Panorama Generation using Feature based Mosaicing and Modified Graph-cut Blending

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Abstract. Panoramic mosaicing has several important area of applications including computer vision/graphics, virtual reality, and surveillance. Different factors like sensor noise, camera motion, and illumination difference affect the quality of the mosaic due to creation of artificial edges (artifacts) between the images in the resulting panorama. This work presents a technique to overcome such problems for the generation of seamless panoramic images. The proposed technique uses Scale Invariant Feature Transform (SIFT) features for image alignment and modified graph-cut (MGC) for blending the seam in the overlapping region between images. The proposed method is tested on various sets of images to show its effectiveness. Comparison with different mosaicing as well as blending techniques show that the proposed method achieves improved results for panorama creation.

Keywords: Panoramic mosaicing, alignment, SIFT, geometric transformations, RANSAC, seam, seamless blending.

1 Introduction

A panorama contains much more information than an image captured using normal camera as it is the complete surrounding view around a person. In panoramic mosaicing multiple images are stitched with each other in such a way that a wide angle view of the scene is generated. Panoramic mosaicing has diverse applications in computer graphics and vision [1], object detection [1], virtual tour in real estate, [2], aerial photography [3], and surveillance using videos [4].

Panoramic mosaicing [5] in general has three steps of final mosaic generation i.e. acquisition of individual images, pre-processing of images, and mosaicing. Mosaicing [3, 4, 5] in turn contains registration of images, warping, and blending.

The aim of this work is to generate seamless panoramic mosaic. A feature based method is used for alignment of images. SIFT features are extracted as these features are robust to scaling, rotation and to some extent robust to the change in illumination. A modified graph-cut blending is applied to smooth the seam in the overlapping region of input images. The use of these methods makes the algorithm efficient for generation of better quality seamless panorama.

The paper organization is as follows: Section 2 gives a brief literature survey on existing mosaicing methods. The fundamental steps of panoramic mosaic generation are reported in Section 3. In Section 4, the algorithm for the proposed technique has been described. The experimental results using proposed algorithm along with comparative analysis over different sets of images has been demonstrated in Section 5. Finally, the paper is concluded in Section 6.

2 Related Work

Over the last few decades, the research in the area of image mosaicing has gained wide popularity. A number of technique has been introduced to address the problems of image mosaicing. The different approaches for mosaicing are characterized based on the domain of the algorithm used. In correlation based methods mosaicing is performed by directly using the image pixels [6]. Fast Fourier transform (FFT) or discrete cosine transform (DCT) is used in frequency domain for mosaicing [7]. Low level features [7] use edges and corners as distinct features whereas high level features use parts of objects for mosaicing [8].

Mainly, all these methods are distinguished in two categories. First, methods that do not use the feature extraction and attempt to use the pixel information directly for minimizing the error function between the two images are called direct methods [9]. Accurate results can be obtained using direct methods as they use all the information present in an image. However, these methods fail in case of variation in illumination or moving objects in the scene. The second category deals with extraction of distinct features for finding the correspondence between the images [10]. These methods are robust to scaling, rotation, and illumination variation. In addition, these methods can also handle the moving objects in the scene. In case of misalignment and intensity discrepancies an appropriate blending algorithm is used. Blending using feathering or alpha blending [11] results in loss of edge information due to smoothing of region. Gradient domain blending work well for smoothing the seam but, it leads to color bleeding [12] which changes the color of the objects after blending. Because of which these methods are rarely used for blending of panoramic images.

Thus, the aforementioned literature survey reveals that a robust mosaicing scheme is required which can align the images accurately and blend the result using an appropriate blending algorithm.

Therefore, to address these issues the work describes: a) A feature based technique for accurate alignment of the images. b) A blending method that is able to handle intensity and color differences for seamless mosaicing.

3 Panoramic Mosaicing

The process of panorama generation has following three steps: 1) Panoramic image acquisition, 2) Pre-processing of acquired images, and 3) Mosaicing of images using appropriate algorithm.

A single camera mounted over a tripod can be used to capture images with different rotation angles. An alternative to this is using multiple cameras mounted over tripod to cover the view of different directional angles of the scene. In some cases, omni-directional image sensors with fisheye lenses or mirrors are used, but their short focal length, high cost and lens distortion limits their access. The captured images are pre-processed for noise filtration or other sorts of intensity variations before mosaicing. The most common pre-processing step is reduction of noise, lens distortion correction, and camera calibration. These pre-processed images are mosaiced by following the necessary steps of mosaicing. An overview of the framework for panorama generation is shown in Fig. 1.

