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An Implementation of Medical Image Mosaicing System Based on Oriented FAST and Rotated BRIEF Approach

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Abstract: Image stitching is a technique that combines two or more images that are taken from different view of the same scene to obtain a panoramic image. Image stitching is used in medical applications for stitching of X-ray images. As the traditional system of X-ray machine cannot capture the whole body structure in a single image. So, images stitching solves this problem by combining two or more x-ray images into a large view one. This paper proposes an algorithm which automatically stitches the x-ray images with overlapped region. The stitching method is based on ORB features (Oriented FAST and Rotated BRIEF features). The proposed system is designed with five stages, preprocessing, features extraction, features matching, Homography estimation and images stitching. In feature detection stage, Oriented FAST approach is used. In feature description stage, Rotated BRIEF approach is applied. The two primary parameters for measuring the stitching performance are the quality of the resultant image and the processing time. Therefore, the main objective of this paper is to produce a high quality image stitching system with low processing time. First, we compare many different features detectors. We test SIFT method, SURF method, Harris corner detector and ORB approach to measure the correct detection rate of the feature points and computation time. Second, we measure the quality of result images that produced by stitching system of different feature detection methods. From experimental results, we conclude that ORB approach is the fastest, more accurate, and higher performance.

Keywords: Biomedical images; Feature based approach ; Image stitching; ORB features ; Panorama

I. INTRODUCTION

A panorama image is any wide angle view of image. It can be created by stitching multiple images that are taken from different view of the same source. This process is known as image stitching or mosaicing. Image stitching has become very popular for many applications such as creating a panorama image, construction of large view satellite image, stitching medical images etc. [1].

Image mosaicing is a common method in medical image processing. Medical image processing is very useful in healthcare services for diagnosis, operations planning and executing the surgical procedures. X-rays images are the latest and most frequently used form of medical imaging. X-rays were discovered by Wilhelm Conrad Roentgen in year 1896. His discovery gave a valuable tool for medical applications. Many surgical operations and medical applications were made with x-rays all over the world. In medical applications, it is necessary to produce panoramic X-ray images with the purpose of observing the full bone structure of the patient, such as full-spine and lower limb. The traditional X-ray system has a limited field of view that cannot capture the whole body structure in a single image [6]. Image stitching solves this problem by combining multiple x-ray images that contain the overlapped regions of the body parts into a full body structure.

Biomedical images such as X-ray images, MRI images, CT images and microscope images are needed to combine to view a large single image [17]. Biomedical images stitching combines these images with overlapped region into a single large view image. Stitching biomedical images is the same procedure as a creating panorama image. The proposed system is

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stitching of x-ray images. This system can help for surgeons to view a panorama image in detecting the diseases.

Image stitching is a process that combines multiple images with overlapping regions into a panorama image. The two basics steps in stitching of X-ray images are registration and blending steps. Image registration is the main process in image stitching. In image registration, portions of two adjacent or consecutive images are compared to find the overlapped regions and the needed translation that will be used to align the images. Once the overlapping images have been registered, the task is to find the optimal spatial and intensity transformations so that the images are matched and merged seamlessly.

According to the literatures, there are mainly two methods for image stitching. They are direct based approach and feature based approach. Direct based methods try to estimate the camera parameters by minimizing an error function based on the intensity difference of the overlapped region. Based on intensity difference, transformation matrix is calculated iteratively. So, these methods give accurate registration, but they are not robust to image scaling, illumination change and noise present in an image. Compared to feature based method, it requires a good initial estimation to achieve transformation matrix which is a major weak point of this method. Feature based method identifies distinctive features, for example points, lines, edges, corners or other shapes, in the input image and calculates the correspondence between these features based on some parameters. While comparing this method to direct method, it is robust to illumination change, image scaling, noise, affine transformation and orientation of the image. It takes care of locality around detected features to describe that feature and is called as feature descriptor. In feature-based approach, all main feature points in an image pair are compared with that of every feature in other image by using the descriptors [18].

