Image Inpainting Using Cloning Algorithms

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Abstract

In image recovery image inpainting has become essential content and crucial topic in research of a new era. The objective is to restore the image with the surrounding information or modifying an image in a way that looks natural for the viewer. The process involves transporting and diffusing image information. In this paper to inpaint an image cloning concept has been used. Multiscale transformation method is used for cloning process of an image inpainting. Results are compared with conventional methods namely Taylor expansion method, poisson editing, Shepard's method. Experimental analysis verifies better results and shows that Shepard's method using multiscale transformation not only restores small scale damages but also large damaged area and useful in duplication of image information in an image.

Keywords: Image inpainting; Multiscale transformation; seamless cloning; poisson editing;

1. INTRODUCTION

Since from the period of Renascence the technique of inpainting for missing area has been in practice. Image inpainting is nothing but restoring damaged region with information available in the surrounding area. It also includes modifying image with the help of inpainting algorithms. It is essential to fill the damaged region in such a way that it should not be identifiable by the viewer.

The artist starts canvassing from the external damaged region towards internal region to fill the damaged region, so that the image looks even. Based on this idea Bertalmio has proposed PDE-based algorithm for image inpainting [1] and [2], called as BSCB model. Chan and Shen presented a Total Variation model based on Rudin-Osher-Fatemi's Denoising bounded variation image model [3]. Atzori and de Natale introduced edge based algorithm for image inpainting [4]. A number of approaches have been introduced in later stages. But these can apply to repair small cracks and small scale damages of inpainted image. Another method has been proposed by using block of image to fill damaged region by Criminisi called block-based structure synthesis [5] and [6] and by Efros [7]. The main idea of this technique is to select appropriate size block of the damaged image in such a way that block should fill the damaged region. But this kind of algorithms need long time to repair damaged area.

In recent year mean-value-coordinate-theory [8] and adaptive grid techniques are used for seamless cloning which is used in image fusion and image reproduction. But these algorithms need lot of preprocessing and take much duration for seamless cloning. Image inpainting using Shepard's method using multiscale transformation method takes less time for cloning of a target region and as well as filling block within damaged region. The results are compared with conventional methods namely Taylor Series Method, Poisson editing, cloning using multiscale transformation. Experimental results show validity of image inpainting technique using Shepard's method.

2. IMAGE INPAINTING METHODS

Consider area R and area to be inpainted as Ω. Following methods are used for image inpainting.

2.1 Taylor Series Method

Taylor series expansion [9] for image inpainting is used to repair damaged image and to remove unwanted objects in an image. Taylor series expansion uses heat equation of the Partial Differential Equation (PDE). This fills the omega by using the information present on the left and the right side of the damaged area depending on the shape, color and texture. Second order Taylor series is obtained by approximating u_{xx} on Taylor series expansion given as:

$$u_{xx}(x, y, t) \approx \frac{2}{h^2}\left[u(x + h, y, t) - u(x, y) - u_x(x, y, t)\, h\right] \tag{1}$$

This method recovers damaged area and removes unwanted objects of image but the process is slow and recovered area is not seamless.

2.2 Cloning Algorithms

In recovery from the damaged image cloning algorithms are used, in which the user specifies the co-ordinates for the area known as source domain. Damaged area is target domain. To interpolate the source domain with target domain seamlessly cloning algorithms are used. Steps of algorithms:

1. Identify the co-ordinate of target domain.
2. Specify the approximate co-ordinates of source domain which is to be used for recovery.
3. Mask source domain and select the region of interest.
4. Apply cloning algorithms namely poisson editing, Multiscale transformation method, Shepard's method to get the seamless inpainted image.

2.2.1 Poisson Editing

Poisson editing method [10] is a mathematical tool used for seamless editing and deriving cloning of selected region. Poisson editing includes Poisson equation:

$$\Delta f = \operatorname{div} \nabla g \tag{2}$$

With Dirichlet boundary condition:

$$f|_{\partial p_A} = f^* \tag{3}$$

where g is target cloning domain and f is source cloning domain. Point p_A represents point on boundary ∂ for interpolation of source and target domain. This algorithm uses laplacian pyramid [11]. This incorporates cloning to remove and add objects seamlessly.

2.2.2 Multiscale transformation method

The method consists of multiscale scheme which resembles the Laplacian pyramid[12]. Repeatedly upsampling and downsampling are performed over image and convolved with and fixed width kernels, so as to operate on all scales of images [9].

Multiscale transformation is performed on both source region and masked target region. The forward transformation consists of convolving signal with filter h1and by factor of two it is subsampled. On subsampled data the process is repeated. At each level unsampled and unfiltered data is kept and compute:

$$a_0^l = a^l \tag{4}$$

$$a^{l+1} = \downarrow (h_1 * a^l) \tag{5}$$

Where l denotes level and a_0^l denotes unfiltered data. ↓ represents subsampling operator. $a^0 = a$ initiates the transfer where a represent input signal.

The backward signal consists of upsampling signal by adding zero in between two samples and convolving with filter h2. Combine the upsampled data with stored data at each level after convolving it with another filter g as :

$$\hat{a}^l = h_2 * \left(\uparrow \hat{a}^{l+1}\right) + g * a_0^l \quad (6)$$

↑ denotes upsampling by zero. Choose h1, h2, g filter so as to accurately isolate and reconstruct lower frequency bands of original data. To keep number of operations O(n)the filter must be small and finite.