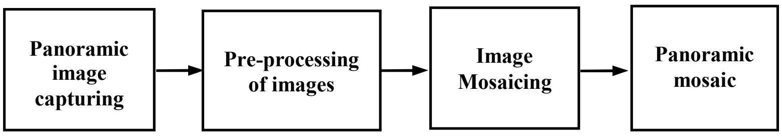

Fig. 1. An overview of the panoramic image generation process.

4 Proposed Technique for Panoramic Mosaicing

The images captured for panorama generation are pre-processed before mosaicing. Once the images are pre-processed the next step is to extract the important features from the images. The following subsections discuss the steps involved in proposed panoramic mosaicing technique.

4.1 Feature extraction and matching

Scale Invariant Feature Transform (SIFT) features [10] is used for feature extraction because of the stability, accuracy, invariance to scaling – rotation of SIFT features. Therefore, they provide robust matching. In SIFT image data is transformed to scale invariant coordinates in the following four stages of algorithm:

1) *Scale space extrema detection* - Difference of successive Gaussian-blurred images called difference of Gaussian (DoG) are taken for candidate point search.
2) *Feature points localization* - Too many candidate points are obtained after scale-space extrema detection, some of which are unstable. Poorly localized or low contrast candidate points are rejected as these are prone to noise.
3) *Orientation assignment* - Every candidate point is assigned one or more orientation based on local gradient directions it provides invariance to rotation.
4) *Feature point descriptor* - Each candidate point of the image is assigned with a location, scale, and orientation such that the image regions around the candidate points are in 2-D coordinate system and provide invariance to these parameters.

Here, a highly distinctive descriptor is computed for the local image region which is invariant to other variations e.g. illumination changes or 3-D viewpoint.

4.2 Correspondence between features

Feature matching between the images is done after detection of feature points. Similar feature points based on a predefined threshold values are selected and rest of the points are rejected. For estimation of homography in order to match the inliers RANdom SAmple Consensus (RANSAC) [13] has been used. The algorithm works accurately even in the presence of significant number of outliers.

4.3 Image Transformation and re-projection

Depending on the geometric distortion of the images different transformations like affine, rigid or projective are employed to transform the images. For panoramic mosaicing projective transform is used [5]. This type of model having less parameter provide more accurate and efficient model for panoramic mosaic generation [4]. Such transformation aligns the images on a common compositing or re-projection manifold. The selection of compositing manifold is dependent on the application of the mosaic to be generated. Out of planar, cylindrical, and spherical a planar manifold has been considered for the proposed algorithm.

4.4 Blending of images

Factors like illumination difference or change in exposure cause difference in intensity values mainly in the overlapping region between images which results in the creation of visible artifacts in the mosaic. Therefore, handling of these regions is different from the rest regions of the mosaic where specific algorithms are used for seam smoothing while avoiding loss of information over that region.

The blending algorithms can be classified as transition smoothing or optimal seam finding. *Transition smoothing* techniques [11] minimize the visible seam by smoothing the region between the images. Feathering or alpha blending approaches fall in this category. In the *optimal seam finding* [12] method a seam is searched in the region of overlap where intensity difference between the images is minimum. In the present work, a modified graph-cut algorithm (an optimal seam finding method) is used for smooth blending of image regions.

4.5 Modified Graph-cut

For the region of overlap, a graph is constructed in such a way that each pixel corresponds a graph node and the edge weights indicate the error between the two nodes. A min-cut shows the least error edges over the region of minimum intensity variations. This seam creation is based on the search of minimized energy of a particular energy function. Conventional algorithms (e.g. dynamic programming) were 'memoryless' therefore could not find the optimized seams as in case of graph-cut.

The graph in Fig. 2 is the representation of two input images and the overlapping region between them. Each node in the graph shows a pixel in the overlap region.

