Automatic Seamless Image Mosaicing: An Approach Based on Quad-tree Technique

D.R. Ramesh Babu , M. Ravishankar, Member, *IAENG*

Abstract :In real-life situations, the field of view of the imaging devices is usually smaller than the scene to be imaged, due to the inherent limitations. Even if the whole scene is captured in a single exposure, it could result in an image having poor resolution. In such circumstances, it will never be possible to capture the scene as a single image for further processing or human inspection. The only solution to such a problem is to capture the scene by splitting the scene into adjacently placed multiple frames. This process warrants a post imaging operation that requires cohering of these small images to create a single image. In this paper, a new approach is used to create a single large image by adopting a quad-tree approach, where the image is decomposed into sub images to find the corresponding points in the sub images and thereby reducing the search space. The proposed algorithm reduces the search space to a greater extent for finding correspondence between the split images where the complexity reduces to the order of $2(\log_4(3n)-1)$

Keywords: Quad-tree, Image Mosaic, Image Registration, Correspondence Points (CP)

I. INTRODUCTION

The process of cohering of small / split images has been referred as Image Mosaicing. But carrying out the process of cohering interactively on a computer or completely automating the task of cohering is an active research area in the development of Image Processing, Pattern Recognition and Computer Vision applications. The efficient working of imaging devices with real-life applications warrants either overcoming of the limitation of resolution or the limitation of field of view. These limitations are overcome through image mosaicing. Research activity in the field of image mosaic started in early 1970's and the interest continues even today to investigate the suitability of image mosaicing in different applications.

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D. R Ramesh Babu is Professor & Head, CSE, Dayananda Sagar College of Engineering, Bangalore;India
e-mail: bobrammysore@ gmail.com).
M Ravishankar is Professor & Head, ISE, Dayananda Sagar College of Engineering, Bangalore; India
e-mail: ravishankarmcn@ gmail.com)

The concept of image mosaicing is essential because it may not be possible to capture a large image with a given source of imaging device in a single exposure. It has to be captured as two or more split images due to the inherent limitations of the capturing media. In such case multiple camera exposures to cover one large image, the split images should necessarily contain overlap region between the images, so that the stitching of two or more such split images into a single image becomes easier. In order to obtain a single complete image from the split images of a large scene, the overlap region between the split images are identified. The mosaiced image is obtained by fusing these two split image along the overlap region, such that the final image becomes continuous without repetition of the overlap region.

The most important task before mosaicing is to find out the overlap region / correspondence points between the split images. The overlap region is found by matching similar features present in the given split images. The simplest method uses pixel by pixel matching approach to find the overlap region. But, such a method is very sensitive to variations in properties of pixels, and found to be more time consuming. The alternative method to find the overlap region is the edge-based approach, which is invariant to changes in properties of pixels. Once the overlap region is found, the need arises to establish correspondence between the given split images. The different types of correspondences are point correspondence, edge correspondence, region correspondence and shape correspondence. Once the correspondence between the two split components (the terms split components and split images are used synonymously) is established, merging of two split components is carried out to create a single large image. There has been extensive research on image mosaicing and its application.

Zhi Qi and Jeremy R. Cooperstock [2] have proposed a method on Overcoming Parallax and Sampling Density Issues in Image Mosaicing of Non-Planar Scenes. The approach overcomes the conventional constraints of parallax-free camera motion. The approach introduce combines previous knowledge of image-based rendering and manifold mosaicing to overcome some of the limitations and produce reasonable mosaics from sparse input sources, situated along a wide baseline.

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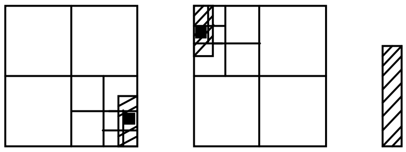
An image mosaicing module for wide-area surveillance is proposed by Marko Heikkila and Matti pietikainen [5]. A feature-based approach was adopted for finding the registration between the images. The approach provides with several advantages like illumination variations, moving objects, image rotation, image scaling, imaging noise.
Doron Feldman [8] proposed an algorithm for mosaicing minimum distorted images, by linear sampling function with maximal slope. The approach uses scene depth and camera parameters for mosaicing of distorted images.
Zhigang Zhu [7] proposed an algorithm which fuses images from video camera and provides wide field of view, preserves 3D information and represents occlusions. This representation can be used as a video interface for surveillance or preprocessing of 3D reconstruction.
Zoghlami and Deriche [10] proposed corner based method to compute the homography between the two images with small overlap and arbitrary rotation around the optical axis .

