

Color Matching for Mobile Panorama Image Stitching

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Abstract— This paper presents an efficient approach to implementation of the image stitching process with a view to address the reduction of processing time which is a concern for the current day mobile users when going for panoramic image generation. The images being matched for panorama creation are overlapped using a basic process of finding matching key-points after which color correction and blending algorithms are applied to bridge up the differences between adjacent images to be stitched together.

This work demonstrates how an approach using SIFT followed by RANSAC algorithm can be speeded up by exploring some basic features of the process. Two approaches are proposed for speed up – fast approach and reduced approach for handling the keypoint to speed up the operation. The proposed approach can be expanded for any process used for identifying key-points and is simple and is very effective.

This work demonstrates that optimizing the key-points identification process between neighboring images can give up speed up in the range of 23 to 28 % for the overall process.

Keywords— *SIFT, RANSAC, Color blending, color correction, mobile panorama.*

I. INTRODUCTION

Many application in computer visualization and computational photography that could only work on Personal Computer before, can now be implemented on mobile devices. Modern mobile phones have developed into not only efficient and convenient communication tools but also practically all modern high-end mobile phones come with a high-resolution camera and relatively lot of processing power, enabling many interesting visual applications for mobile computational photography and augmented reality [1], [2]. In the last few years, it seems that digital photography has finally reached classic photography in many aspects like resolution has become sufficient, quality of image and color interpretation are fine and noise levels have also been reduced. Moreover, digital photography gives user the possibility to process taken images in various ways to picture the real world in a more realistic way, to emphasize any aspect of the image or just to impress the viewer. This includes joining the picture together which captured at single location with slightly different viewpoints to create wide-angle representation of scene called panoramas. With panorama imaging application a user can take a photo sequence from scene with a mobile phone and initiates a panoramic image created on the mobile phones immediately. The user can also send the panoramic image to his friends and upload it to website to share with other people. Panoramic images are constructed from image sequences

which are captured continuously by rotating a camera so it covers the whole scene. As the image parameters such as exposure and white balance are recalculated for each input image, changes in illumination in different parts of the scene lead to different exposure levels in adjacent images, and objects of different colors in different parts of the scene affect the white-balance settings, causing the same objects to appear different, either brighter or darker, or even with a different apparent color, in neighboring images. If there is no additional color and luminance processing, artifacts in the overlapping areas of the images may be created in the final panoramic image, and stages of image stitching which assume that the same object has the same color values fail.

II. LITERATURE REVIEW

Over the period of last several years, many approaches have been proposed for image stitching. This section gives detailed reviews on various Image stitching techniques used to combine multiple images together to make a wide angle picture called Panorama. Algorithms for stitching and aligning have many applications in computer vision like texture synthesis, object recognition, medical imaging. Images of any object or place are acquired using 360 degree rotating camera and the overlapped portion of images should be aligned properly. Image stitching requires identical exposures to produce seamless results. It is also known as mosaicing.

Stitching can be done into six stages Acquisition, Feature Detection, Remapping, Color correction, Image labeling Blending.

Performing image acquisition in image processing is always the first step in the workflow sequence because, without an image, no processing is conceivable. Chi Yen et. al. [3] portrayed and examined three set-up's to procure images for panoramic images that are rotating camera, translating camera and hand held camera. The second step in image stitching is feature detection which is the fundamental piece of image stitching process. In an image, features of the image are the components of that specific image. The speed at which features in an image are detected is essential in many applications [4]. The least complex approach to locate all relating highlight focuses in a picture match is to analyze all components in one picture against all elements in the other utilizing one of the nearby descriptors. Inappropriately, this is quadratic in the normal number of features, which makes it impractical for some applications [5]. Feature based methods start by establishing correspondences between points, lines, edges, corners, or other geometric elements. Qualities of vigorous detectors include invariance to image noise, scale invariance, translation invariance, and rotation transformations. There are many feature detector procedures, for example Harris [6], SIFT [7], SURF [8], FAST [9], PCA-SIFT [10] and ORB [11] techniques. After feature matching Image Remapping involves Alignment, conversion of camera image to Sphere, Selection of final projection, Exposure setting. Image remapping is also called Warping. At this point RANSAC [12] is used, to compute homography between two input images which can be stitched and mixed into conclusive yield display.

