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REVIEW ON HARRIS, SIFT AND SURF TECHNIQUES OF IMAGE MOSAICING

Jyoti Patel [1], Dr. Sarabpreet Kaur [2]

[1]*School of Electronics and Electrical Engineering,*
Lovely Professional University, Phagwara, Punjab, (India)
[2]*School of Electronics and Electrical Engineering, Lovely Professional University,*
Phagwara, Punjab, (India)

ABSTRACT

Image mosaicing is the technique of assembling different images which belongs to the same scene into a bigger or larger image, combining two images and giving one mosaiced image as an output. Image mosaicing is getting popular in the field of computer vision, computer graphics, image processing, multimedia, medical imaging, and data from satellites etc. There are main five phases involved in the procedure followed as feature point extraction, image registration, homography computation, warping and lastly blending. This paper presents a review of Harris corner detector, SIFT and SURF algorithms.

Keywords**: **Harris corner detector, RANSAC (Random Sample Consensus), SIFT (Scale Invariant Feature Transform), SURF (Speeded up Robust Features),

I INTRODUCTION

Image mosaicing is an overlay that is created from a series of images which belong to the same scene. Mosaic originates from an old Italian word mosaico which means a picture or pattern that is produced by arranging together small pieces of stone, tile, glass etc. It is a computer vision based approach which gives the large field of view without degrading the quality of an image. Image mosaicing is getting popular in the field of computer vision, computer graphics, image processing, multimedia etc. Image mosaicing is possibly done by implementing different mosaicing algorithms. The important points to produce perfect seamless results are that the input images should have exact overlapping regions and similar exposures.

Various steps to be followed in image mosaicing are feature extraction from the two input images, image registration, followed by homography computation using RANsac algorithm, ended up lastly with warping and blending of images. There are various applications of image mosaicing like in reconstruction of 3 Dimensional images, creating panoramic images, video compression, military automatic target recognition, the mosaic of satellite remote sensing image, medical imaging, meteorological and environmental monitoring, geological survey, sea bottom surveying, the digitized saving of file, image mosaicing for Tele-Reality applications [1] . In our

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daily life we stitch panoramas, which are a real time application of image mosaicing, it stitches all the small images which are taken from the same scene. Image mosaicing model is shown below in Fig. 1:

Different steps involved in image mosaicing are feature extraction for which the desired algorithm according to situation is applied, next image registration, homography computation using RANSAC, then warping and lastly blending of images together. In feature extraction desired features from the input images are extracted. Feature extraction reduces the amount of resources which is required to represent the large set of data. Image registration is the most important task of mosaicing procedure. In simple languages it is the process of matching two or more than two input images. In this one image is designated as the reference image and applying geometric transformation to the other image. [2]. There are different classes for image registration as shown below:

- Correlation methods: Using this algorithm one can use the image pixel values directly.
- FFT Based methods: It's an algorithm which uses the frequency domain.
- Feature based methods: This algorithm use only low level features such as corners, edges, contours and lines.
- Graph – Theoretic methods: In this algorithm only high level features are used like similar parts of an image objects, relation between features of an image etc.

In homography the corners which are not of our interest or simply areas which not belong to the overlapping region are removed. For computing homography there exist many powerful robust techniques. One of the most attractive techniques is RANSAC. RANSAC is an abbreviation for "RANdom Sample Consensus". It is a technique which is very well suited for estimation problems with small no. of parameters and having large percentage of outliers. Further in image warping, warping includes correcting distorted images. Image blending is the final step of image mosaicing.

Figure 1: Image Mosaic model

It is the process to get even transition from the two input images. Image blending removes the seam line created in the blended image. Different blend modes are used to blend two layers into each other using different blending techniques like alpha blending, multiband blending which can be used accordingly. Two most important factors in image mosaicing are the quality of mosaiced image and the other is time efficiency of the algorithm. Along with the detailed description of the algorithms, the pros and cons of each of the algorithm has been also discussed in this paper.

II HARRIS CORNER DETECTION ALGORITHM

Harris is corner detection algorithm proposed by Chris Harris & Mike Stephens in the year 1988. Harris and Stephens improved the moravec's operator. It is a point feature extracting algorithm [9]. They developed the corner and edge detector which overcomes the limitation of the moravec operator. Harris detector is appropriate in terms of detection and repeatability but takes more computational time. This algorithm is widely used in spite of high computational time. Harris took the idea of mathematical form, for the displacement of say coordinates *(u ,v)* it basically finds the difference in intensity in all the directions given as below:

$$E(u,v) = \sum_{x,y} w(x,y) \quad [I(x+u,y+v) - I(x,y)]^2 \tag{1}$$

where

$E(u,v)$ represents the change in intensity for the [u, v] shift.