Schutte et al [12] have described the usage of flat bed scanners to capture large utility maps. The method selects the control points in different utility maps to find the displacement required for shifting from one map to the next. These control points are found from the pair of edges common to both the maps.
Irani et.al [11] proposed an algorithm to mosaic video sequence images. The algorithm is effective only in very limited cases where the image motion is almost a uniform translation or the camera performs a pure pan.

In order to circumvent the above mentioned drawback and to mosaic different intensity images, a robust method is devised in this paper. The method uses quad-tree approach, where the image is decomposed into sub images to find the corresponding points in the sub images and thereby reducing the search space. It is motivated by the fact that it reduces the search space as well as the storage requirement by decomposing an image into number of sub-images. To achieve proper mosaicing of split components, it is assumed that the two adjacent split images shall have sufficient overlap region**.**

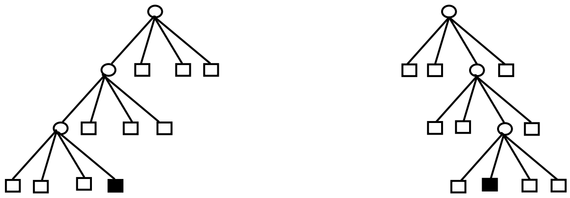
II. PROPOSED METHODOLOGY

The proposed algorithmic model for mosaicing split images has two phases. The first phase determines the correspondence points using quad-tree technique and the second phase is to merge the adjacent split images. Consider the given two images I_1 and $I_{2,}$ which are the split images to be mosaiced. These are divided into four quadrants as shown in Figure 1 (a) and (b). Texture features like first order moments, second order moments are extracted from the first quadrant of the first image and matched with all (other four quadrants) quadrants of the second image. The best matched quadrants are chosen for further division. In Figure 2, the fourth quadrant of I_1 and second quadrant of I_2 are chosen for further subdivision, because of the overlap region present in these quadrants. The process of subdivision of the images is repeated, until the region of interest is obtained. This will reduce the search space for finding the correspondence between the images.



(a) Image 1 (b) Image 2 (c) Overlap region

Figure 1. Two Split Images with overlap region



"(a)" **"(b)"**
"(a)" Quad-tree representation of Image 1
" (b)" Quad-tree representation of image 2

Figure 2. Quad-tree representations

Algorithm 1: Image Mosaicing Based on Quad-tree Approach

Input : 1. Image 1 and its size(I_1_size)
2. Image 2 and its size(I_2_size)
3. Threshold_windowsize
4. Threshold_windowmatch
Output : Best matching / overlap region of Image 1 & 2.

Step 1: Intializations:
1.1 window1 ←Image 1
1.2 window2 ← Image 2
1.3 window_size ← I_1_size
1.4 window_match ←Threshold_windowmatch - δ /* where δ varies from 1 to 10 */

Step 2: While((window_match < Threshold_match) and (window_size > threshold_windowsize))
2.1 Divide Image 1 into 4 equal parts and extract texture features of each sub-window and its position information.
2.2 Divide Image 2 into 4 parts, extract texture features of each sub-window and its position information.
2.3 Find highest matching sub-window in Image 1 and Image 2.