Recently there has been great progress in the use of invariant features for object recognition and matching. These features can be found more repeatable and matched more reliably than traditional methods such as cross-correlation using Harris corners. Harris corners are not invariant to scaling of the image, and cross-correlation of image patches is not invariant to rotation [4].

There are numerous feature detector methods exist, out of which some are, Harris, [8], Scale-Invariant Feature Transform (SIFT), [3], [12], Speeded Up Robust Features (SURF), [5], [9], Features from Accelerated Segment Test (FAST) and ORB [13] techniques. For any category of movement of scene happened in image, feature based technique is suitable because of its robustness. This method is very faster, and it has the capability to identify a panorama image by automatically detecting the adjacency relationship between two images. But, feature based techniques rely on precise recognition of image features.

There had been done researched in direct based approach for medical images stitching. Among them, cross correlation is a basic statistical approach. It was used as a similarity measure in many image registration processes. It is a match metric between two images. This similarity measure is widely used because it can be computed efficiently using the Fast Fourier Transform (FFT) for combining two images of the same size. But both direct correlation and correlation using FFT have high costs [18]. The proposed system uses Oriented FAST in feature detection and Rotated BRIEF in feature description. This system can help the surgeons to diagnose the diseases in a fast and accurate way.

Many researchers have been done image stitching using feature based approaches. The mostly used feature based methods are SIFT, SURF, and Harris detectors [8]. Jun-Hui Gong was proposed the stitching of x-ray images with low resolution and SURF method was used in feature extraction. SURF method is fast in computing time than SIFT method, but it extracts less features. The disadvantage of this approach is sensitive in noise images. It extracts wrong features in this situation [5]. R. Botan also used SURF detector in features extraction stage [7]. Singla was proposed medical x-ray images stitching using combined SIFT and SURF method [11]. In feature detection stage, both SIFT and SURF methods were used and then found the correlation of these features. The correct feature points were selected using RANSAC algorithm but there still had high computation complexity. Adel et al. [14] compared many feature-based detectors that can be used in image stitching. They tested Harris corner detector, Good Features to Track detector, SIFT, SURF, FAST, MSER detector, and ORB technique to measure the detection rate of the corrected key points, time, and accuracy of the detection process. The experimental result showed that the SIFT method is a robust algorithm, but it takes more time for computations. ORB and MSER algorithm are robust as well as SIFT algorithm, but ORB is the fastest technique. In addition, they introduced a real-time image stitching system based on ORB feature-based technique.

According to the literature, many researchers have been developed the biomedical images stitching using feature based approach, but ORB method has not been applied yet. Therefore, this research work is the first work of biomedical images stitching using ORB feature based approach. The proposed system uses ORB (Oriented FAST and Rotated BRIEF) in feature detection and matching and then RANSAC algorithm is used to find the best four features pairs. After four features pairs to align the two images are obtained, Homography matrix is computed. Finally, the system stitched the two images together using Homography matrix. This system can help the surgeons to detect the diseases and to save time in medical applications.

The rest of this paper is organized as follows: Section II describes the details of the materials and methods that are used in this study. Section III discusses the experimental results of the proposed system. Finally, the Section IV summarizes and discusses the paper.

II. METHODOLOGY

The stitching procedure for the proposed system is illustrated in Fig.1.

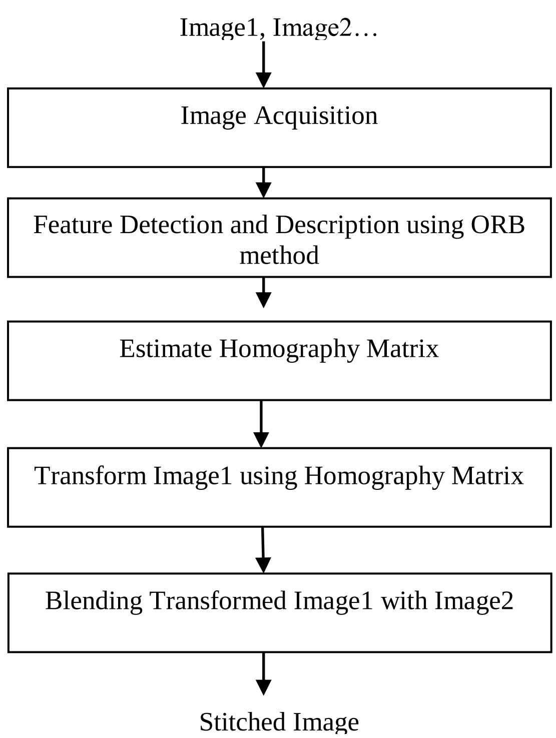

Fig.1. Proposed Images Stitching System Using ORB Feature Based Approach.