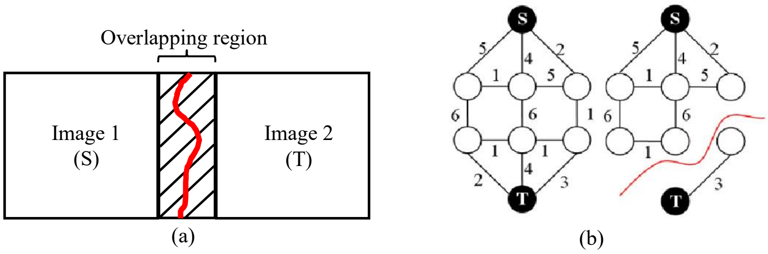

Fig. 2 Example demonstrating minimum cut in a graph. **(a)** Overlapping region between two images and min-cut. **(b)** Graph showing min-cut with a total cost of the cut as 2+4+1+1=8.

Two additional nodes 'S' and 'T' represent source and sink i.e. Image 1 and Image 2 in present case. The arcs connecting the adjacent pixel nodes 'S' and 'T' are labelled with some matching quality cost M. In Fig. 2 red line shows the minimum cut which separates the overlap pixels in two parts indicating the pixels to be copied from either of the two images. In the algorithm, the matching quality measure [14] calculates the intensity difference between the pairs of pixels for each color channel L^*, a^* and b^* of CIE $L^*a^*b^*$ color space. Let $'s'$ and $'t'$ be the position of two adjacent pixels in the overlapping region, $A(s)$ and $B(s)$ be the pixel intensities at $'s'$ for old and new patch. Similarly $A(t)$ and $B(t)$ be the pixel intensities at position $'t'$. The matching quality cost is defined as,

$$M(s,t,A,B) = \|A(s) - B(s)\| + \|A(t) - B(t)\| \tag{1}$$

where $\|\bullet\|$ denotes the appropriate norm. In the $L^*a^*b^*$ color space the formula for matching quality cost can be defined as,

$$\begin{aligned} M(s,t) = {} & \sqrt{wt_1(L_A(s)-L_B(s))^2 + wt_2(a_A(s)-a_B(s))^2 + wt_3(b_A(s)-b_B(s))^2} \\ & + \sqrt{wt_1(L_A(t)-L_B(t))^2 + wt_2(a_A(t)-a_B(t))^2 + wt_3(b_A(t)-b_B(t))^2} \end{aligned} \tag{2}$$

where, $wt_1 + wt_2 + wt_3 = 1$. All the steps of the proposed panoramic mosaicing algorithm have been summarized in Fig. 3.

5 Results and Discussions

The experiments were carried out on an Intel®Core™i7 2600 CPU at 3.40GHz on MATLAB® under Microsoft® Windows 7 over various image sets. Fig. 4 shows the sequence of processing involved. Fig. 4 (a)-(c) show the input images captured with different camera rotations. Initially, SIFT is used for features extraction and RANSAC is used for feature matching keeping the inliers while rejecting the outliers. The aligned images are then re-projected on a re-projecting surface (which is planar for this case) for mosaicing. However, the seam or artificial edges in the transition region are generated which can be clearly seen in Fig. 4 (d). The red boxes show the misalignment and the intensity differences in the transition region. Simple averaging or feathering will not solve the problem as it may lead to over smoothing of the transition region resulting in loss of important information. Graph cut, on the other hand, results in horizontal artifacts when there is photometric difference between images shown in Fig. 4 (e) and zoomed view is shown in Fig. 4 (f).

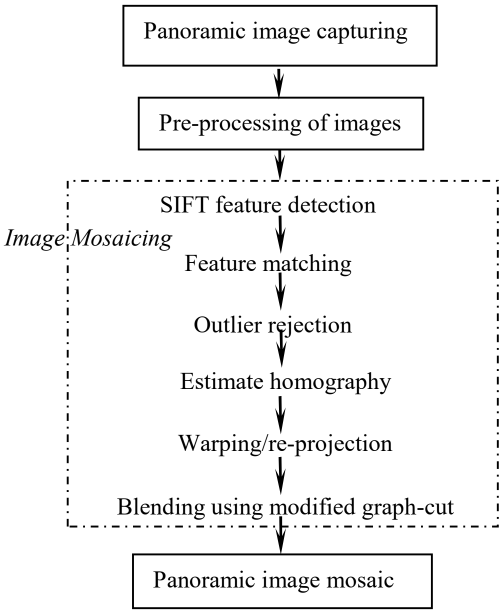

Fig. 3 Proposed algorithm for panoramic image mosaic generation.

The proposed algorithm employs modified graph-cut for the blending. Fig. 5 (a) shows the mosaic obtained on applying modified graph-cut with zoomed view (Fig. 5 (b)) of the same region of the image without any artifact. Thus, the proposed method of panoramic mosaicing generates visually appealing seamless mosaics.

