ABSTRACT
The filling in of missing region in an image is known as image inpainting. Image inpainting or completion is a technique to restore a damaged image. Recently various approaches have been proposed. Wavelet transform has been used for various image analysis problems due to its nice multi-resolution properties and decoupling characteristics. We propose to utilize the advantages of wavelet transforms for image inpainting. Unlike other inpainting algorithms, we can expect better global structure estimation of a damaged region in addition to shape and texture properties. Inpainting is the art of modifying an image in a form that is not detectable by an ordinary observer. There are numerous and different approaches to tackle the inpainting problem. This paper puts forth the overview of the work done in the field of image inpainting. The inpainting technique can be classified into two categories: (1) texture oriented and (2) structure oriented. Both the technique have their advantages and disadvantages. The wavelet based algorithm combines the advantages of both of these approaches. Wavelet transform has been used for various image analysis problems due to its nice multi-resolution properties and decoupling characteristics [1]. This algorithm proposes to utilize the advantages of wavelet transforms for image inpainting. Exemplar based structure synthesis contains the essential process to replicate both texture and structure [9].

KEYWORDS
Wavelet, Wavelet transform, Object Removal, Image Inpainting, Texture Synthesis, Multi-resolution.

1. INTRODUCTION
The filling-in of missing region in an image is known as Image Inpainting. Inpainting is the art of modifying an image or video in a form that is not easily detectable by an ordinary observer. Image Inpainting has become a fundamental area of research in image processing. The modification of images in a way that is non-detectable for an observer who does not know the original image is a practice as old as artistic creation itself. Medieval artwork started to be restored as early as the renaissance. The motive was simple, to bring medieval pictures, ‘up to date’ as to fill any gaps. This practice is called ‘retouching’ or ‘Inpainting’. Also image Inpainting has been widely investigated in the applications of digital effect (i.e. object removal, image editing, image resizing), image restoration (e.g. Scratch or text removal in photograph), image coding and transmission (e.g. recovery of missing blocks) etc.

This paper demonstrates a novel algorithm for removing large objects from digital photographs and replacing them with visually plausible backgrounds. Fig. 1 shows an example of this task, where the foreground person (manually selected as the target region) is automatically replaced by data sampled from remainder of the image. The process of Inpainting can be graphically represented as shown in fig.2. The input to the algorithm is an image to be inpainted i.e. original image. The user selects the region to be inpainted i.e. the target region. Then the algorithm proceeds filling the target region with features around it. The output is an inpainted image.

The conventional schemes that are proposed for image Inpainting can be divided into two categories:
- Texture oriented
- Structure oriented

Several researchers have considered texture synthesis as a way to fill large image regions with ‘pure’ textures-repetitive two dimensional textural patterns. This approach effectively generates new texture by sampling and copying color values from the source [9]. Though the techniques of texture synthesis are effective, they have difficulty in filling holes in photographs of real world scenes consisting of composite textures. However, the structure-oriented scheme obtains the missing region by propagating linear structure into the target region via diffusion. They are inspired by the partial differential equations. Their drawback is that the diffusion process introduces some blur, which becomes noticeable when filling larger regions.

(a) Original photograph     (b) Inpainted photograph

Fig. 1 removing large objects from images

Input image              Select target

Input image

Fig. 2 data flow diagram of Inpainting process

M. Bertalmio is one of the legendary names in the field of Image Inpainting, proposed a simple algorithm (2000) where filling in the missing region is carried out by the property of Isophotes.(lines of equal gray value) [4]. Also soon after this in 2001
Chan, Shen and coworkers proposed a variation model for filling in gray level and color images. Later Mumford-Shah model in 2002 has been adopted for good obtaining good approximations from mathematically neat image modeling. These proposed algorithms were structure oriented. These algorithms were able to keep good continuation smoothly however, broken edge estimation with large gap could fail and detail texture surface is not easily reproducible. Again in 2003 Bertalimo proposed to decompose each original image into two separate component images of different characteristics. One of them is processed by texture-oriented scheme and the other by structure-oriented one. In 2007 Ching and coworkers proposed an algorithm using wavelet. This algorithm could be applied to highly lose image. Also in 2008 Wong proposed nonlocal means approach for exemplar based Inpainting algorithm. The image patch is inferred by nonlocal means of a single best match patch. Also simultaneously Dongwook Cho, and Tien D. Bui in 2008 showed the use of advantages of wavelets to Image Inpainting. The technique presented in this paper uses the advantages of wavelet transform for image inpainting.