The stitching procedure proposed in this study consisted of five steps: preprocessing; ORB feature detection and description; features matching; compute Homography matrix and stitch images. The first step in this system was preprocessing. Two images with overlapping area were accepted. ORB algorithm used Oriented FAST in features detection and Rotated BRIEF in features description. After features detection process was completed, feature matching process was used to match features pair that will be used to compute alignment of the two images. In features matching process, Hamming distance is used to find the nearest and adjacent neighbors of the feature points. Only four features pairs are needed to align the two images correctly. But there are many matched features pairs after matching process. So, the system needs to compute for choosing four features pairs that would be satisfied to align the two images correctly. This system used homogenous coordinates to find correct four features pairs. The RANSAC (random sample consensus) algorithm is applied to remove the mismatch points and to estimate the transform matrix H. According to the transformation matrix H finds a subset of the images that have a matching relationship. Finally, the weighted average method is used to fuse the images.

A. Image Preprocessing

The input biomedical images for the proposed system are from the Department of Medicine, 'Aung' Hospital in Lashio, Myanmar. Since the size of original biomedical images is quite large, the computation amount will be overwhelming in practice. The size of the standard format (DICOM) for medical images is about 7226KB for each image. Therefore, the images should be compressed in jpeg file to reduce the size about 171KB. Firstly, in this proposed system, these DICOM images are converted to jpeg format. There are 100 images in total and 50 pairs of overlapped images to stitch. The sample of the input images for proposed system is illustrated in Fig.2.

B. Features Extraction and Description

In this system, ORB algorithm is used for features extraction and description. This algorithm uses Oriented FAST to detect feature points and Rotation BRIEF to generate descriptors. The FAST algorithm detects feature points with a simple operation than that of SIFT or SURF. It detects feature points by comparing 16 pixels around the center pixel. The BRIEF algorithm generates descriptors more quickly than the other algorithms by comparing the brightness values of pixels around the feature points. In addition, the generated descriptor is composed of binary strings. This descriptor has less memory usage and simple operation compared to the 256-byte string descriptor generated by SIFT or SURF algorithm. The result images of ORB features extraction are displayed in Fig.3 and Fig.4.

i. FAST Detector

The ORB algorithm improves FAST detector to determine the orientation of the corners. The original FAST detector cannot produce information about orientation. ORB method obtains the rotation invariance by defining the moment of image patch. It can be defined as follows:

$$m_{pq} = \sum_{x,y} x^p y^q I(x,y) \quad (1)$$

The centroid (center of gravity) of an image patch is given by:

$$C = \left(\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}}\right) \quad (2)$$

Now we can compute the centroid C for the square patch that embeds the FAST circle for a detected corner. Then the orientation of the vector from corner to centroid can be computed by:

$$\theta = \arctan 2(m_{01}, m_{10}) \quad (3)$$

In the feature extraction, the circular area as a feature point is used to determine whether the point is the rotation invariance point.

ii. BRIEF Descriptor

BRIEF descriptor is a bit string description of an image patch constructed from a set of binary intensity tests. A binary test τ is defined by:

$$\tau(P, X, Y) = \begin{cases} 1, P(X) < P(Y) \\ 0, P(X) \geq P(Y) \end{cases} \quad (4)$$

Where p(x) is the brightness of the pixel block at that point. The feature is defined as a vector of n binary tests:

$$f_n(P) = \sum_{1 \leq i \leq n} 2^{i-1} \tau(P; Xi, Yi) \quad (5)$$

Now we have n BRIEF pairs (a_1, b_1), ……., (a_n, b_n). Then we can write them as a matrix S:

$$S = \begin{bmatrix} a_1 & \cdots & a_n \\ b_1 & \cdots & b_n \end{bmatrix}$$

Using a rotation matrix R_θ for the orientation θ of a given key point, we compute a rotated version of S_θ the BRIEF pairs as follows:

$$S_\theta = R_\theta S \quad (6)$$

In which R_θ is the rotation matrix of the main direction, the rotation angle is θ, S_θ is the test position for the binary pixel after rotation.