Color correction is therefore frequently utilized before the stitching procedure to adjust colors and luminance in the entire image sequence. A typical approach is to change the shade of every one of the image in the arrangement to coordinate the basic image. The transform matrix crosswise over images can be represented as a linear model [13], [14] or a diagonal model [15], in which the mapping parameters are registered from the midpoints of each channel over the overlapping regions or from the mapping of histograms [13], [16]. There are two primary methodologies in literature to stitch numerous images for panorama: optimal seam finding and transition smoothing, assuming the images have been already aligned. Optimal seam finding algorithm [17], [18], [19] search for a seam in the overlapping area so that the differences between two neighboring pictures on the seam are minimized. The optimal seam can be found by graph-cut [17], dynamic programming [18], [19] or other algorithms. At that point each image is copied to the corresponding side of the seam. The benefit of optimal seam finding is its low computational and memory

cost, but it is sensitive to photometric inconsistency, which appears as a global intensity or color difference between the images because of changes of scene enlightenment and camera reactions. In this way the fundamental issue of optimal seam finding is that sometimes the seam are also visible and artifacts may arise in the final panorama. Transition smoothing methodology can diminish the seam artifacts by smoothing the transition between images. One of the easiest approach is utilizing alpha blending [20] to consolidate adjacent images through weighted combination. The weighting coefficients fluctuate spatially as a function of the distance from the seam. Pyramid mixing [21], [22] then again blends the frequency bands of the images and distinctive frequency band are combined with various blending masks. Gradient domain techniques [23], [24] are also widely utilized. They operate directly on the gradient field of an image and the blending is typically carried out by settling a Poisson condition with limit conditions. Although these approaches can reduce artifacts effectively, they require large computational costs and memory utilization. In addition, these methodologies concentrate on smoothing the transition in the vicinity of the covering range. On the off chance that the illumination and color differences among images are very big, despite the fact that seam can be smoothed to practically undetectable, the color tones change from one range to another zone appeared on the last display may make the picture look unnatural.

III. PROBLEM STATEMENT

Panoramic photography is technique that creates images with extended fields of view. Modern digital camera technology allows for continuous capturing of images up to a 360 degree field of view. The images can then stitched together to form a single panorama photograph. Due to the cost and difficulty of producing wide-format digital sensors, very few dedicated digital panoramic systems have been developed. Those that are available are very expensive and technically complex compared to similar film-based systems. Some digital point-and-shoot cameras include a "panorama" shooting mode, but this is simply an in-camera crop. Digital photographers are therefore left with the option of stitched panoramas, where the camera captures multiple views of a scene that is then reconstructed with software. Still image capture angle poses a problem for the application existing. A high quality panorama photograph requires low parallax errors that can be achieved if the camera taking the images in exactly the same place for each image in the panorama. Other disadvantages of panorama imaging systems are color/luminance inconsistency problem that existed in the panoramic images due to differences in camera responses and scene illuminations, or spatial alignment errors. Since image parameters are automatically recalculated for each input image during panorama capture, changes in illumination levels lead to different exposure levels in the adjacent images, and

different distribution of various colored objects affects the white-balance settings, yielding images where the same objects seen in different images appear different, either brighter or darker, or even have different apparent colors. In previous approaches they use seam finding and image blending techniques to avoid ghosting and blurring effect but the problem with that approach is computational cost is high and unwanted delay occurs because of keypoint detection ,color correction process and panorama stitching process can only be started after the complete image sequences captured.

IV. SYSTEM DESIGN

Panorama image creation is now available in most smart phones. In order to make a contribution to the research work the objective of improving the process was chosen. The improvement can be done broadly in two ways like

- 1) Reducing memory requirement.
- 2) Reducing the process time

The memory requirement of the process being a highly hardware tied this point was not preferred as getting multiple devices to test with the process was a hurdle. Also the approach would mean a lot of effort in identifying the necessary development tools and support from the phone manufacturers. In order to remove the constraints placed by this issue the approach of a high level language based simulation of process time reduction operation was chosen.

MATLAB was selected as the support for memory handling in terms of arrays is very good and it treats images as arrays. Also it supports most image formats for input output and display. Ease of use and quick code development are other advantages.

