# PERFORMANCE ANALYSIS OF KLT, HARRIS AND SIFT FEATURE DETECTOR FOR IMAGE STITCHING

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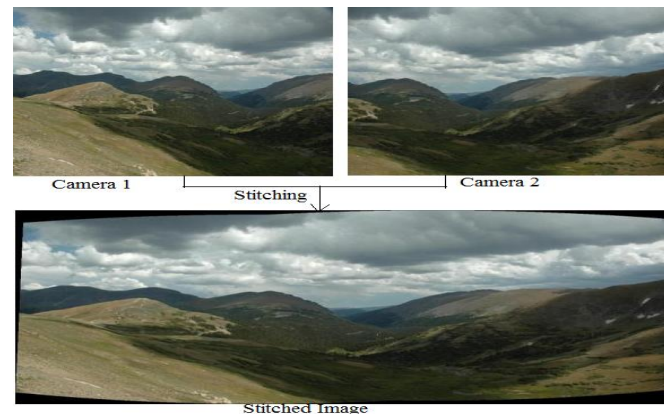
## ABSTRACT

*Image stitching is a technique to generate large field of view from multiple, overlapping images. It is used in many application such as computer vision, panoramic viewing of images and medical applications. This research is related to combine multiple images to make a panoramic view with overlapping region by the detection of feature points from images. In this paper, the performance of KLT, Harris and SIFT feature detector are analyzed for stitching of two images for indoor and outdoor circumstances. RANSAC is used to remove mismatches. All detector algorithms are compared with respect to matching rate and computation time. The experimental results shows SIFT gives better matching alignment than others. Also, SIFT takes more processing time to stitch images. Harris is the fastest feature detector among all.*

***Keywords: Harris, Image stitching, KLT, RANSAC, SIFT.***

## I. INTRODUCTION

Recently an image stitching is become increasingly common, for the panorama generation. It basically combines two or more different images to form one single image that is panorama. In past to capture a panoramic view one basic requirement was the different cameras in different location and at different angles. Still it was not possible to obtain a perfect panorama due to lack of coordination between the shots taken by camera due to time lag [1]. And also images observed by the human eye contain more information than the images captured by camera. This problem is solved by using multiple cameras but images captured by multiple cameras are tedious and also it is not helpful for the user to get entire scene in better vision. For this, image stitching is used to stitch multiple images together [2]. Also with the latest digital cameras with panorama facility have some restriction like when motion of camera and objects are in the similar direction in the scene, the grade of the panorama image is reduced due to the effect of either blurring and ghosting or both. And if the motion of camera is less than certain speed, it results in failure of capturing complete panorama image. The aim of stitching is to increase image resolution as well as the field of view.

The image stitching technique is used in many applications such as generating panoramic images, video compression and video matting. From Fig. 1, it is seen that the stitched image gives a more effective vision on the large scene than the two images taken from two different cameras separately. Image Stitching is the process of combining multiple images with overlapping fields of view to organize a high-resolution panorama which contains all the information of the sequence image. Panoramic image stitching is the process of generation of one panoramic image from a series of smaller, overlapping images [3]. Requirement of image stitching is exact overlaps between images and identical exposures to produce seamless results.



**Fig. 1 Output of Stitching two images [3]**

The image stitching technique is start with using a feature detector to extract the feature points from the images, and then to look for any matching pair compares the feature points. Parameters of a transformation is generated which is based on matching then images are transform into the same coordinate system for proper stitching. Finally, the stitching of images is carried out. In this paper, the performance of KLT, Harris and SIFT feature detectors is evaluated by extracting feature points from the images.

The paper is organized as follows. Study of many previous techniques and researches has discusses in Section II followed by Section III explains stitching techniques. Section IV describes the methodology. Section V gives experimental results. Finally paper is concluded in section VI.