Qualitative analysis

The proposed method of panoramic mosaic generation has also been tested for a set of images consisting of left and right views of a mountain for different mosaicing and blending techniques as it has geometric as well as photometric distortions. Fig. 6 (a) and (b) show the two input images with some overlapping part. Fig. 6 (c) shows the mosaic generated using classical cross correlation which fails to align the images properly. Due to geometric distortion even FFT-based phase correlation method [6] fails to achieve good result as shown in Fig. 6 (d). DCT-based phase correlation method [7] aligns the images up to some extent (Fig. 6 (e)) but the photometric difference still makes the exact overlap, an impossible task. When SIFT based feature detection method is used for image alignment, correctly aligned images are obtained, as revealed in Fig. 6 (f), in spite of the geometric distortion. However, the photometric difference still persists and results in visible seam in the final mosaic.

To reduce the photometric difference between the input images, within the mosaic, a number of blending methods have been incorporated. Fig. 6 (a)-(h) show the results of using different blending methods to smooth the seam. The results clearly show that the averaging, feathering and minimum blending do not overcome the problem of visible seam. Graph-cut on the other hand [15], finds the optimal seam however, in some cases results in horizontal artifacts when the photometric difference is more. The proposed method is able to reduce such artifacts while producing smooth blend between the images. The proposed method has also been tested for various sets of images with geometric and photometric differences. The mosaicing results for 5 sets of images have been shown in Fig. 7.

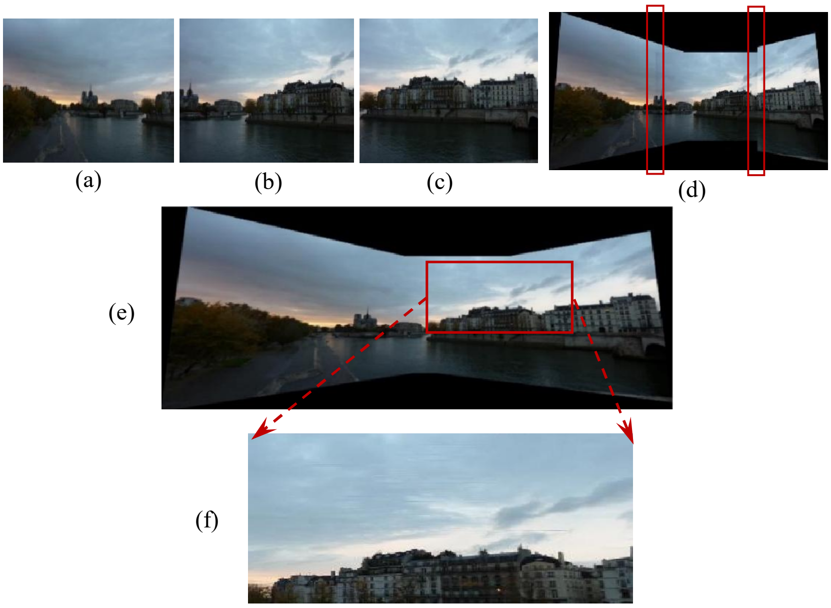

Fig. 4. Panoramic mosaicing **(a) - (c)** Input images, **(d)** Misalignment error & intensity discrepancies, **(e)** Blending using graph-cut, **(f)** Zoomed view showing artifacts.

Fig. 5. Seam visibility **(a)** Panoramic mosaic using proposed method **(b)** Zoomed view to show the removed horizontal marks (artifacts) of the mosaic.