The option of reducing process time was more amicable and found to bit challenging. On analyzing the basic process for panorama creation the following steps are identified. It was observed that the Feature detection consumes most of the time in the process.

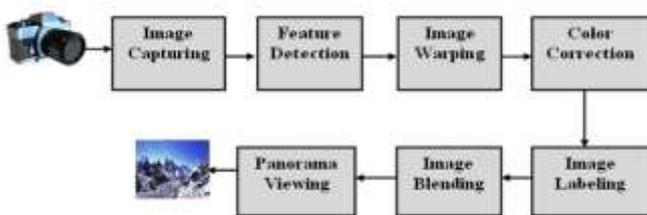
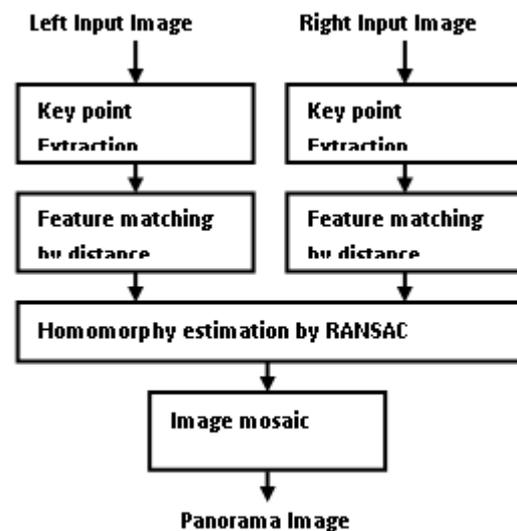


Figure IV-1 Basic steps for panorama processing

Considering the fact that the feature detection and image warping steps take major time we propose to improve this timing. The most common approach use to implement the feature detection is SIFT followed by homomorphy estimation using RANSAC for reduction of the key points count. The observed process is as shown below for panorama processing when the camera is moved horizontally while clicking the photos for panorama.



In order to speed up the SIFT and RANSAC processes we make rely on some observations which are as below:

- The Left Image and Right Image for a particular stitch overlap in only a small part.
- The SIFT key point detector works on full images which consumes good amount of time.
- The keypoints generated in the part which is to overlap in between the two images holds majority of the useful key points.

We make use of heuristics based approach to improve the process by reduction of the keypoints in the non-overlapping areas of the image, this causes the time needed to compute the keypoints to reduce leading to saving of processing time. The indirect impact of having the battery power saving due to less processing time forms the bonus.

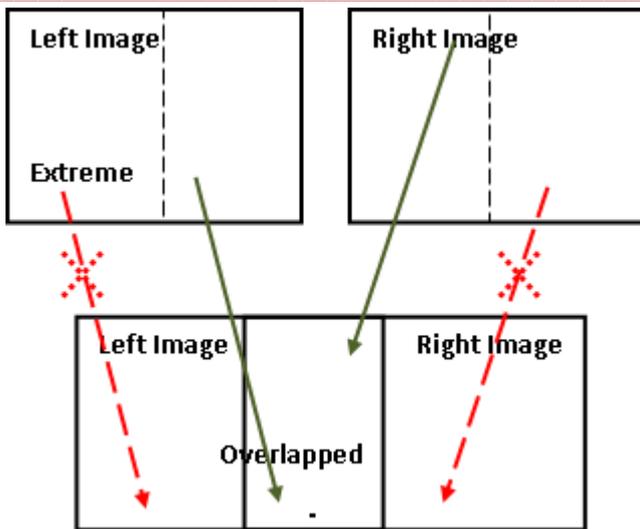
The approach to reduce the key point computations is carried out in two parts:

- a. Reduced point's operations approach.
- b. Fast Operations approach

The two approaches are described below for their details:

A. Reduced point's operations approach.

The reduced points approach makes use of the fact that the keypoints in the overlapping area are only useful for homomorphy detection. The key points in the uncommon area can be discarded without using them, the red arrows with cross depicts the activity. The green arrows in the overlapping part indicate the computed and used key points. The figure below depicts the operations. The images submitted to the basic SIFT operation can be actually cut into half and only the overlapping parts can be submitted to SIFT algorithm. The locations of key points obtained for left image overlapping part need ot be adjusted by half the image in their column number, the row number does not change. The Right half overlapping part need not use any adjustment.