## II. LITERATURE REVIEW

There are two types of image stitching algorithms. The first is the direct method and the second one is features based [4], [5]. In direct method pixel-to-pixel matching is used. A suitable error metric is used in direct method to compare the images. A suitable search technique is invented after the establishment of this. The simplest technique is to try all possible alignments. But this is too slow in practice, so for this hierarchical coarse-to-fine technique based on image pyramids is developed. Comparing with feature-based methods, measuring the contribution of every pixel by direct methods shows better performance over specific images like blurred images where feature-based registration could fail especially. But this type of images is rarely occurred in our work and those feature-based methods show a robust performance for changing in scale and lighting. The direct methods require an ambient initialization and also have limited range of convergence but during registration feature based methods do not require initialization. To find relevant image features like corners, point like structures, line intersections, line ending points or high curvature points, feature-based method is used which are used to

match between two or more images [6]. The intersection of two edges called as a corner. And also it is defined as points for which there are two dominant and different edge directions in a local neighbourhood of the point. From this feature based detector is used to detect features for image stitching in this paper.
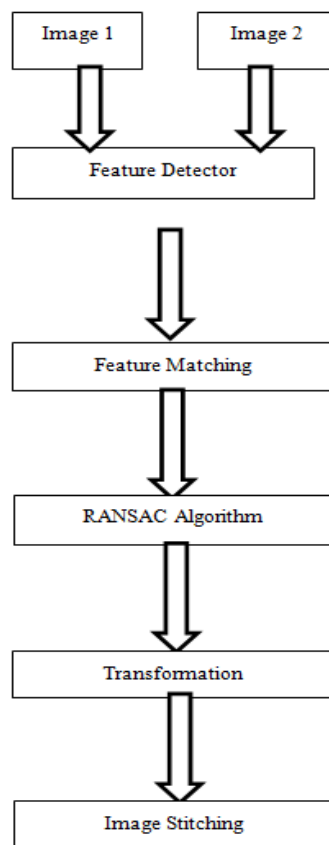
## III. IMAGE STITCHING

Fig. 2 shows the steps required for the stitching of images. In this paper the stitching will be carrying on two images. The image stitching process is start with feature detector to extract the feature points from the two images. In this paper, KLT, Harris and SIFT detectors are used for detection of features. After the feature point extraction, an "identity" is given to each of the feature points and it is obtained using the information which is acquired from the neighboring pixels of a feature point.

After the feature detector, the next step is match feature points which is obtained from the two images to determine the overlap region or similarity. The matching is done by comparing feature point to feature point.

Once a set of matched feature points is obtained, the Random Sample Consensus (RANSAC) algorithm is used to estimate transformation parameters [7]. Based on this, the RANSAC algorithm will try to estimate a model that is best fitted for them. Then, for computation of transformation parameters this best fitted model is used.

In new coordinate system, the new location of original pixel is determined by transformation parameters. The images can be stitched together using the transformation parameters.

For stitching two images we need to detect the features of each image. For feature detection KLT, Harris and SIFT feature detector is used which are explained in section A, B and C respectively.

**Fig. 2 Steps of Image Stitching**

## IV. METHODOLOGY

*A. KLT Detector*

KLT feature tracker, which is sometimes referred to as the Kanade-Tomasi corner detector, is based on the early work of Lucas and Kanade and was later developed fully by Tomasi and Kanade. For the location of good features there is need of examine the smallest eigenvalue of each 2 by 2 gradient matrix, and Newton- Raphson technique is used for tracking feature to reduce the variation between the two windows.

For Image $I(x)$ the matrix **G** is describe as [8]:

$$G = \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix} \qquad (1)$$

With $I_x = \frac{\partial I}{\partial x}$ and $I_y = \frac{\partial I}{\partial y}$

Shi and Tomasi show that a good feature is identified by analyzing the eigen values of G. For good feature detection the eigen values of G should be large. The window in question has smallest change in intensity when both eigenvalues are less and a one dimensional horizontal or vertical edge is describe only when one is less and one is more. If both eigenvalues are big then this shows the existence of a corner or some pattern that can be track surely. In practice, because the changes in intensity in a window are bounded by the maximum pixel value, when the smallest eigenvalue is big enough to describe an edge, the matrix G is well conditioned [8] [9]. Therefore if $\lambda_1$ and $\lambda_2$ are the eigenvalues of $G$ then the window shows a good "feature" to track if:

$$\min \lambda_1, \lambda_2 > \lambda_{th} \qquad (2)$$

where $\lambda_{th}$ is predefined threshold.