$w(x,y)$ is a window function.

$I(x + u, y + v)$ is the shifted intensity

$I(x,y)$ is the intensity of the individual pixel.

Window function is either a rectangular or a Gaussian window. The corner point will be the centre point of the window function. And this corner point can be recognized by observing at the intensity values of the small window. Big change in the appearance happens by shifting the window in any of the direction. The function *E(u, v)* has to be maximized for corner detection. That means, maximizing the second term is needed. Taylor Expansion is applied to above equation and then using some mathematical steps and on rearranging we get the final equation as:

$$E(u,v) = [u \quad v]\, M\binom{u}{v} \tag{2}$$

where,

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x I_x & I_x I_y \\ I_x I_y & I_y I_y \end{bmatrix} \tag{3}$$

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Here, I_x and I_y are image derivatives in x and y directions respectively. Next is to create a score, basically an equation, which determines whether a specific window contains a corner or not.

$$R = \det(M) - k(trace(M))^2 \tag{4}$$

where,

determinant (M) = $\lambda_1 \lambda_2$

trace (M) = $\lambda_1 + \lambda_2$

Matrix M has two large eigen values λ1 and λ2 for an interest point. The corner, edge or flat area of an image is determined based on the magnitude of these eigen values as shown in the above Fig. 2:

1. If λ1 and λ2 both are almost equal to zero, then its flat area.

2. If out of both λ1 and λ2 one is smaller and the other larger, then edge is found.

3. If both λ1 and λ2 has large positive values, then corner is found.

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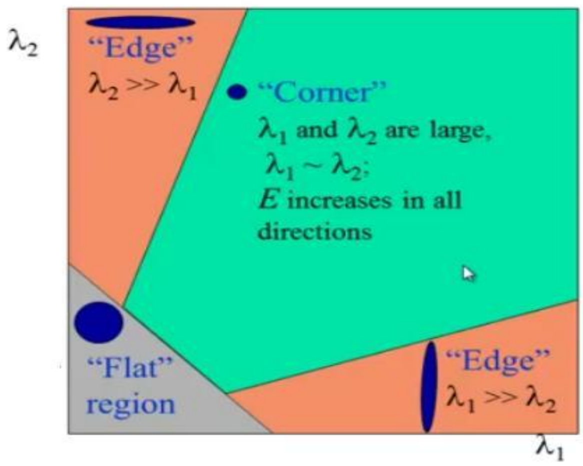

Figure 2: Harris Operator

This algorithm is only rotation invariant but not scale invariant. Harris algorithm is better for rotational image stitching but in case of illumination variation it doesn't give good results.

III SIFT (SCALE INVARIANT FEATURE TRANSFORM)

The Scale Invariant Feature Transform (SIFT) algorithm was proposed by David Lowe, [7] University of British Columbia in the year 1999. It is a feature detection algorithm. It detects the features from an image 1 that is very similar to the objects that are present in the image 2. The image features detected helps to produce the key point descriptors. Harris corner detection algorithm is only rotations invariant but SIFT is both rotation invariant as well as scale invariant [8]. SIFT help us to find key points and descriptors. The basic goals of SIFT are:

1. Extracting distinctive invariant features (so that can features can be matched from one image to other image)
2. Robustness to:
   - Affine distortion
   - Change in 3D Viewpoint
   - Addition of noise
   - Change in illumination
3. Invariant to image scale and rotation.

3.1 Computational Phases of SIFT

SIFT algorithm includes basic four computational phases as below shown in Fig. 3, which includes:

(1) Scale Space peak selection

Scale space peak selection is the first major phase of SIFT algorithm. Peak selection detects the desired potential interest points from an image. It locates the peak in scale space, the scale space is generated by generation of different smoothing version of same image varying different size of s**i**gma (σ) in Gaussian. With the help of DoG (difference-of-Gaussian) function it search over all the scales and the image locations present [1]. After the search is done the scale and the location is determined for all the obtained interest points found in scale.

(2) Key-Point localization

In this phase location and scale is determined for all the interest points that is obtained from scale space peak selection. Based on the stability, key points are selected and these key points which are selected should be unaffected to the image distortion. This is implemented with the help of Taylor series expansion.

