A Novel Technique for Mosaicing of Medical Images

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***Abstract*—Image mosaicing has numerous applications in the area of computer vision, virtual reality, robotics, medical imaging, computer graphics and advertising. The creation of the seamless image mosaic often becomes a difficult task due to the presence of alignment errors and intensity discrepancies. The present paper discusses the development and implementation of a novel algorithm based on the discrete cosine transform (DCT) for mosaicing of medical images. The proposed method is implemented in three steps: image alignment, image reprojection, and image blending. In the first step, the geometric correspondence between the images to be mosaiced is calculated. The aim of the second step is to project the aligned images in a common compositing surface. Finally, the third step minimizes the intensity variations in the overlapping region of the final mosaic. As a result, a high quality seamless image mosaic is generated. The obtained results and its comparative analyses clearly illustrate the efficacy of the approach in obtaining visually pleasant mosaiced images.**

Keywords—Mosaicing, DCT, alignment, blending, compositing

I. Introduction

Image mosaicing is one of the most interesting area of research in the fields of image processing, computer vision, texture mapping, panoramic imaging, satellite imaging, object tracking [1], medical application [2], [3], robotics [3] etc. Aligning a series of images to create a composite image or panorama, with more information and larger field of view (FOV) than the input images, is the main purpose of image mosaicing. The construction of a mosaic requires mainly three steps: alignment of image sequences, projection of aligned images onto a common compositing surface and finally blending the images to get a smooth transition from one image to another within the mosaic. However, factors such as; illumination difference caused by the source, moving objects, presence of noise, multimodal imagery, camera rotation and zoom pose a problem in creation of visually pleasing image mosaic, making it a challenging research topic.

There are a number of ways for creation of image mosaic in the literature. A survey on different approaches is available in [4]. Different types of mosaic representation have been described by Irani et. al. [5]. Image mosaicing methods are broadly classified as two groups in the literature: direct methods [6]–[9] and feature based methods [10]–[13]. Direct methods establish correspondence between two images by minimizing an error function, which is the intensity difference of images in the overlapping region. Direct methods use all of the available data in an image and hence, can produce more accurate results. But, these methods are not robust against variations in illumination. Feature based methods establish correspondence between the images based on features such as point, line, edge, corner, etc. The advantage of these methods over their direct counterparts is that these are robust to camera rotation as well as zoom and are able to overcome the illumination variations. Both these methods are spatial domain methods and perform well in most of the cases. However, these are computationally expensive and in some cases, both the methods fail to deal with the problems encountered in real-world scenes. Therefore, an algorithm needs to be developed which can be applied successfully in real-world applications for the generation of image mosaics while being computationally efficient.

The proposed method tries to resolve the above stated problems by taking advantage of both direct and feature based mosaicing methods along with the discrete cosine transform (DCT). DCT-domain approach is used to preserve the image information content while significantly reducing the computational complexity and providing better accuracy. Using these properties, an algorithm is developed for mosaicing of medical images. The algorithm is successfully applied over different sets of medical images. The resultant mosaiced images have been analyzed for its quality measurement.

The organization of the rest of the paper is as follows: Section II presents the background information related to mosaicing along with basics of DCT. The proposed algorithm and subsequent steps are described in section III. Results obtained on implementation of the algorithm for different sets of input images are discussed in Section IV. Section V contains conclusions based on the experiments and analyses.

II. Methodology

A. *Image mosaicing*

The use of computers and vision techniques have made the process of image mosaicing easier and simplified as compared to the cumbersome conventional panoramic cameras used for capturing panoramic images [14]. However, the generation of high resolution image mosaics is still a challenge since even a small variation in color and alignment can lead to the creation of seam between stitched images thus degrading the quality of it.