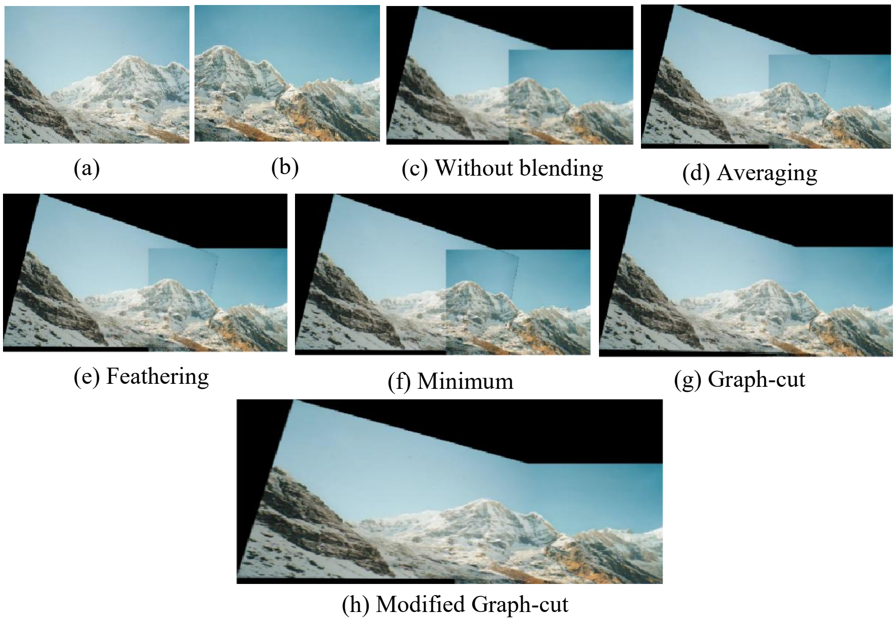

Fig. 6. Blending algorithm comparison.

Quantitative analysis

The quantitative analyses results for Fig. 7. are summarized in Table 1 and Table 2. Table 1 shows the quality assessment parameter using spectral angle mapper (SAM) and intensity magnitude ratio (IMR) measures [16]. These parameters evaluate the geometric and photometric quality of stitched images. SAM is used to calculate the angle between the two pixels p_1 and p_2 from the input image 1 and input image 2 respectively. The formula for SAM is given as, $SAM = \arccos \frac{\langle p_1, p_2 \rangle}{|p_1||p_2|}$. Large values of the angle indicates that pixels/vectors are different from each other. IMR is the ratio of the two 3-D color vectors. For the two pixels p_1 and p_2 it can be defined as, $IMR = \frac{\min(|p_1|,|p_2|)}{\max(|p_1|,|p_2|)}$. Large values of IMR indicates the difference in two images i.e. photometric difference.

Table-1

	Average Parameters	
Images	*SAM*	*IMR*
Mountain	0.0283	0.4896
Stadium	0.0897	0.7783
Floor	0.0301	0.776
Building	0.0404	0.8378
Scene	0.0222	0.8432

Since to measures the quality of the blended part these two parameters may not suffice. Therefore, other commonly used parameters such as entropy and standard deviation have also been calculated for different blending techniques.

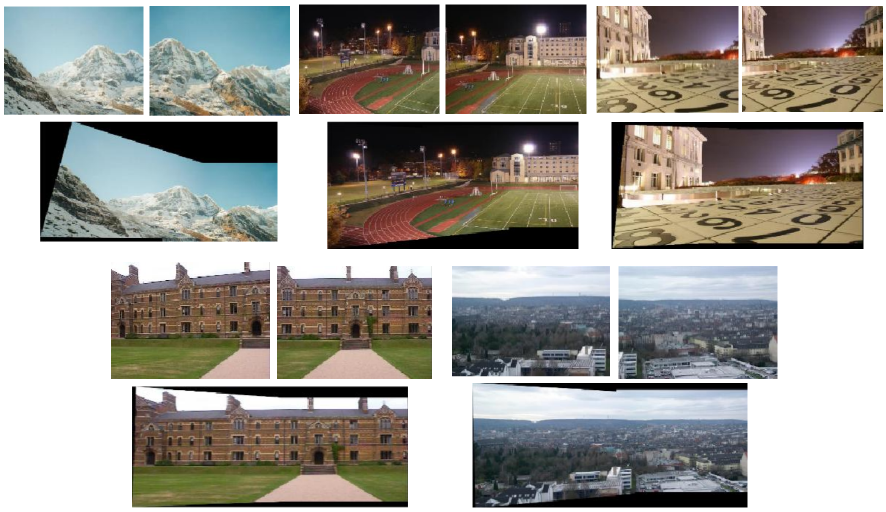

Fig. 7. Panoramic mosaics for five sets of images using proposed technique.

The results for quantitative assessment of the 5 sets of images have been summarized in Table 2. Increased values of entropy and standard deviation is indicative of the fact that the images have been blended over the overlapping region while retaining the important information.

