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A Survey of Feature Based Image Registration Algorithms: Performance Evaluation of SIFT Algorithm

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Abstract- Image registration is a process of aligning two or more images of the same scene collected at different time periods, using different sensors, and from different perspectives in efficient manner. Image registration finds applications in matching a target with a real-time image of a scene, target recognition, monitoring global land usage using satellite images, matching stereo images to recover shape for navigation, and aligning images from different medical modalities for diagnosis. This paper summarizes the robust feature based image registration algorithms: Scale Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF), Principal Component Analysis (PCA), Normalized Cross-Correlation(NCC), K-Nearest Neighbor (KNN), KD tree, Random Sample Consensus (RANSAC), Best Bin First (BBF), Mosaic. SIFT presents its stability in most situations although it's slow and finds application in removing redundant areas. SURF is the fastest one with good performance as the same as SIFT. PCA-SIFT show its advantages in rotation and illumination changes.

Key words: **SIFT SURF, PCA-SIFT, NCC, KNN, RANSAC, BBF, and MOSAIC.**

I. INTRODUCTION

Image registration is an important pre-processing step in many image processing applications such as computer vision, remote sensing and medical image processing [8]. Its purpose is to overlay two or more images of the same scene taken at different times or from different viewpoints and/or by different sensors [9],[10],[15]. There are four basic steps for image registration, 1) feature detection, 2) feature matching, 3) mapping function design, and 4) image transformation and resembling [2]. In this paper we propose an algorithm where SIFT, RANSAC, NCC, PCA-SIFT, KNN, and BBF [15],[16],[17] together is used to determine the corresponding points in the overlapping areas of both the images [3]. SURF is the fastest one with good performance as the same as SIFT. PCA-SIFT [15],[16],[17] show its advantages in rotation and illumination changes [4]. Best bin first search using KD tree is used for feature matching.

II. STEPS INVOLVED IN IMAGE REGISTRATION

Image registration essentially consists of following steps as per Zitova and Flusser [2].
Figure 1 illustrates the process.

- **Feature detection:** Salient and distinctive objects (closed-boundary regions, edges, contours, line intersections, corners, etc) in both reference and sensed images are detected.
- **Feature matching:** The correspondence between the features in the reference and sensed image established.
- **Transform model estimation:** The type and parameters of the so-called mapping functions, aligning the sensed image with the reference image, are estimated.
- **Image resembling and transformation:** The sensed image is transformed by means of the mapping functions.

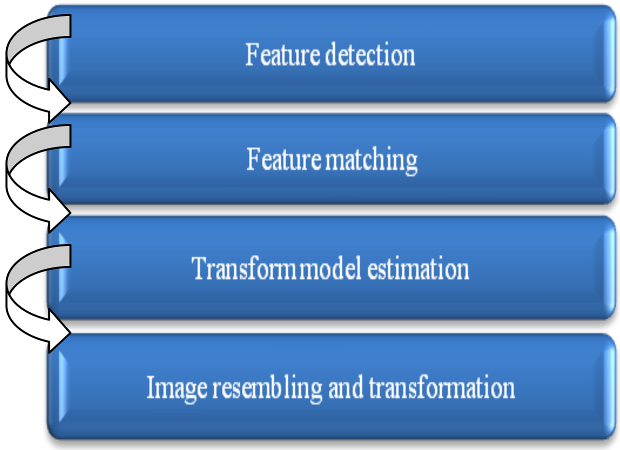

Fig 1: Steps involved in Image Registration

III. OVERVIEW OF DIFFERENT ALGORITHM

A. Scale Invariant Feature Transform (SIFT)

The SIFT algorithm developed by Lowe (2004) is invariant to image translation, scaling rotation, and partially invariant to illumination changes and affine 3D projection. SIFT consists of four major stages:

- Scale-space extrema detection
- Key point localization
- Orientation assignment
- Key point descriptor.

The first stage used difference-of-Gaussian function to identify potential interest points, which were invariant to scale and orientation. DOG was used instead of Gaussian to improve the computation speed [4].

$$D(x, y,\sigma) = (G(x, y, k\sigma) - G(x, y,\sigma)) \times I(x, y) \quad \ldots\ldots (1)$$

Where, G is the Gaussian function and I is the image.

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In the key point localization step, they rejected the low contrast points and eliminated the edge response. Hessian matrix was used to compute the principal curvatures and eliminate the key points that have a ratio between the principal curvatures greater than the ratio. An orientation histogram was formed from the gradient orientations of sample points within a region around the key point in order to get an orientation assignment [1].