C. Features Matching

In this paper, the ORB features are used to match image. Hamming distance is used to find the nearest and adjacent neighbors of the feature points, and the ratio of the two distances is compared with the threshold to determine whether the feature point pair is matched. Fig. 5 and Fig. 6 show the matching features of the two x-ray images with overlapped regions used in this system.

D. Compute Homography Matrix

Homography matrix is a conversion matrix between two images. It is used to stitch the two images. RANSAC technique is used to estimate homography matrix. After feature matching process was completed; two images can be stitched together. Firstly, a homography matrix is calculated using RANSAC. Then, the two input images can be stitched and blended into final output panorama.

i. Apply RANSAC to Compute Homography

There are three steps in RANSAC algorithm. First, it selects four random feature pairs and then computes the homography matrix for those randomly selected feature pairs. The third step computes an error measure between feature pairs after transforming the points using homography.

ii. Estimating Homography from Point Correspondences

If two images have a correspondence between 4 points, homography H can be computed. Homography can be computed as follow:

$$\begin{bmatrix} x_i' \\ y_i' \\ 1 \end{bmatrix} \cong \begin{bmatrix} a & b & c \\ d & e & f \\ h & i & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}$$

For each correspondence, it is needed 2 linear equations and 8 unknowns, and so for 4 correspondences, it is required 8 linear equations. Two linear equations are obtained as follows:

$$ax_i + by_i + c - x_i'(hx_i + ky_i + 1) = 0 \qquad (7)$$

$$dx_i + ey_i + f - y_i'(hx_i + ky_i + 1) = 0 \qquad (8)$$

Where xi’ and yi’ are homogenous coordinates of transformed warp image.

E. Stitch Images

One of the two images is transformed by the estimate homography matrix. This transformed image is blend with the other input image and keeps the coordinate constraints of both images. The output of the blending images is the result image of the two overlapped images. In image fusion, weighted average method is used. The output of the proposed system is depicted in Fig.7.

(a) (b)

(c) (d)

Fig.2.The sample input x-ray images of the proposed system ((a) and (b) are two hand x-ray images with overlapped areas, (c) and (d) are two spine x-ray images that have overlapping regions)

