original Image

Fig 7: Selected region

Fig 8: Result by [6]

Fig 9: Result using proposed method

5. CONCLUSION AND FUTURE SCOPE

The proposed method is a combination of two image processing techniques which are image inpainting and superresolution, thereby increasing its application for image restoration. Enhanced Exemplar based algorithm is used for digital image inpainting which compares the current patch and candidate patch for selecting the best matching patch for filling the selected part of image. This gives better results than the core Exemplar based algorithm.

The downsampled inpainted image has been superresolved to get a high resolution result, thus enhancing the image quality. For superresolution Single image superresolution method is used; this method does not require a dictionary of low and high resolution patches which may reduce the scope of super resolution as it gets limited to certain types of images only. The proposed method works well for the RGB and Grey scale images, and gives satisfactory results.

Inpainting and superresolution have wide use in many fields like photography, cinema, medical, etc. Blocks of coded images lost during transmission can be replaced using this method. In future this technique can also be applied for streaming videos, to remove watermarks and logos in it. The use of superresolution for smoothening 3D images can also be possible.

6. REFERENCES

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