The goodness of the corners is measured as the smallest eigenvalue of $2 \times 2$ gradient matrix estimated from a specific window around the corners and only those whose eigenvalue meet requirement of equation (2) are accepted. $\lambda_1$ and $\lambda_2$ is Calculated by,

$$\lambda_1 = \frac{a_{11}+a_{22}}{2} + \sqrt{\frac{(a_{11}-a_{22})^2}{4} + a^2{}_{12}} \qquad (3)$$

$$\lambda_2 = \frac{a_{11}+a_{22}}{2} - \sqrt{\frac{(a_{11}-a_{22})^2}{4} + a^2{}_{12}} \qquad (4)$$

Where,

$$a_{11} = \sum_{(i,j)} I^2{}_x(i,j)$$

$$a_{12} = a_{21} = \sum_{(i,j)} I_x(i,j)\, I_y(i,j)$$
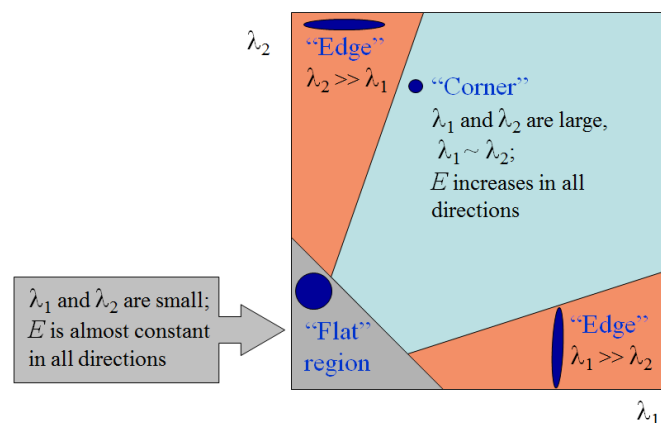
$$a_{22} = \sum_{(i,j)} I^2{}_y(i,j)$$

### B. Harris Detector

The Harris corner detector is constructing using the local auto-correlation function of a signal; where the local auto-correlation function calculates the local changes of the signal with patches shifted by a less amount in different directions. Here pixel gradient variation is calculated. In this algorithm, to decide pixel as corner the absolute gradient value must be change in all directions [2] [10]. It is used to detect the corners. It is able to do quickly and easy detector.

$$R = \det(M) - k\big(trace(M)\big)^z \qquad (5)$$

$$M = G(\sigma) * \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix} \qquad (6)$$

R is measure the corner response at each pixel coordinates $(x, y)$. $k$ is a constant and value is 0.04 and $I_x = \frac{\partial I}{\partial x}$ and $I_y = \frac{\partial I}{\partial y}$. G($\sigma$) is an isotropic Gaussian filter with standard deviation $\sigma$ and the operator * denotes convolution.

**Fig. 3 Harris Operator [10]**

There are three conditions to be considered:

$\lambda_1$, $\lambda_2$ are eigenvalues of M.

1. When $\lambda_1$, $\lambda_2$ both are small the local auto-correlation function is flat, changes are not dramatic.

2. One eigenvalue is large and one is small this means partial autocorrelation function changes slightly in one direction, changes in the vertical direction is more means this indicates an edge.

3. When the both $\lambda_1$, $\lambda_2$ are large, indicating the local autocorrelation function is at a peak, this indicates a corner.

*C. SIFT Detector*

The Scale Invariant Feature Transform (SIFT) algorithm was proposed by Lowe in the year 1999. It is used to detect and describe features in images. It is invariant to image scale and rotation. SIFT is slow for image comparison but it is robust algorithm to noise, illumination. The steps for SIFT are [11]:

1. Scale-space extrema detection: It is first step where the Interest or keypoints are detected. It uses a difference-of-Gaussion function which is an approximation of LoG.