B. Speeded Up Robust Features (SURF)

SURF (Speeded-Up Robust Features) approximates or even outperforms respect to repeatability, distinctiveness, and robustness, yet can be computed and compared much faster. The task of finding point correspondences between two images of the same scene or object is part of many computer vision applications [13].

The search for discrete image point correspondences can be divided into three main steps. First, 'interest points' are selected at distinctive locations in the image, such as corners, blobs, and T-junctions. The most valuable property of an interest point detector is its repeatability. The repeatability expresses the reliability of a detector for finding the same physical interest points under different viewing conditions.

Next, the neighborhood of every interest point is represented by a feature vector. This descriptor has to be distinctive and at the same time robust to noise, detection displacements and geometric and photometric deformations.

Finally, the descriptor vectors are matched between different images. The matching is based on a distance between the vectors, e.g. Euclidean distance. The dimension of the descriptor has a direct impact on the time this takes, and less dimensions are desirable for fast interest point matching. However, lower dimensional feature vectors are in general less distinctive than their high-dimensional counterparts [13].

C. Principal Component Analysis (PCA) – SIFT

Local descriptors (termed PCA-SIFT) accept the same input as the standard SIFT descriptor: The Sub-pixel location, scale, and dominant orientations of the key point. PCA-SIFT can be summarized in the following steps:

- Pre-compute an eigenspace to express the gradient images of local patches.
- Given a patch, compute its local image gradient.
- Project the gradient image vector using the eigenspace to derive a compact feature vector.

This feature vector is significantly smaller than the standard SIFT feature vector, and can be used with the same matching algorithms. The Euclidean distance between two feature vectors is used to determine whether the two vectors correspond to the same key point in different images [7].

Principal Component Analysis (PCA) is a standard technique for dimensionality reduction and has been applied to a broad class of computer vision problems, including feature selection, object recognition and face recognition. While PCA suffers from a number of shortcomings, such as its implicit assumption of Gaussian distributions and its restriction to orthogonal linear combinations, it remains popular due to its simplicity. The idea of applying PCA to image patches is not novel. Our contribution lies in rigorously demonstrating that PCA is well-suited to representing key point patches (once they have been transformed into a canonical scale, position and orientation), and that this representation significantly improves SIFT's matching performance [7].

D. Normalized Cross-Correlation (NCC)

Normalized cross correlation (NCC) has been commonly used as a metric to evaluate the degree of similarity or dissimilarity between two compared images. The main advantage of the normalized cross correlation over the cross correlation is that it is less sensitive to linear changes in the amplitude of illumination in the two compared images. Furthermore, the NCC is confined in the range between –1 and 1. The setting of detection threshold value is much easier than the cross correlation. The NCC does not have a simple frequency domain expression. It cannot be directly computed using the more efficient FFT (Fast Fourier Transform) in the spectral domain. Its computation time increases dramatically as the window size of the template gets larger [15],[16],[17].

Correlation-based methods have been used extensively for many applications such as object recognition, face detection, motion analysis and industrial inspections of printed-circuit boards, surface-mounted devices, printed characters, fabrics, ceramic tiles, etc. The traditional normalized correlation operation does not meet speed requirements for industry applications.

Correlation is to reduce data dimensionality by converting the 2D image into a 1D representation. The traditional normalized cross correlation [15] is one of the most effective and commonly used similarity metrics in computer vision. However, it does not meet speed requirements for time-critical applications.

E. Random Sample Consensus (RANSAC)

RANSAC is an abbreviation for "Random Sample Consensus". It is an iterative method to estimate parameters of a mathematical model from a set of observed data which contains outliers. It is a non-deterministic algorithm in the sense that it produces a reasonable result only with a certain probability, with this probability increasing as more iteration are allowed. The algorithm was first published by Fischer and Bolles at SRI International in 1981 [12].

A simple example is fitting of a line in two dimensions to a set of observations. Assuming that this set contains both inliers, i.e., points which approximately can be fitted to a line, and outliers, points which cannot be fitted to this line, a simple least squares method for line fitting will in general produce a line with a bad fit to the inliers. The reason is that it is optimally fitted to all points, including the outliers. RANSAC [2],[11],[15],[16],[17] on the other hand, can produce a model which is only computed from the inliers, provided that the probability of choosing only inliers in the selection of data is sufficiently high. There is no guarantee for this situation, however, and there are a number of algorithm parameters which must be carefully chosen to keep the level of probability reasonably high.