Let i^{th} sub-window of window1 (of Image 1) show highest match with j^{th} sub-window of window2 (of Image 2). Let window1i be the sub-window of Image 1 and window2j be the sub-window of Image 2

Window1 = window1i; Window 2 = window2j

Step 3: Return (window1_position as matching portion of image 1 and window2_position as matching portion of image2)

II. A. TIME COMPLEXITY OF QUAD-TREE BASED METHOD

The time complexity of Algorithm 1 is of the order 2($\log_4$(3 n)-1) plus the time taken for comparison at each level

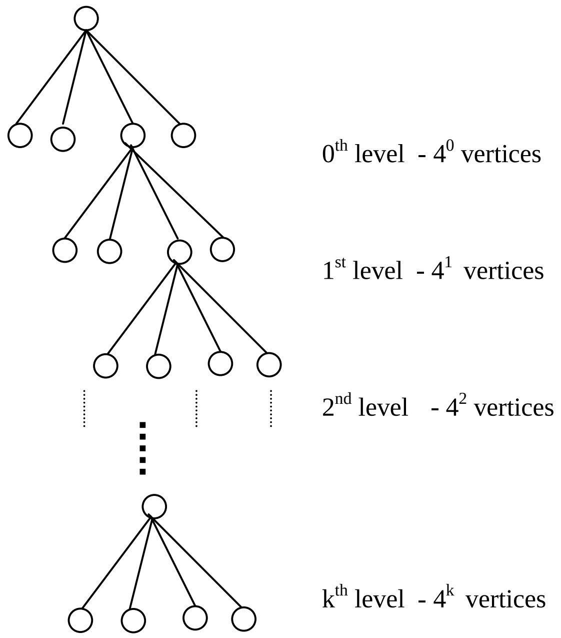


Figure 3. Graphical representation of Quad-tree

Quad-tree is an acyclic graph. The fact is that the sum of degrees of the vertices is equal to twice the number of edges in the given graph, which is expressed as under.

$$\sum_{i=1}^{n} d(V_i) = 2e$$ (i.e. Total degree = twice the number of edges)

Therefore, degree of the root node + P * degree + [(*n*-P-1)*5] = 2e, where 'P' is number of pendent vertices and '*n*' is number of vertices present in the quad-tree.

$$4 + P*1 + (n - p - 1)*5 = 2e \quad (1)$$

$$4 + P + 5n - 5p - 5 = 2e \quad (2)$$

It is also the fact that the number of edges is equal to one less than the number of vertices in a tree, (e=*n*-1), where '*n*' is the number of vertices present in the quad-tree.

$$4p = 3n + 1 \quad (3)$$

$$p = \frac{3n+1}{4} \quad (4)$$

The number of nodes (also called vertices) at k^{th} level is same as the number of pendant vertices.

$$\text{i.e. } 4^k = p \quad (5)$$

$$4^k = \frac{3n+1}{4} \quad (6)$$

$$4^{k+1} = 3n + 1 \quad (7)$$

Taking log with base 4 on both sides, the equation (7) is written as

$$\log_4(4^{k+1}) = \log_4(3n+1) \quad (8)$$

$$k + 1 = \log_4(3n+1)$$

$$k = \log_4(3n+1) - 1$$

For sufficiently large value of n, the above expression is expressed as

$$k = O(\log_4(3n) - 1) \quad (9)$$

The time complexity of Algorithm1 for finding correspondences between the images is of the order 2($\log_4$ (3*n*)-1) plus time for comparison at each level in the worst case and the best case time complexity is of the order $\Omega(1)$.

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II. B. IMAGE COMPOSITION

In section2.1, the algorithm to find the corresponding points based on quad-tree is presented and these corresponding points give the transformation parameters. Based on these parameters the split images are composite by taking an average of the pixels values in the overlap region if the images to be mosaic are of same intensity and translated such that the overlap region coincide with each other. Different intensity images are mosaiced by considering the brightness difference between the corresponding points. The relative brightness difference between the corresponding points is added in Image 2 which nullifies the effect of seam in mosaiced image.

III. EVALUATION OF PROPOSED ALGORITHM

The indicators defined to evaluate the performance of the proposed algorithm are mean and standard deviation. The values of the indicators are obtained by testing the algorithm on different images. The sample images are captured as two split images with overlap region. At the same time, a single image with the same imaging device is also captured and

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these images are used as reference images to test the efficacy of the proposed algorithmic model. The indicators evaluated during testing of algorithm for different data sets are given in Table 1 and 2.