2 WAVELETS AND THEIR APPLICATION IN IMAGE INPAINTING

2.1 Introduction

For the wavelet transform, the coefficients at the course level represent a larger time interval but a narrower band of frequencies. This feature of the wavelet transform is very important for image coding. In the active areas, the image data is more localized in the spatial domain, while in the smooth areas, the image data is more localized in the frequency domain. With traditional transform coding, it is very hard to reach a good compromise. The target region (damaged or lost data or object to be removed) information of the image can be divided into two kinds of conditions. The first class, the distribution of the target information of the image is the local and concentration. So the decision method of the image repair can depend on the characteristic and direction of the neighboring textures to decide. The second class, the distribute of the image target part is global and dispersion. Therefore when the data a great deal of creation lost, we can't clearly repair the repair image through the consult data of the neighboring district. To solves the problem, we use the mankind's vision characteristic which make the basis of the repair. When the reference data shortage to repair the image, we zoom-out the distorting image can observe the image shape. Actually in the image processing, we use the down-sampling method to reach the visual effect. Wavelet transform has been used for various image analysis problems due to its nice multi-resolution properties and decoupling characteristics. The proposed algorithm utilizes the advantages of wavelet transforms for image inpainting. Wavelet transform has been used as a good image representation and analysis tool mainly due to its multi-resolution analysis, data reparability, compaction and sparsity features in addition to statistical properties [12]. A wavelet function (t) is a small wave, which must be oscillatory in some way to discriminate between different frequencies. The wavelet contains both the analyzing shape and the window. In order to observe the degree of influence of image textural on the reconstructed composition, we applied the two-level wavelet transformation to separate an image into three frequency components: high, medium, and low, as shown in Fig. 3(c). The original image was processed through a secondary-level wavelet transformation analysis, as illustrated in Fig. 3(c), where the highlighted image in the uppermost left hand corner is represented by the section LL2 illustrated in Fig. 3(d). Where analysis is concerned, the components of the overall image composition are all taken into consideration. This procedure can also be utilized as preliminary image analysis. The four components LL2, LH2, LH2, and HH2 are then processed through reversed wavelet transformations to heighten the resolution of the image. As shown in Fig. 3(a), where the highlighted image in the upper left hand corner is represented by the section LL1 illustrated in Fig. 3(b). This would result in the increasing of frequency components within the image, which would then contribute towards the depiction of local area textural features.

Fig. 3 Results of the wavelet transformation analysis derived from various layers of a given image
(a) 1-Level DWT image (b) 1-Level DWT Resolution (c) 2-Level DWT image (d) 2-Level DWT Resolution