2. Keypoint Localization: Scale-space extrema detection generates too many keypoint but some are unstable. So they are refined for more accuracy. For this Taylor series expansion of scale space is used to get more accurate location of extrema. The extreme points and location are determined by using following equation:

$$D(x) = D + \frac{\partial D^T}{\partial x} x + \frac{1}{2} x^T \frac{\partial^2 D}{\partial x^2} x \qquad (7)$$

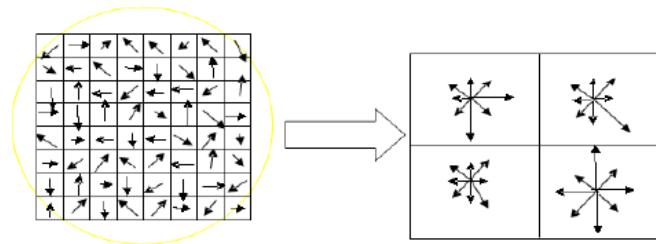3. Orientation Assignment: Here an orientation is assigned to each keypoint to achieve invariance to image rotation. A neigbourhood is taken around the keypoint location depending on the scale, and the gradient magnitude m(x,y) and direction θ(x,y) for an image I(x,y) is calculated by,

$$m(x,y) = \sqrt{\left(L(x+1,y) - L(x-1,y)\right)^2 + \left(L(x,y+1) - L(x,y-1)\right)^2} \qquad (8)$$

$$\theta(x,y) = \tan^{-1}\left(\frac{L(x,y+1) - L(x,y-1)}{L(x+1,y) - L(x-1,y)}\right) \qquad (9)$$
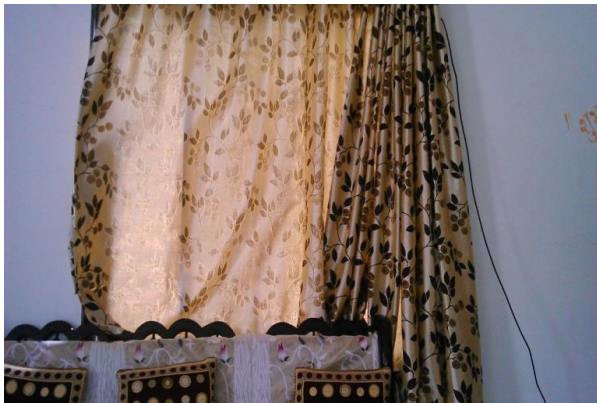
4. Key point descriptor:

In this step, descriptor of keypoint is computed as shown in Fig. 4. Feature vectors are generated to form keypoint descriptor. The arrow in each cell stands for gradient direction along with the amplitude of pixels. In addition to this, several measures are taken to achieve robustness against illumination changes, rotation etc.
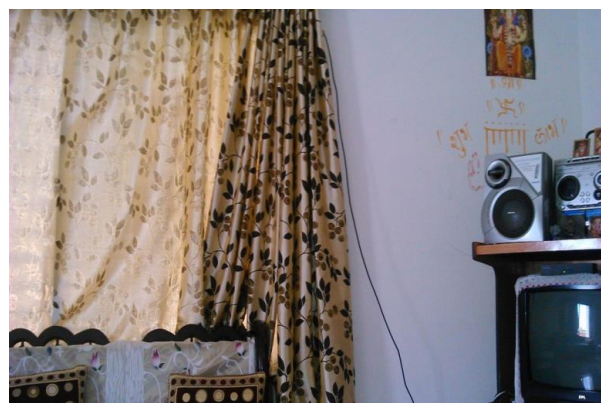
**Fig. 4 Feature Vector Generation [11]**
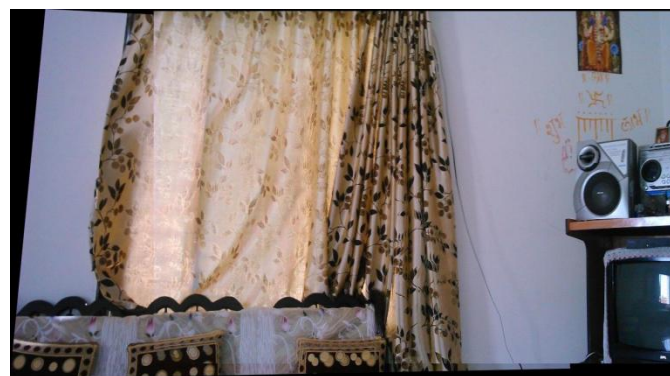
## V. RESULTS & DISCUSSIONS