The steps involved in forming a mosaic are shown in Fig. 1 [15]. Three key steps involved in the creation of an image mosaic from a series of images are registration, reprojection and blending. These steps are detailed as follows:

1) Image registration

The objective of registration is to establish a mathematical relationship that maps pixel coordinates from one image to another. This aligns all of the images into a common global coordinate frame rather than local coordinates of each image. Some transformations (i.e. translation, rotation, scaling and shearing) are applied over the set of images so that the matching between the images is possible and the matched images can then be aligned. Image registration can be geometric or photometric.

2) Image reprojection

A single mosaiced image is created by overlaying the aligned images together in a common compositing surface which is called reprojection manifold. The selection of this manifold entirely depends on the camera motion. Points in the global coordinate frame are projected back on the selected manifold. It is of three types; planar, cylindrical and spherical.

3) Image blending

The final step of mosaicing is image blending. Since the images are captured from different sensors, different viewing angles or different illumination sources, there might be the creation of edges in the overlapping region of the images. These artifacts make the mosaiced image visually unpleasant. Therefore, it is essential to choose the best possible color for each pixel over the area to make the mosaic seamless. Appropriate blending approach is used for overcoming the above mentioned problem. In this way, the sequence of images is mosaiced rendering a complete view of the scene.

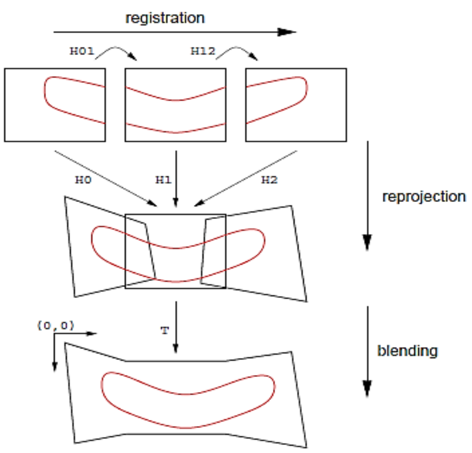


Fig. 1 Steps in forming image mosaic

B. Discrete cosine transform

The discrete cosine transform is a variant of the Fourier Transform suitable for many image processing applications. A discrete cosine transform represents the signal as a sum of cosine function of different frequencies. 1-D DCT is expressed [16] as

$$C(u) = \alpha(u) \sum_{x=0}^{N-1} f(x) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (1)$$

where $u = 0, 1, 2, \ldots, N-1$

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{N}}, u = 0 \\ \sqrt{\frac{2}{N}}, u \neq 0 \end{cases}$$

For $u = 0$, first coefficient or first basis function is a constant (DC value) whereas for the other values of u, the waveforms are progressive frequencies as shown in Fig. 2 [17]. Similarly, in case of 2-D basis function, first coefficient is constant and progressively increases in both horizontal and vertical direction. Image processing applications use 2-D DCT as a direct extension of the equation (1) which is defined as

$$C(u,v) = \alpha(u)\alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)u}{2N}\right] \quad (2)$$

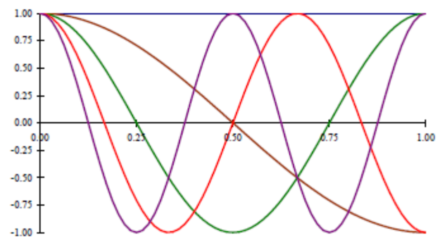


Fig. 2 DCT basis functions. (First basis is blue line with constant value, second is brown waveform and so on).

III. PROPOSED ALGORITHM FOR MOSAICING

Phase correlation method [18] is based on the shifting property of the Fourier Transform. It states that shift in the coordinate frame of two functions is transformed in the Fourier domain as linear phase differences.