TABLE 1. PERFORMANCE PARAMETER

Image	Original Image		Mosaiced Image	
	Standard Deviation	Mean	Standard Deviation	Mean
Calcutta City	45.96	51.14	44.43	50.89
New York	55.57	97.32	55.42	95.30
Aerial Image	34.88	141.75	35.3	137.59

TABLE 2. ERROR COST PARAMETER

Image	Standard Deviation Error (%)	Mean error (%)
Calcutta City	3.32	0.488
New York	0.269	2.07
Aerial Image	1.204	2.93

IV. EXPERIMENTAL RESULTS

Several experiments are conducted on various sets of images like natural, satellite, aerial and medical images and the results obtained are found to be satisfactory. The efficiency of various developed algorithms are expressed by counting the number of pixels between the original image and the mosaiced image.

V. CONCLUSION

In this paper, a novel, simple and self-acting approach for mosaicing of multiple split images based on quad-tree is presented. In this approach, the images are decomposed into sub images to find the corresponding points in the sub images and thereby reducing the search space. The proposed algorithm reduces the search space to a greater extent for finding correspondence between the split images. The complexity reduces to the order $2(\log_4(3n)-1)$. The proposed method assumes that the images to be mosaiced are orthonormal and distortion free. Though images with contrast can be mosaiced, a seam is obtained in the mosaiced image, which needs to be rectified. This paper provides good results for brightness changes in the split images and needs to be worked for contrast variations.

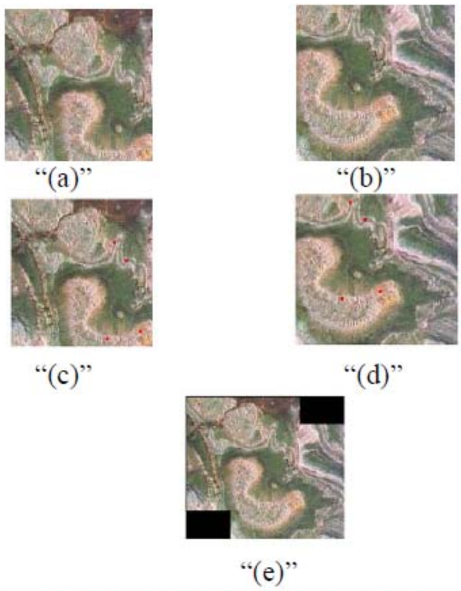

Figure 4. SIR-C/X-SAR Radar Image of Eastern Morocco taken from the Space Shuttle Endeavour (a)-(b) split images;(c)-(d) shows corresponding CPs images; (e) Mosaiced image.

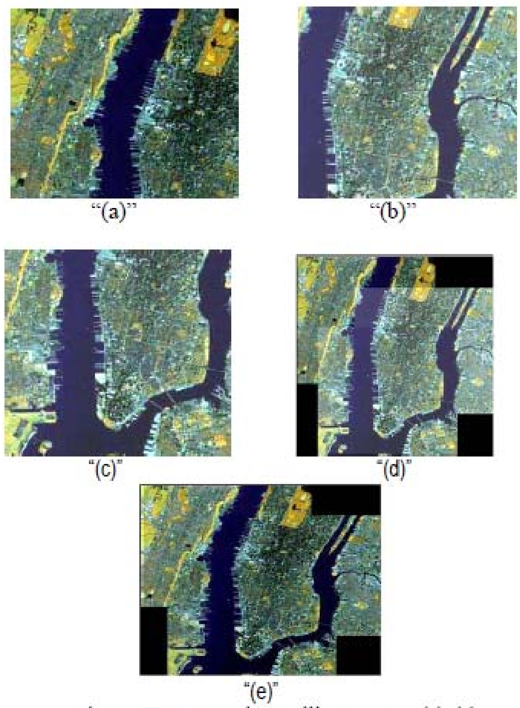

Figure 5. New York Satellite Images (a)-(c) different intensity split images; (d) mosaic of (a)-(c) without brightness correction; (e) mosaic of (a)-(c) with brightness correction.

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