B. Fast Operations approach

The fast approach makes use of the fact that the right hand side image which is submitted for a stitch becomes part of the left hand side image during the next stitch. In this case the keypoints operations can be reduced by simply remembering the right hand side image key points, transforming their coordinates with identified homomorphy based on current left and right image set and using these transformed coordinates of these key from right image side and use them as left image key points during the next stitching.

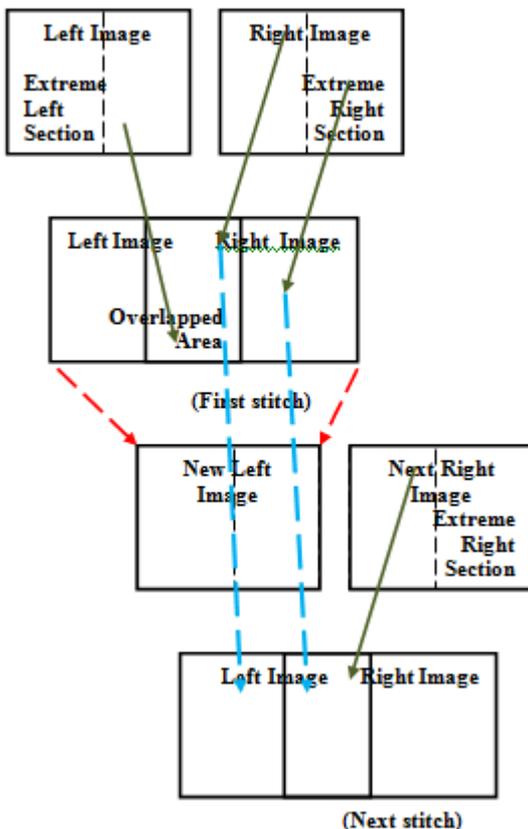


Figure IV-2 The Fast Operations approach

These two operations give rise to four combinations in which we can use these operations are labeled as Fast and

Validate points for user selection from the GUI. This leads to four different operational timings which we record by use of different folders as detailed in the implementation section.

V. IMPLEMENTATION

System Implementation uses the structure created during system design and the results of system analysis to construct system elements that meet the stakeholder requirements and system requirements developed in the early life cycle phases. These system elements are then integrated to form intermediate aggregates and finally the complete system. The design steps are implemented with MATLAB code and system is build. This system uses pictures with overlap region which clicked by mobile camera (Samsung J7) and import images into MATLAB. GUI system uses MATLAB GUI objects for accepting the user interaction with the system. To create panorama processing user first select camera folder path by providing select dialog box. If user clicks cancel then the function returns back with saying 'No folder selected by user'. If the user selects folder then the following operations are carried out.

- Save Input Folder Path from camera folder
- Save Process Folder Path in Photos folder
- Declare the Path is available for use and update the status line with folder selected and the file count in it.

After this when user the Process button from GUI the confirmation is done if that path has been selected for camera folder. When a path with more than one file is already selected prior to this button click the process is carried out one step further by clearing the previous diary log file, setting up the session folder by its creation if needed, if it exists any previous output files are flushed off. The settings for Fast and Reduce points operations are also recorded. After this the View session Images and Create Panorama buttons are enabled. GUI provides two check boxes named as Use Fast Operation and Validate Points. When the check boxes are clicked these corresponding callbacks, get the state of both the checkboxes, update the status string to reflect which mode of operation is selected. i.e. Fast or Reduce operation is either enabled or disabled. Based on this settings of the check box one of the four folders names are generated which are –

- Fast-AllPoint
- Fast-Reduce
- Regular-AllPoint
- Regular-Reduce

These folders are created inside the session folder for folder corresponding to the selected camera folder.