An advantage of RANSAC [11] is its ability to do robust estimation of the model parameters, i.e., it can estimate the parameters with a high degree of accuracy even when a significant number of outliers are present in the data set.

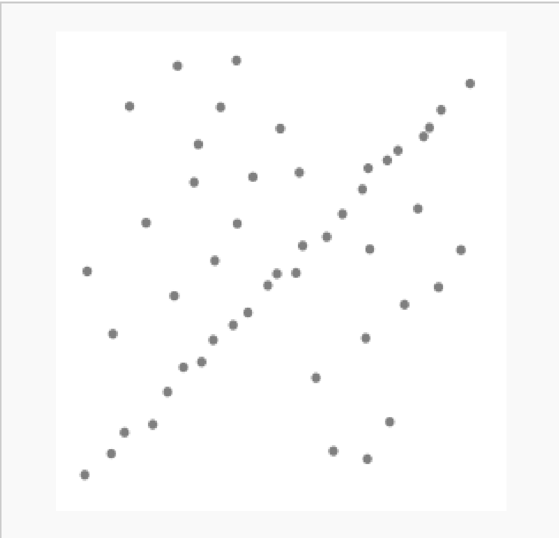

Fig 2: A Data Set with Many Outliers

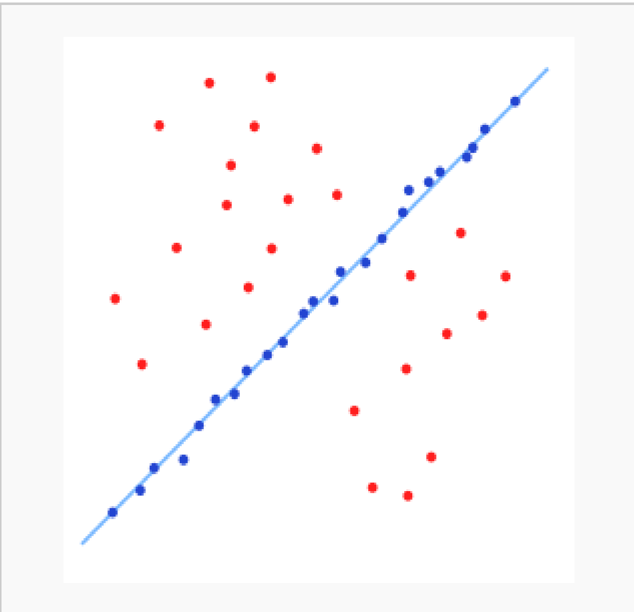

Fig 3: Fitted line of Outliers with RANSAC

Here figure 2 shows data set with many outliers, but when we use RANSAC for this scenario, this shows fitted line with outliers have no influence on the data set.

F. Best bin first (BBF)

Best bin first is a search algorithm that is designed to efficiently find an approximate solution to the nearest neighbor search problem in very-high-dimensional spaces [3]. The algorithm is based on a variant of the Kd-tree Search algorithm which makes indexing higher dimensional spaces possible. Best bin first is an approximate algorithm which returns the nearest neighbor for a large fraction of queries and a very close neighbor otherwise

G. Mosaic

Image mosaicing is an active area of research in computer vision. The various methods adopted for image mosaicing can be broadly classified into direct methods and feature based methods [2], [11]. Direct methods are found to be useful for mosaicing large overlapping regions, small translations and rotations. Feature based methods can usually handle small overlapping regions and in general tend to be more accurate but computationally intensive. Some of the basic problems in image mosaicing are the following:

- **Global alignment:** Global Alignment involves calculation of the transform (homography), which aligns two images.
- **Local adjustment**: Even after good global alignment, some pixel might not align in the two images. This might cause ghosting or blur in the blended image.
- Automatic selection of images to blend from a given set of images.
- Image blending: After one of the images has been transformed using the homography calculated above a decision needs to be made about the color to be assigned to the overlapping regions. Blending also becomes important when there exists a moving object in the images have been taken.
- Auto exposure compensation: Most cameras have an automatic exposure control. The images taken can therefore be of variable brightness in the overlapping region which might cause the mosaic to look unrealistic [13].