Taylor Series expansion of DoG, D:

$$D(x) = D + \frac{\partial D^T}{\partial x} x + \frac{1}{2} x^T \frac{\partial^2 D}{\partial x^2} x \quad (5)$$

(3) Orientation Assignment

This orientation assignment is the third phase of SIFT. The main task of this is to figure out the gradient direction. Now this gradient direction is detected around the key points which were detected in the previous phase. Each key points are assigned with either one or more than one orientation based on local image gradient directions. The gradient is given by m(x, y) and the direction is given as ɵ(x, y). This gradient and the direction both are calculated for an image given by L(x, y) [3]. This is given in the form of mathematical expressions as:

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$$m(x,y) = \sqrt{\left(L(x+1,y) - L(x-1,y)\right)^2 \left(L(x,y+1) - L(x,y-1)\right)^2} \quad (6)$$

$$\theta(x,y) = arctan\left(\frac{L(x,y+1) - L(x,y-1)}{L(x+1,y) - L(x-1,y)}\right) \quad (7)$$

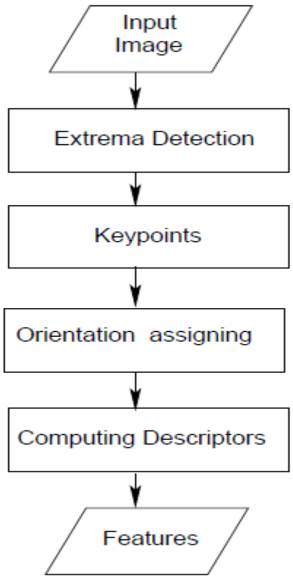

Figure 3 Major phases of SIFT algorithm

Taking both the values into consideration the histogram is created which is created on adding all the sample points to it. You will get maximum peak in the histogram obtained, this peak indicates the direction for the feature points.

(4) Key Point Descriptor

This denotes the last phase [8]. Key point descriptor generates feature vectors which are shown in Fig. 4. There are different cells and the arrow present in each cell not only denotes the gradient direction but also the amplitude of pixels. The seed point can be formed by aligning the unidirectional gradients followed by the normalization.

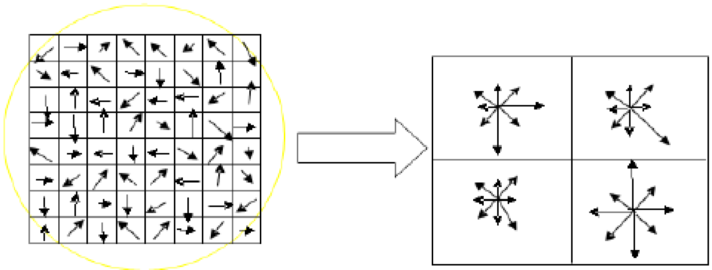

Figure 4 Feature vector generation

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IV SURF (SPEEDED UP ROBUST FEATURES)

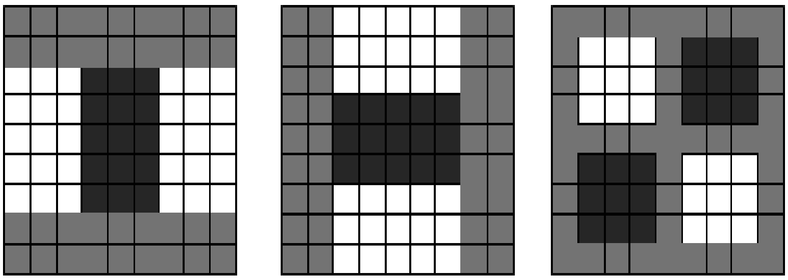
In 2006 Herbert Bay came up with the SURF algorithm, because SIFT was comparatively slow algorithm. SURF is a feature point extraction algorithm [10]. It is speeded form of the earlier feature extraction algorithm SIFT. SURF is both rotation as well as scale invariant. It generally uses three feature detection steps: first is detection then description and matching. SURF proves to be better than the previous discussed algorithms in terms of distinctiveness, repeatability, and robustness. The features extracted by this way present fixed size and fixed rotation, also show partly in variation in lighting transformation, affinities and projective transformation. The focus of algorithm is more on speeding up the matching step. It takes less computational time [4]. SURF algorithm is broadly divided into major four phases: extraction of feature points, matching of the extracted feature points, and determination of image transformation relationship and lastly fusion of an image.

(1) Establishing integral image

The first step the extraction of the feature points include feature detection and feature points description. In SURF firstly establishment of an integral image is done, after that the building of scale space image and at last positioning of those feature points. Here in SURF there is one big advantage of using an integral image is that it increases the speed of convolution between the box filters with different sizes and original images. Major difference between the SIFT and SURF is that in SIFT for finding the scale space LoG (Laplacian of Gaussian) is approximated with DoG (Difference of Gaussian) but in SURF it goes bit different. In SURF LoG is approximated with box filter.