This section discusses the implementation of the system in a top down approach. The user interface being the GUI we

start from there and dive into the workings. After this to start Panorama creation user clicked on Create Panorama Image. The image stitching procedure starts with setting the stitching order of the source images by sorting their offsets and allocating memory space for the final panoramic image I_c . After loading the first source image S_1 and setting the initial parameters, we start the first part with loading the next source image S_2 . SIFT function is used to find keypoints based on SIFT and returns the list of matched points for both images. The next stage of code is to compute a homography mapping the coordinate of one image to the coordinate of the other image. To this RANSAC algorithm is used to find a fit between coordinated for feature points and do the mosaic. The color and luminance correction coefficients for the current source image S_i are computed with the sum of pixel values in the overlapping area between the current image S_i and the previous image S_{i-1} in the linear RGB color space. Thus we can obtain color correction coefficients for all source images. This is followed by global adjustment for these coefficients in the whole image sequence to further smooth color transition for the panoramic image and reduce the likelihood of correction coefficients over-exposing and thus saturating the images. The global adjustment is obtained by minimizing an objective function which makes the color correction for each source image as small as possible. After obtaining the color correction coefficients and the global adjustment factor, color correction is performed for each source image with these coefficients and stitches them onto the final panoramic image sequentially. In Next step image labeling approach is used which is capable of combining a set of aligned source images into a composite image by finding optimal seam in overlapping areas between adjacent source images. After this color blending is used to further smooth the color transition between adjacent images. After all source images are processed the final panoramic image is obtained.

VI. RESULTS AND DISCUSSION

In order to process the images for panorama generation the user selects either Fast operation or Regular operation by first check box and also selects if the Validate points (Reduce) option is to be chosen or all points are to be processed. In order to evaluate the improvement following set of images were processed using the MATLAB scripts triggered by GUI software.

Sr. No.	Folder Name	Image count	Stitches needed
1	Temple	2	1
2	Friends	2	1
3	Mahotsav	3	2
4	Nature	2	1
5	Mountain	3	2

6	Volleyball	3	2
7	Roadhouse	5	4
8	Sunlight	2	1
9	Greenery	3	2
10	Family	3	2
11	Railway	2	1
12	Village	5	4

A. Results from Railway folder:

- Input Images:



Figure VI-1 Railway Image 1



Figure VI-2 Railway Image 2

- Fast-AllPoint:



Figure VI-3 Railway Fast-AllPoint Final Stitched Image



Figure VI-4 Railway Fast-AllPoint Final Blended Image

- Railway Fast-Reduce:

After reduction (Count=2864)



Figure VI-5 Railway Fast-Reduce Image-02-After reduction (Count=2864) –View



Figure VI-6 Railway Fast-Reduce Image-02-Connected Points-View

Keypoints reduced based on Slope (Count=2862)

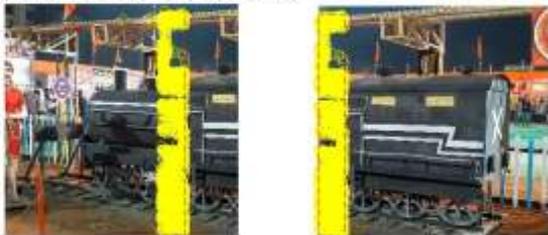


Figure VI-7 Railway Fast-Reduce Image-02-Keypoints reduced based on Slope (Count=2862) -View



Figure VI-8 Railway Fast-Reduce Final Stitched Image



Figure VI-9 Railway Fast-Reduce Final Blended Image

- *Regular-AllPoint:*



Figure VI-10 Railway Regular-AllPoint Final Stitched Image



Figure VI-11 Railway Regular-AllPoint Final Blended Image

- *Regular-Reduce:*

After reduction (Count=2864)

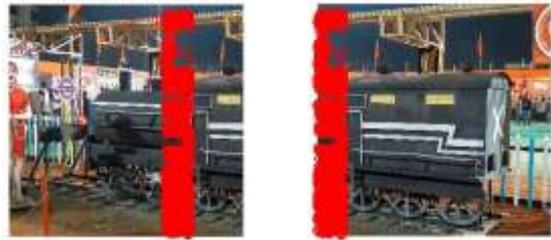


Figure VI-12 Railway Regular-Reduce Image-02-After reduction (Count=2864) -View



Figure VI-13 Railway Regular-Reduce Image-02-Connected Points-View

Keypoints reduced based on Slope (Count=2862)



Figure VI-14 Railway Regular-Reduce Image-02-Keypoints reduced based on Slope (Count=2862) -View



Figure VI-15 Railway Regular-Reduce Final Stitched Image



Figure VI-16 Railway Regular-Reduce Final Blended Image

Table V-1 show that Compiled Timing for multiple image set which are tested by this proposed approach.