The proposed algorithm depends on DCT based phase correlation method which in turn depends on the shift property of DCT [19]. It describes that the information related to displacement in coordinate values of two functions (images) resides in the phase of the cross power spectrum as linear phase differences, but it has only a few coefficients where all energy has been compacted. Hence it involves less mathematical complexity and makes the hardware realization easier. The complex shift invariant DCT used for computing the DCT coefficients is defined as

$$C(u,v) = \alpha(u)\alpha(v) \sum_{m,n=0}^{N-1} f(x,y) e^{-j\frac{\pi u}{N}(m+0.5)} e^{-j\frac{\pi v}{N}(n+0.5)} \quad (3)$$

$$for\ u,v = 0,1,2,\ldots,N-1$$

The working principle is described as follows; let $C_1(u,v)$ and $C_2(u,v)$ denote discrete cosine transforms of 2-D signals $f(x,y)$ and $f(x-x_0, y-y_0)$ respectively, with the size of $N \times N$ each. $C_2(u,v)$ can also be expressed as,

$$C_2(u,v) = C_1(u,v) e^{-j\frac{\pi u}{N}(m_0)} e^{-j\frac{\pi v}{N}(n_0)} \quad (4)$$

The normalized cross power spectrum is given as,

$$C_2(u,v)C_1^*(u,v) \Big/ \left|C_2(u,v)C_1^*(u,v)\right| = e^{-j\frac{\pi u}{N}m_0} e^{-j\frac{\pi v}{N}n_0} \quad (5)$$

or

$$D_2 D_1^* \Big/ \left|D_2 D_1^*\right| = P \quad (6)$$

Where D_1 and D_2 are the DCTs of the first and second image respectively. The inverse of normalized phase correlation function provides the displacement vector information (x_0, y_0) which can be determined by locating the impulse peak in spatial domain. Inverse DCT of the ratio, i.e. $'P'$ is taken to get an array having zeros everywhere except at the location of displacement. Calling 'max' function finds the maximum value in the array. The steps of the algorithm are described as follows:

Input: Images with some overlapping part

Step1: Read the input images.

Step2: Convert RGB to grayscale images.

Step3: Compute DCT of each image and take the conjugate of the second image.

Step4: Compute the normalized cross power spectrum.

Step5: Take IDCT to find the array.

Step6: Call 'max' function to get maximum value of the array i.e. the displacement vector.

Step7: Transformations.

Step8: Reconstruction (Reprojecting on a compositing surface)

Step9: Blending

Output: Mosaiced image

An efficient representation of the displacement field can be obtained using few coefficients of the DCT basis by implementing this algorithm,. Fast implementation of DCT is readily available and therefore, it can be used to further reduce the computational time.

The use of this algorithm would be feasible, since most of the present coding standards utilize DCT representation for coding. Thus, the generated mosaic can either be decoded for display or stored for later use.

IV. Results and Discussion

Four sets of medical images have been taken, each having different complexity, type and displacement, for testing the consistency of the proposed algorithm. First of all, the algorithm is applied over X-ray images and is found to be effective in generating high quality image mosaic. Fig. 3 (a) and (c) are the input images and Fig. 3 (b) and (d) show the respective DCTs of the images. Fig. 3 (e) shows the phase correlation in which the highest peak shows the maximum value of normalized phase correlation. The final mosaic generated using the algorithm is shown in Fig. 3 (f).