2.2. Implementation

The damaged of the color image will be divided into the color composition and the texture composition [16]. In fig 5(a), we can find the importance of the texture composition in color image reconstruction. We use n level wavelet transform to separate the
texture image (Y) into different frequency compositions. The method repaired the distortion image from the low frequency composition repair to high frequency composition repair gradually. When we repair to the highest frequency layer in the wavelet domain, we will acquire the reconstruction image of the highest resolution. Besides in fig. 5(b) and 5(c), we can obviously find the color composition, Cb and Cr, has the highly neighboring relativity. So we only need to use the neighboring information of the valid to repair the color image. According to the concept, we have to put the reference target on the neighboring district. So we choose the linear interpolation to be used as the repair method in the color distortion image. Finally we get repaired image by converting YCbCr to RGB. This algorithm uses both texture composition image repair method and color composition image repair method. The texture composition image repair method uses wavelet domain to reconstruct characteristics of space frequency relativity. We analyze the multi-layers of the image from low frequency layer to high frequency layer with the help of wavelet transform. We should repair grand amount of losing pixels at the high frequency layer which will ultimately repair the pixels at low frequency layer. A layer number n to be reduced means performing 1-level inverse discrete wavelet transform (IDWT). We have to decide initial layer of repair then we have to decide how to repair image. Here we uses inter and intra scale dependency of the pixels. The tree structure includes four components (mean, horizontal, vertical, diagonal). Repairing is done by calculating differential energy of the damaged image and search image. In case of color composition image repair method we use linear interpolation technique. We define different weighting values that consider relative distance from the target T. The new linear interpolation is expressed by equation 4 and equation 5.

![Flowchart of the proposed visual resolution inpainting algorithm.](image)

Fig. 4 Flowchart of the proposed visual resolution inpainting algorithm.
3. THE IMAGE REPAIR METHOD

3.1 The Image Repairing Method In Color Composition

In the image in order to separate the texture composition and color composition, we have to use the color conversion formula to the process. Among them, the texture composition is important than the color composition. The color conversion formula is as follows:

\[
Y = 0.299 \times R + 0.587 \times G + 0.114 \times B
\]

(1)

\[
Cb = -0.169 \times R - 0.331 \times G + 0.555 \times B
\]

(2)

\[
Cr = 0.500 \times R - 0.419 \times G - 0.081 \times B
\]

(3)

The algorithm makes use of the color composition of the image that have the regional characteristic. The proposed repair method defines different weighting values that consider the relating distance from the repair target P, as shown in the Fig. 6. If the most neighboring district exist more than two reference pixel value, we will only consider the most neighboring district pixel value to repair image. But if the reference pixel is not exists anyone or just only one, we must extensive the distance of the consideration [19]. Using this concept, we proposed the revised method of the linear interpolation for the color restoration repair method.

\[
\begin{array}{cccccc}
0.5 & 0.5 & 0.5 & 0.5 & 0.5 \\
0.5 & 1 & 1 & 1 & 0.5 \\
0.5 & 1 & P & 1 & 0.5 \\
0.5 & 1 & 1 & 1 & 0.5 \\
0.5 & 0.5 & 0.5 & 0.5 & 0.5 \\
\end{array}
\]

Fig 6 Related weighting value of the different distance

\[
W_{total} = \sum_{i} \sum_{j} W_{ij} \text{if px}(i,j) \text{is valid}
\]

(4)

\[
C_{new} = \frac{1}{W_{total}} \sum_{i} \sum_{j} W_{ij} \times C_{ij}
\]

(5)

Where px(i,j) is the valid pixel value of the image, i,j w is the weighting value on (i,j), total w is the total weighting value of valid pixel value, i,j C is the valid pixel value and new C is repair pixel value on the target T. The total w be calculated for normalize the repair value of the linear interpolation pixels, in function (5).

3.2 The Image Repairing Method In Texture Composition

In the human's vision, the texture composition of the color image has the important contribution. For repair the texture composition, we proposed the global and the multi-frequency method to reconstruct the image. The repair method established on the wavelet domain characteristic of the space-frequency relativity. According to this concept, the repairing method must to decide the initial layer of the repairing pixel. When the layer number n be reduce by one which mean carrying out the 1-level inverse discrete wavelet transform (IDWT), the layer exists its relative sub-band n LL. We must to calculate the relative amount of the valid pixels of the original image that per pixel be included in the n LL. If the any pixel exists in the LL layer which relative the amount of the valid pixels is to satisfy the following equation, and the pixel in the n LL will start being repaired in this layer.

\[
N_{p}^{n}(i,j) = 2^{2n}\times 2^{n}
\]

(6)

Where N_{p}^{n} n , is the total number of the valid pixel in the layer n. In another condition,

\[
N_{p}^{n}(i,j) \leq 2^{2n}\times 2^{n}
\]