Table-2 Blending Approaches

Images	Averaging		Minimum		Feathering		Graph-cut		Modified Graph -cut	
	Entropy	*Std dev*	*Entropy*	*Std dev*	*Entropy*	*Std dev*	*Entropy*	*Std dev*	*Entropy*	*Std dev*
Mountain	5.827	0.3254	5.9311	0.314	5.8188	0.3276	5.8219	0.2217	6.529	0.3409
Stadium	6.6845	0.1822	6.6307	0.1763	6.698	0.183	4.7199	0.1788	6.7872	0.1898
Floor	7.5734	0.2479	7.5062	0.2545	7.5509	0.2518	3.9671	0.123	7.5944	0.2628
Building	6.8506	0.2726	6.8213	0.2734	6.7525	0.2726	4.3514	0.2211	6.9861	0.2734
Scene	6.9662	0.3104	6.9516	0.3103	6.9656	0.3104	6.9788	0.2745	7.1659	0.3112

6 Conclusion

Camera motion, sensor noise, difference in illumination, and parallax affect the process of mosaic generation making the mosaic visually distorted. In this work, an efficient method of mosaicing is presented to mitigate the effect of above mentioned problems. The algorithm has two steps: first, it uses feature based technique for image alignment and second, a modified graph-cut method is used for reducing the visual artifacts or seam in the region of overlap. Results have been evaluated by comparing with other mosaicing as well as blending techniques. The qualitative and quantitative comparison show the superior performance of our method. Presently, the images have photometric and geometric distortion for two or three views of a scene. In future, more images will be considered for panorama generation.

References

[1] Hsieh, J.W.: Fast stitching algorithm for moving object detection and mosaic construction. Image Vis Comput, Vol. 22, no. 4, (2004) 291–306.

[2] Chan, S.C., Shum, H.Y. and Ng, K.T.: Image based rendering and synthesis. IEEE Signal processing magazine, Vol. 24, no. 6, (2007) 22–33.

[3] Kekec, T., Vildirim, A. and Unel, M.: A new approach to real-time mosaicing of aerial images. Robotics and Autonomous Systems, Vol. 62, (2014) 1755–1767.

[4] Marzotto, R., Fusiello, A. and Murino, V.: High resolution video mosaicing with global alignment. Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Washington, DC. Vol. 1, (2004) 692–698.

[5] Gledhill, D., Tian, G. Y., Taylor, D. and Clarke, D.: Panoramic imaging – a review. Computers & Graphics, Vol. 27, (2003) 435–445.

[6] Kuglin, C.D.: The phase correlation image alignment methed. In Proc. Int. Conference Cybernetics Society, (1975) 163–165.

[7] Pandey, A. and Pati, U.C.: A novel technique for mosaicing of medical images. Annual IEEE India Conference (INDICON), Pune, India, (2014) 1–5.

[8] Bhosle, U., Chaudhuri, S. and Dutta Roy, S.: A fast method for image mosaicing using geometric hashing. IETE journal of research Vol. 48, no. 3–4, (2002) 317–324.

[9] Irani, M. and Anandan, P.: About direct methods. Vision Algorithms: Theory and Practice, 2000. 267–277.

[10]Lowe, D.: Distinctive image features from scale-invariant keypoints. International Journal of Computer Vision, Vol. 60, no.2 (2004) 91–110.

[11]Xiong, Y. and Pulli, K.: Fast panorama stitching for high-quality panoramic images on mobile phones. IEEE Transactions on Consumer Electronics, Vol. 56, no. 2, (2010) 298–306.

[12]Perez P, Gangnet M, Blake A. Poisson image editing. ACM Transactions on Graphics (TOG), Vol. 22, no. 3, (2003) 313–318.

[13]Fischler, M. and Bolles, R.: Random sample consensus: A paradigm for model fitting with application to image analysis and automated cartography. Communications of the ACM, Vol. 24 (1981) 381–395.

[14]Kwatra, V., Schodl, A. Essa, I., Turk, G. and Bobick, A.: Graphcut Textures: Image and Video Synthesis Using Graph Cuts. ACM Transaction on Graphics, (2003) 277–286.

[15]Pandey, A. and Pati, U.C.: Panoramic image mosaicing: An Optimized Graph-cut Approach, Proceedings of International Conference on Advanced Computing, Networking, and Informatics ICACNI Bhubaneswar, India, (2015) Vol. 43, 299-305.

[16]Qureshi, H. S., Khan, M. M., Hafiz, R., Cho, Y. and Cha. J.: Quantitative quality assessment of stitched panoramic images. IET Image Processing, Vol. 6, no. 9, (2012) 1348–1358.