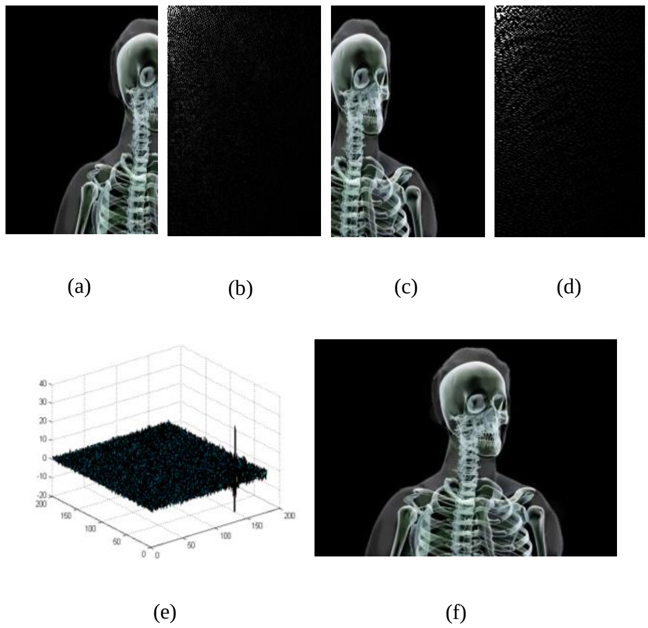
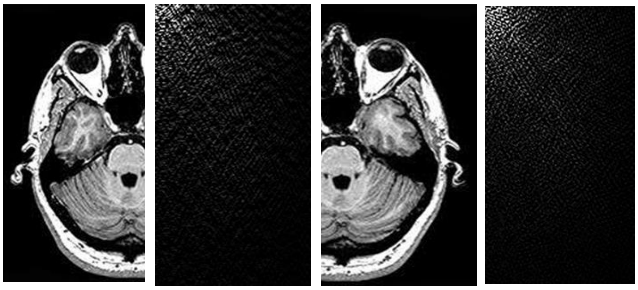


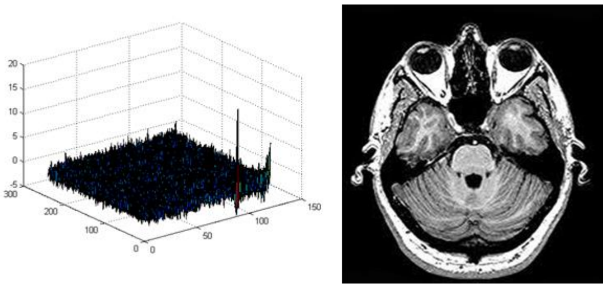
Fig. 3 X-ray images (a) Input image I_1 (b) DCT of I_1 (c) Input image I_2 (d) DCT of I_2 (e) Phase correlation (f) Mosaiced image

The second set for testing is CT images of the brain. The input images with some overlapping parts have been aligned and mosaiced to generate a composite image. The input images are captured with some overlapping part so that the mosaics can be generated without creation of artificial edges in the area of overlap. Fig. 4 (a) - (f) show the implementation of the algorithm.

The algorithm has also been applied over a third set of MRI images of the knee and is found to be effective for this set as well. The results of implementation of the algorithm on MRI images are shown in Fig. 5 (a) - (f).

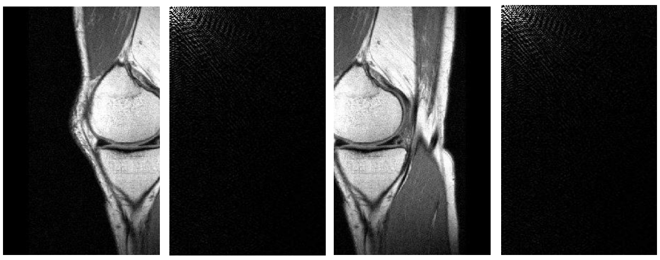


(a) (b) (c) (d)

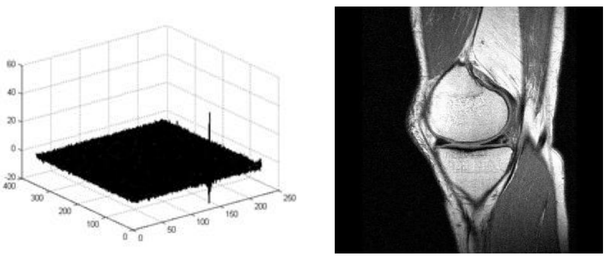


(e) (f)

Fig. 4 CT images of brain (a) Input image I_1 (b) DCT of I_1 (c) Input image I_2 (d) DCT of I_2 (e) Phase correlation (f) Mosaiced image