2.2.3 Shepard's method

By constructing smooth membrane it is possible to formulate seamless image cloning as boundary value problems can be effectively solved. By approximating Shepard's scattered data interpolation method using a convolution pyramid is easy to construct suitable membrane faster. If region of interest is denoted by Ω, and b(x) is the boundary value to interpolate these values inside Ω, Shepard's method defines the interpolant r at x as a weighted average of known boundary values:

$$r(x) = \frac{\sum_k w_k(x) b(x_k)}{\sum_k w_k(x)} \quad (7)$$

Where x_k are the boundary points. The weight function of satisfactory membrane interpolation is obtained by:

$$w_k(x) = w(x_k, x) = 1/d(x_k, x)^3 \quad (8)$$

Defining $\hat{r}$ as an extension of b to the entire domain, to rewrite Shepard's method in terms of convolutions is given by:

$$\hat{r}(x_i) = \begin{cases} b(x_k), & \text{for } x_i = x_k \text{ on the boundary} \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

If $\chi_{\hat{r}}$ is the characteristic function corresponding to $\hat{r}$, the ratio of convolutions is as follows:

$$r(x_i) = \frac{\sum_{j=0}^{n} w(x_i, x_j)\hat{r}(x_j)}{\sum_{k=0}^{n} w(x_i, x_j)\hat{r}(x_j)} \quad (10)$$

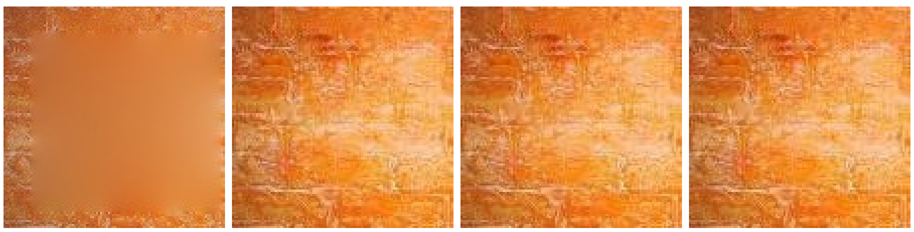
3. RESULTS AND COMPARISON

In order to verify the image inpainting algorithm based on cloning concept is used on more than ten images with different level of damages. Consider image1 of figure 1 is damaged image which shows the image of a wall but some text has been written on image. The algorithms discussed in this paper are applied on image1 to remove the text. Images of figure 2 (a), (b), (c), (d) show inpainted image after applying Taylor Series method, Poisson editing method, multiscale transformation method and Shepard's method respectively. Inpainted images are compared with original images using mean square error (MSE) and peak signal noise ratio (PSNR). By comparing results of cloning algorithms and traditional method it shows that Shepard's methods achieve high efficiency in terms of time and error factors. These methods used for recovering large scale damaged region and for duplicating objects of images unlike Taylor expansion method which is used only on small scale damages. Hence cloning algorithm used for image inpainting achieves good results and overcomes the issues of traditional method to repair damaged image.

Multiscale transformation, Shepard's method, poisson editing algorithm give results more seamless than and Taylor series. Time complexity of MVSC and Taylor series are higher.Taylor Series algorithms are used only for object removal but algorithms of convolution pyramid can replicate the objects within the image as modification in the image.User interaction is more in Taylor expansion.

Figure 3 is considered as a sample image for object duplication. Images of figure 4 (a), (b), (c) are the inpainted images using poisson editing, multiscale transformation and Shepard's method respectively for manipulation in a sample image with duplicated small bird which is seamless.

Figure1: Damaged image Considered as image1.



(a) (b) (c) (d)

Figure2: Inpainted images with removed distorted area.

	Taylor series		**Poisson Editing**		**Multiscale Transformation**		**Shepard's Method**	
	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE
Image 1	37.34	0.2678	46.62	0.2173	66.35	0.1507	66.4	0.1506
Image 2	24.18	0.4135	32.96	0.3282	37.29	0.2681	37.31	0.25
Image 3	65.68	0.1167	68.65	0.1056	93.46	0.1053	95.13	0.0954

Table1: MSE and PSNR values of inpainted images

Figure 3: Sample image

(a) (b) (c)

Figure 4: Inpainted images with duplicated object for image manipulation.

4. CONCLUSION

This paper discusses not only methods for removing occlusion as well as scratches from image but also replicate the objects. For cloning of target region which is to be filled in damaged region is cloned using Poisson editing, multiscale transformation and Shepard's method. Taylore series method uses PDE based algorithm and poisson editing algorithm uses Laplacian membrane and Dirichlet equation where as Multiscale Transformation and Shepard's method use optimized filters which are commonly used in computer graphics. Time complexity of Multiscale transformation, Shepard's method, poisson editing algorithm is less than Taylor series algorithm. The experimental result shows that the Shepard's method using multiscale transformation is more efficient than other methods and algorithm is fast, iterative, simple to implement and provides good results.

5. FURTHER WORK

Using above mentioned methods it is possible to duplicate objects in an image and recover damaged image. But it is not possible to deform the objects of an image. Future work includes embedding mesh deformation algorithm for an object, so that inpainted image will have deformed object in it.

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