(7)

The repair procedure of the pixel (i,j) will not carry out under the layer n. But the opposite pixel of the pixel (i,j) will be checked whether handle the repair procedure after the next layer by the IDWT [19]. We use the different size of the damage block to explain which damage block should be repaired in which layer. If we decided the initial repair in which layer, after we must to decide how to repair the image. So we according to the characteristic of the tree structure of the wavelet domain to decide the repairing coefficients [1], shown as the fig. 7. The tree structure includes the different repairing method of the four components (Mean, Vertical Branch, Horizontal Branch and Diagonal Branch). According
to separate the idea of the repair, we consider the pixel value of the different direction to handle the repair procedure. The repair of the MEAN composition influence the shapes of the object therefore we consider the whole of the bigger area, shown as the Fig. 8(a). Besides, the repair method of the directional branch will consider its corresponding directional reference coefficient, shown as the Fig. 8(b)-(d). The best similar pixel search which using calculates the energy of the differential pixel by the following equation:

$$DE = \sum_{i1} \sum_{i2} \left[ (d(i1, i2) - s(i1 + t, i2 + j))^2 \right]$$  \hspace{1cm} (8)

4. EXPERIMENTAL RESULTS
In experimenting result, we try the different experiment to prove the superiority of proposed method. Two major experimental processes are conducted: it shows a comparison of inpainted images. We use the several different characteristic of the images, prove that our repair method be used provides better results than other existing technique. In order to test the quality of our proposed image inpainting method, we used various images, including photos, scenery, and artistic compositions. Also we have used different wavelet transforms.

![Fig. 7 The “tree structure” correlation of wavelet Transformation](image)

![Fig. 8 the directional valid pixel (VP)](image)

(a) Mean (b) Vertical (c) Horizontal (d) Diagonal

![Fig. 9 Experimental results for the Nice test image](image)

(a-1), (a-2) (DB 1) PSNR=25.22dB, (a-3) (BIOR 1.3) PSNR=24.60dB, (a-4) (SYM 3) PSNR=25.33dB

![Fig. 10 Experimental results for the Bungee test image](image)

(b-1), (b-2) (DB 1) PSNR=29.54dB, (b-3) (BIOR1.3) PSNR=23.56dB, (b-4) (SYM 3) PSNR=23.80dB

5. OUR PROPOSED RESULTS

<table>
<thead>
<tr>
<th>Input Image</th>
<th>Wavelet Used</th>
<th>PSNR(dB)</th>
<th>Elapsed Time(sec)</th>
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</thead>
<tbody>
<tr>
<td>Nice Image</td>
<td>Daubechies (DB1)</td>
<td>25.22</td>
<td>45.69</td>
</tr>
<tr>
<td>Nice Image</td>
<td>Biorthogonal (BIOR1.3)</td>
<td>24.60</td>
<td>41.71</td>
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<tr>
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<td>Symlet (SYM 3)</td>
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<tr>
<td>Nice Image</td>
<td>Coiflet (COIF 1)</td>
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6. CONCLUSION
In this paper, we propose a new image inpainting technique that emphasizes image textures and color components. By taking advantage of the characteristics unique to the image veins and color, the image repair procedure can be determined individually. Since the Y component is the primary factor of a color image, this paper focuses on the reconstruction procedure of the Y component. By utilizing the multi-layer wavelet transformation analysis, a sequential image restoration process can be generated and performed on various layers of the image, while the color components of the image (Cb and Cr) serve as a supplementary reference to support the linear interpolation method applied during damaged data prediction. Our proposed method could successfully resolve high image vein defections which simple color image restoration methods would be unable to process. Empirically, the results generated by our proposed method clearly illustrate superior image inpainting that other present image inpainting methods and techniques are unable to achieve. In the future, we will strive to modify the repair method in the color components of Cb and Cr of an image using wavelet transformation as our working foundation in order to achieve even more superior image inpainting results.

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