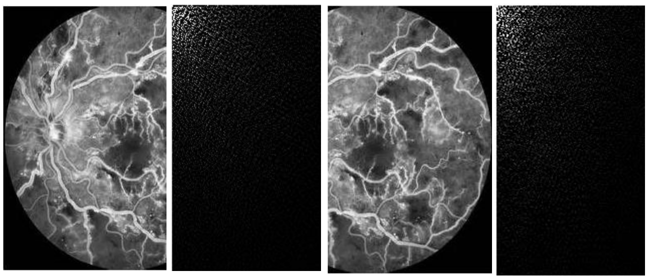
(a) (b) (c) (d)



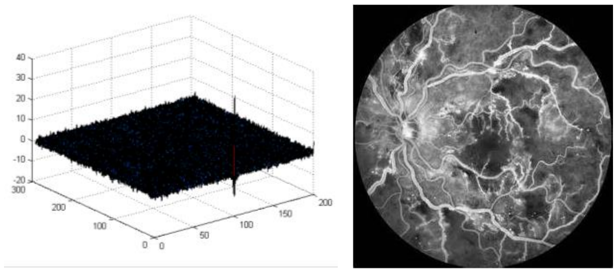
(e) (f)

Fig. 5 MRI images of knee (a) Input image I_1 (b) DCT of I_1 (c) Input image I_2 (d) DCT of I_2 (e) Phase correlation (f) Mosaiced image

The final set of image is angiogram obtained after Fluorescein angiography of retina. Fig. 6 shows the result of mosaicing for this set of images and is found to be effective.



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



(e) (f)

Fig. 6 Fluorescein angiography images of retina (a) Input image I_1 (b) DCT of I_1 (c) Input image I_2 (d) DCT of I_2 (e) Phase correlation (f) Mosaiced image

Quantitative evaluation

After the visual examination, the quantitative evaluation of the algorithm is necessary to prove the effectiveness of the algorithm. Some nonreferrential parameters have been considered to evaluate quality of the generated mosaic and has been compared with the original image. Table I presents the values of different nonreferrential parameters calculated for the different original images. The values of blur metric, standard deviation, entropy and edge based contrast measure (EBCM) are determined for original image sets and compared with the values calculated for mosaiced images as presented in Table II.

TABLE I. PARAMETERS OF ORIGINAL IMAGE

Image Type	**Quality assessment parameters**			
	Blur Metric	***Standard deviation***	***Entropy***	***EBCM***
X-ray	0.2785	53.5346	3.4669	22.1102
Brain CT	0.2546	86.0339	5.5389	62.5755
Knee MRI	0.2997	83.1930	6.5042	58.9011
FA of retina	0.2219	60.2429	6.8982	61.8004

TABLE II. PARAMETERS OF MOSAICED IMAGE

Image Type	Quality assessment parameters			
	Blur Metric	***Standard deviation***	***Entropy***	***EBCM***
X-ray	0.2781	53.5995	3.6835	22.0961
Brain CT	0.2498	86.1069	5.5969	62.6677
Knee MRI	0.2966	83.2011	6.5460	59.0422
FA of retina	0.2218	60.2320	6.9207	61.4682

It can be observed from the comparison that the values of the quality assessment parameters slightly vary for mosaiced image sets. The small variation indicates that the quality of the image is not degraded even after mosaicing. The information content of the image is preserved resulting in good quality image mosaic.

Thus, these results clearly show that the performance of the algorithm is satisfactory both visually as well as qualitatively for mosaicing of different types of medical images.

CONCLUSION

This paper describes an image mosaicing algorithm which is applicable for different set of images used for medical applications. The novel feature of this algorithm is the use of both direct and feature based techniques along with the discrete cosine transform in image mosaicing. Use of direct and feature based technique makes it robust while the DCT domain access makes it even more accurate and reduces the computational complexity. The approach is robust to changes in illumination and geometric transformations. It is also consistent with different type of medical images used for mosaicing. Quality analyses and comparison show that the algorithm ensures the generation of high quality seamless image mosaic of medical images.

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