To evaluate the performance of the KLT, Harris and SIFT detector, the experiments carried on images which are taken by the camera. Images are taken with the help of NOKIA Lumia 830 windows phone with scree. The performance of KLT, Harris and SIFT detector is expressed in terms of time. The numbers of match features, inliers, outliers, matching rate and computation time for stitching as shown in table I. Two indoor input images are taken for stitching as shown in Fig.5 and Fig.6. Output stitched images using KLT, Harris and SIFT detector are shown in Fig.7, Fig. 8 and Fig. 9 respectively. Table I show the comparison of performance analysis of KLT, Harris and SIFT detector for indoor images.



**Fig. 5 Indoor Image 1**        **Fig. 6 Indoor Image 2**



**Fig. 7 Output of Image stitching using KLT detector**

**Fig. 8 Output of Image stitching using Harris detector**

**TABLE I comparison of performance analysis of klt, harris and sift detector for indoor images**
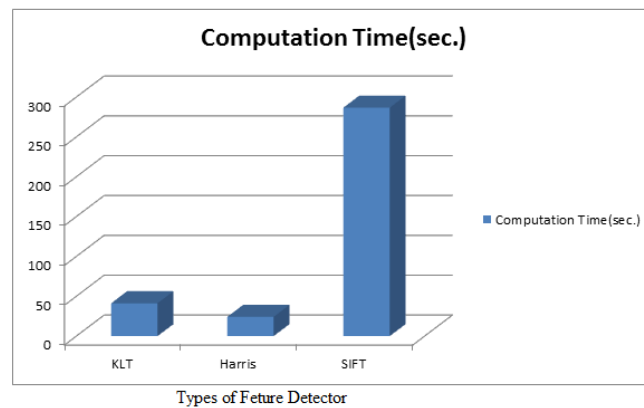
| Parameters | KLT | Harris | SIFT |
|---|---|---|---|
| Number of Match Features | 129 | 261 | 568 |
| Number of Inliers | 48 | 171 | 395 |
| Number of Outliers | 80 | 90 | 173 |
| ComputationTime (sec) | 41.22 | 24.08 | 286.62 |
| Matching Rate (%) | 37.20 | 65.51 | 69.54 |



**Fig. 9 Output of Image stitching using SIFT detector**

From Table I, it depicts that SIFT detects more features as compared with others and these features are invariant to rotation, scaling, blurring and illumination. It has highest percentage matching rates. Iterations for feature matching are kept constant for all algorithms. In spite of these, computation time required to stitch images is more. Harris algorithm detects corners in very less time of span. The comparison of computation time is shown in Fig. 10.

**Fig. 10 Computation time of KLT, Harris and SIFT detector for Indoor images**

## VI. CONCLUSION

In this paper direct and feature based methods of stitching are discussed. The performance of feature corner detectors is expressed in terms of computation time and matching rate for indoor scenario. It is observed that the Harris detector is better than KLT and SIFT detector in terms of computation time. The percentage matching rate using SIFT is improved by 32.34 % as compared with KLT and 4.03 % as compared with Harris. In future, we employ same technique over outdoor images. Also, different variants of SIFT algorithm is compared with qualitative and quantitative parameters.

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