Fig.3. The extracted ORB features of the hand x-ray images

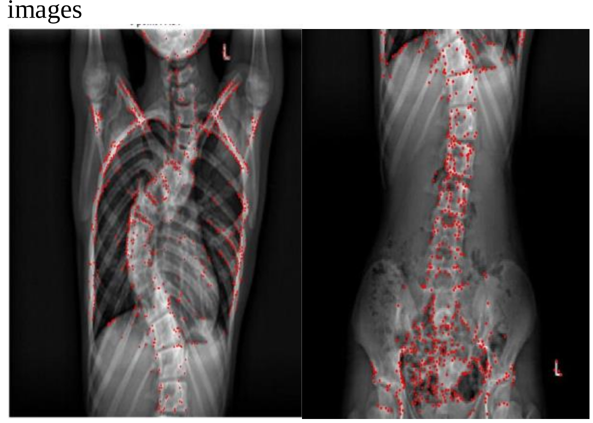

Fig.4. ORB features of two spine x-ray images

Fig.5. ORB features matching of the two hand x-ray images

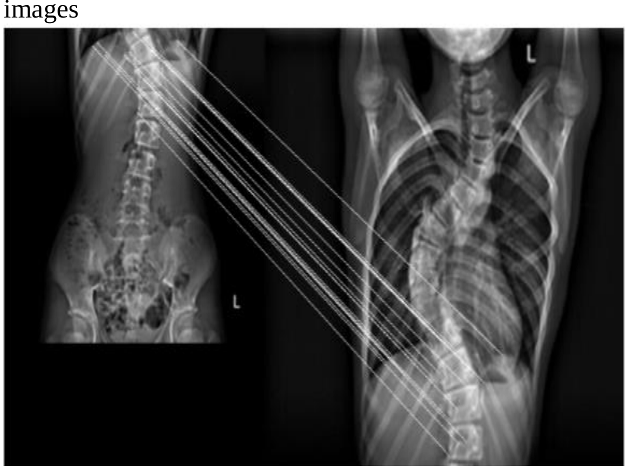

Fig.6. ORB features matching of the two spine x-ray images

Fig.7. Final output images of the proposed system

TABLE I. The comparison of features extraction performance (SIFT, SURF, Harris and ORB)

Methods	***Image Pixels***	***Features 1***	***Features 2***	***Time(s)***	***Matched features***
SIFT	985 x1065 938 x825	1277	941	8.012932	265
SURF	985 x1065 938 x825	307	183	0.65411	183
Harris	985 x1065 938 x825	2899	1658	0.75314	305
ORB	985 x1065 938 x825	41	17	0.102941	16

III. RESULTS

The 100 X-ray images studied in this paper were obtained from 50 patients in Aung Hospital, Lashio, Myanmar. The experimental databases contain spine, chest and lower limb X-ray images. The image acquisition equipment is SIEMENS Aristos FX DR, with the image size of 1428*2589 pixels. The overlapping region to be stitched occupies about 15–30% of the images. The proposed method is running on a computer with an Intel Core i7 2GHz CPU and 4GB RAM. In features detection step, we found that Harris and SIFT detect the highest number of features points but SIFT took the longest processing time among all other feature detectors. However, ORB method satisfies the highest performance as well as SIFT but has the least computation time. The results show that SIFT technique took the highest matching time, whereas ORB technique had the least matching time. Therefore, ORB is the most appropriate for real-time applications.

From the results, we concluded that the number of extracted features is not a measure of the full success or performance of the detector, but the performance and quality of these features in matching with the features in the other image. For example, SIFT may waste the time for detecting features that are not seemed to contain enough information for the matching step. The key points detected by ORB, although fewer, are more accurate than those detected by SIFT and SURF. The advantages of this proposed system are that it can detect reliable key points, reducing mismatch rate compared to other features detectors. In addition, the proposed method has fast matching speed because of using binary string descriptors. But our proposed algorithms fail to accurately register in case of complex images. Table II shows the comparison of quality measurement of the ORB method and other feature based image stitching methods using MSE and PSNR values. According to this table, images stitching using ORB method has lager PSNR value and smaller MSE value compared with other feature based methods.

TABLE II. Quality measurement of the resultant image that produced by ORB method and other feature based image mosaicing methods.

Methods	MSE	PSNR	Processing Time(s)
Image Stitching Using ORB	139.23	26.89	0.102941
Image Stitching Using SIFT	146.47	26.51	8.012932
Image Stitching Using SURF	186.75	25.91	0.65411
Image Stitching Using Harris	216.31	23.67	0.75314

IV. DISCUSSION

In this paper, the image stitching system to stitch the biomedical images with overlapped regions of the same part is proposed. 100 x-ray images from 50 patients with overlapped areas are used in this proposed system. The proposed system is designed with five stages, preprocessing, ORB features detection and description, features matching, Homography estimation and stitch images. In features detection and description stage, ORB feature points are used. According to the experiment, ORB method can produce the results with a rapid time compared with traditional methods. The proposed system is compared with other feature based images stitching algorithm, SIFT, SURF and Harris. The final image quality measured between the ORB algorithms and other feature based methods were computed using MSE and PSNR values. Experimental results show that the ORB algorithm can produce high quality seamless image mosaic of medical images with low processing time. As a future work, the system can be improved in 3D image stitching, 2D images stitching with moving objects and using the different feature based methods or using hybrid of feature based with direct based approaches to get better results.

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