(2) Building Scale-Space Image

For building the scale space, leaving the size of the real image unchanged and only varying the size of the box we conduct the image convolution and this forms an image scale space. The filter with four boxes are called an octave. In the first Octave, the adjacent box filter size at 6 pixels, the second Octave differ at 12 pixels, the third Octave differ at 24 pixels, and so on. In each octave the size of first box is similar as the second box in the next octave. This is shown in Fig. 5 below.



(a) x direction **(b) y direction** **(c) xy direction**

Figure 5 Box Filters with 9*9 pixels

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(3) Fast-Hessian Detector

The extreme points of the image are detected using fast Hessian matrix. The performance of hessian matrix is good in terms of accuracy and computation time. Say in an image I at certain point *(x, y)*, the hessian matrix is given as:

$$\mathcal{H}(\mathbf{x}, \sigma) = \begin{bmatrix} L_{xx}(\mathbf{x}, \sigma) & L_{xy}(\mathbf{x}, \sigma) \\ L_{xy}(\mathbf{x}, \sigma) & L_{yy}(\mathbf{x}, \sigma) \end{bmatrix} \quad (8)$$

where L_{xx} (x, σ) denotes the convolution of the image and the Gaussian second order derivative at point x, in a similar way others are defined in different directions. The need is to reduce the calculation steps which is done by replacing L_{xx}, L_{xy} and L_{yy} with D_{xx} , D_{xy} and D_{yy}, which represent the convolution of the box filter with the original image.

$$Det\ (H_{approx}) = D_{xx}D_{yy} - w(D_{xy})2 \quad (9)$$

In the above equation *w* represents the weighting factor and the value of *w* is 0.9. Threshold value based on calculation is decided. The extreme points are considered only when it is greater than the threshold.

(4) SURF Descriptor

This descriptor works on the property of similarity. To fulfill the need of being invariant to the image rotation is made possible with the use of Haar wavelet response. This Haar is used within the circular neighborhood which is approximately having radius of 6s, assign dominant orientation to each interest point. Square descriptor window of 20s is generated which is centered on each and every interest point. This descriptor window is divided into further sub-regions of size 4 x 4 square. For each sub-region total 4 values are calculated. Therefore, 64 dimensional feature vectors are generated for detecting each interest point.

V COMPUTING HOMOGRAPHY

In homography the corners which are not of our interest or which do not belong to the overlapping area are removed. For computing homography there exist many powerful robust techniques. One of the most attractive techniques is RANSAC. RANSAC is an abbreviation for “Random Sample Consensus [15]. It is a technique which is very well suited for estimation problems with small no. of parameters and having large percentage of outliers. For applying RANSAC the following steps are followed:

1. The data is assumed to contain certain percentage of outliers opposite to inliers. The following test is performed on the inliers:

- On the base of observed inliers a model is fitted accordingly.
- Test is performed to detect whether other data fit the model or not. If the data fit the model, that particular point is considered as hypothetical inliers.

- Once all the hypothetical inliers are obtained, re-estimate the model again.
- At last error is calculated which is obtained from the inliers with respect to the model.

2. Next parameter is estimated, denoted as x.
3. Now next tolerance is defined, which is determined from the count of data that fits to the model. It is denoted as K
4. Success is obtained only if K tolerance is large enough.
5. Above process is repeated for 1.4M times.
6. The value of M is obtained as:

$$M = \frac{Log\ (P_{fail})}{Log(1-(P_g)^N)} \quad (10)$$

where,

P_{fail} is the probability of failures.

$$P_{fail} = (1 - (P_g)^N)^2 \quad (11)$$

To deal with the large percentage of errors, RANSAC is the most powerful adopted technique.

VI CONCLUSION

In this paper three algorithms Harris, SURF and SIFT have been discussed. Harris is only rotationally invariant but better is SIFT which is both rotationally and scale invariant, although it is slow. Although SIFT is slow but it is robust. The running time is large as it takes more time to compare two images, has affine transformation and noise immunity. It is computationally expensive to be used in real time or large scale projects and more effective in presence of noise. However it suffers from illumination variation. SURF is a speeded version of SIFT hence its focus is on speeding up the matching step. The increase is made possible only with the use of hessian matrix along with their descriptors. It is more effective, efficient detector and descriptor. The feature extraction speeded up with the use of SURF algorithm. It's overall performance is much better than SIFT. SURF has proven its efficiency and robustness in the invariant feature-localization.

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