Table VI-1 Compiled Timing for multiple image set

Image set	Regular-AllPoint	Regular-Reduce	Fast-AllPoint	Fast-Reduce
Temple	59.574	61.635	60.946	61.785
Friends	9.268	7.358	7.800	9.131
Mahotsav	49.281	50.168	38.318	40.025

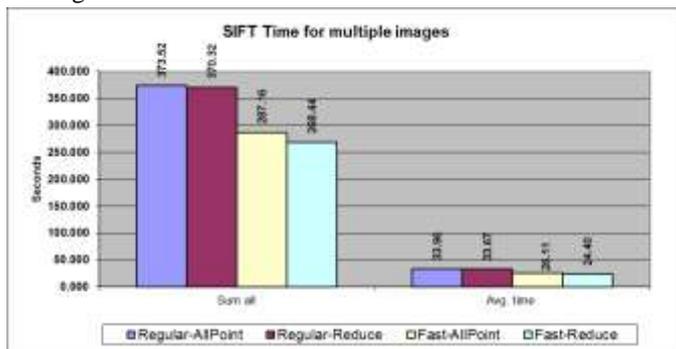
Nature	4.529	4.521	4.558	4.629
Mountain	10.301	10.739	5.397	5.355
Volleyball	71.935	64.062	54.691	53.722
Roadhouse	59.809	64.019	25.452	25.081
Sunlight	12.941	10.496	8.747	10.263
Greenery	2.625	2.464	19.095	1.981
Family	38.822	40.112	32.393	31.989
Railway	29.313	34.600	36.934	34.755
Village	54.439	54.747	29.765	24.477
Operation	Regular-AllPoint	Regular-Reduce	Fast-AllPoint	Fast-Reduce
Sum all	373.524	370.321	287.162	268.439
Avg. time	33.957	33.666	26.106	24.404
Saving per image %	Baseline Method	-0.858	-23.121	-28.133

The table above indicates the overall performance of the approach discussed in this work. The Regular all point is the conventional method considering no optimizations we choose this as the baseline for comparison. Considering the average time used for the base line method which is 33.957 seconds we have the following calculations in place.

Timing improvement in a method = (Timing for the method – Timing for baseline method)

Percentage Timing improvement for a method

=100* (Timing for the method –Timing for baseline method) / Timing for baseline method



Using the above equations we get the average timing saved per image as

- For Regular-Reduce method

Timing improvement = 33.666 - 33.957 = -0.291 sec

Percentage improvement = 100* (33.666 - 33.957) / 33.957 = -0.857 %

- For Fast-AllPoint method

Timing improvement = 26.106 – 33.957 = -7.851 sec

Percentage improvement = 100* (26.106 – 33.957) / 33.957 = -23.121 %

- For Fast-Reduce method

Timing improvement = 24.404 – 33.957 = -9.553 sec

Percentage improvement = 100* (24.404 – 33.957) / 33.957 = -28.133%

VII. CONCLUSION

The method presented in this work is a modified approach to panorama processing with an effective result of providing a saving of about 23% of average time per image processed as compared to the conventional panorama processing operations. The baseline method of Regular-AllPoint (which is the conventional method) performs better than the Regular-Reduce method this indicates that the effort needed to reduce the points is overriding the time saved by using the reduced point set. The Fast approach always works well and even when the reduction is not applied (Fast-AllPoint) it provides a gain of 23% of average timing per image. When it's augmented by the reduction approach the process (Fast Reduce) improves the timing can say 28%.

The approach being based on key-points has the advantage of being applicable to all panorama processing systems as keypoint form the integral part of homography generation.

VIII. FUTURE WORK

The work done herein can be extended further using following approaches:

1. *At program level:* The current MATLAB based code can be improved by a set of routines which perform faster by converting the current set of routines to mex files.
2. *At optimization level:* Distributed processing capabilities of MATLAB can be used to explore the possibilities of processing the key points in parallel and exploring timing improvement.
3. *At hardware level:* Involving the use of FPGA or allied digital hardware can be harnessed for timing improvements. This can also be explored using GPU based processing.

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