IV. RESULTS ANALYSIS

Fig 4: Test Image 1 and Test Image 2

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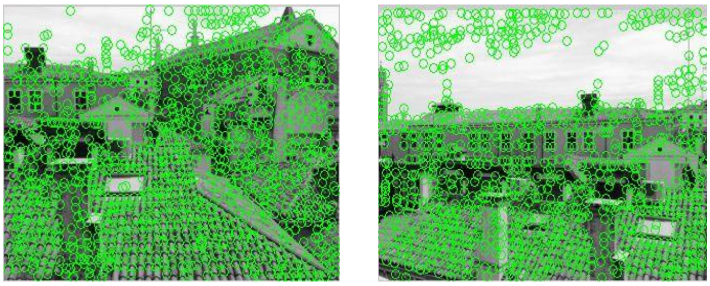

Fig 5: Detected Features using RANSAC of Test Image 1& Image 2

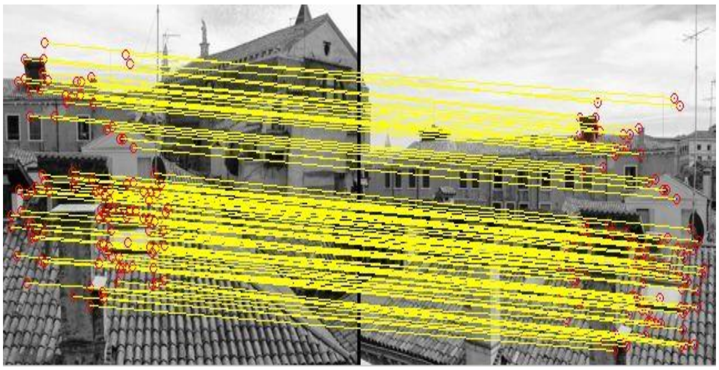

Fig 6: Key Points Matching between Image 1 & Image 2

Fig 7: Registered Image using SIFT Algorithm

Fig 8: Test Image 3 and Test Image 4

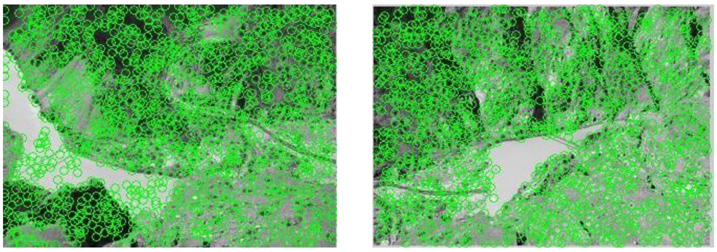

Fig 9: Detected Features using RANSAC of Test Image 3 & Test Image 4

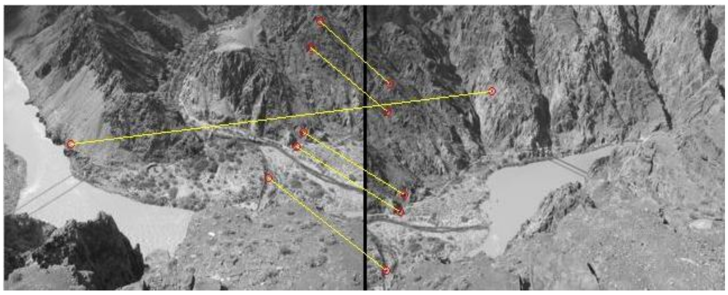

Fig 10: Key Points Matching between Image 3 & Test Image4

Fig 11: Registered Image using SIFT Algorithm of Test Image 3 & 4

Figure 4 shows two input images (240 x 320) on which RANSAC algorithm is applied feature extraction and detection. In the Test Image 1, 1095 key points are detected and in Test image 2, 931 key points are detected which is shown in figure 5. From these all 105 key points are matched shown in figure 6. After this matching SIFT algorithm is applied to get registered image shown in figure 7. Another example of SIFT algorithm is shown in below sequential figures.

From the figure 7 and figure 11, it can be seen that by higher number of features matching 90% to 95 % percentage portion of main images get registered and also take less registration time. Otherwise due to less key points matching registered image get disturbed and also take high registration time. Here figure 7 takes registration time 15.15sec, while for figure 11 time taken 24.11sec for registration

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V. CONCLUSION

Various methods are reported in literature to register images which are in same band. The feature based method makes use of features like point of intersection, edges, corners, centers of contours etc. for matching sample template with reference image. But this method is slow and hence time consuming. The main advantage of feature based method (SIFT Algorithm) filter out the redundant information and gives accurate output. Our future scope is to make these algorithms work for the video registration and also make HARRIS affine region detector algorithm for image as well as video registration.

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