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Hybrid Invariant Local Features for Multiple Satellite Image Matching and Registration

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Abstract: ***Automatic image registration (IR) is very challenging and very important in the field of hyperspectral remote sensing data. Efficient autonomous IR method is needed with high precision, fast, and robust. A key operation of IR is to align the multiple images in single co-ordinate system for extracting and identifying variation between images considered. In this paper, presented a feature descriptor by combining features from both Feature from Accelerated Segment Test (FAST) and Binary Robust Invariant Scalable Key point (BRISK). The proposed hybrid invariant local features (HILF) descriptor extract useful and similar feature sets from reference and source images. The feature matching method allows finding precise relationship or matching among two feature sets. An experimental analysis described the outcome BRISK, FASK and proposed HILF in terms of inliers ratio and repeatability evaluation metrics.***

Keywords: ***Automatic image registration, BRISK, Feature from Accelerated Segment Test feature, inliers ratio, repeatability.***

I. INTRODUCTION

Satellite IR (SIR) plays a significant feature in building countries infrastructure development, which includes town and urban planning and management [1], [2]. Along with, SIR becomes into a basic element in identifying and detecting any change in environmental condition, pollution monitoring, nation border security monitoring [3], [4] etc. Feature sets that affects the IR operation and accuracy of satellite images are distortion, objects motion, sensor characteristics, and higher computational overhead. All these feature set characteristics makes SIR a challenging task [5]. Traditionally, SIR approaches can be classified into two types such as, Feature based approaches and area (i.e., intensity and spatial) based approaches [6]. The feature based approaches utilizes the useful feature sets of satellite pictures for example edges, lines, point sets and so on. The identified feature sets are distinguished and compared to locate the necessary change feature values [7, 8]. Such pictures are progressively adequate for further utilizing these picture for land cover variation detection task, object detection and identification, etc. [9]. On the other side,

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Area based approaches, spatial parameter of each pixel in hyperspectral pictures are utilized for figuring it out the identicalness metrics like objective strategy for determining the transformation optimization. Though, for large hyperspectral pictures the computation complexity is higher fir area based approaches.

In this scenario, feature based technique is employed for Image Registration (IR). The model is composed of four phases such as, FM (Feature Matching), FE (Feature Extraction) transformation and SIR [10], [11]. Initially, feature extraction is the action of mapping the image from feature space, which mainly depends on descriptor schemes. In SIR, numerous feature descriptor methods are employed such as, SURF (speeded up robust features), HOG (Histogram of oriented gradients), Local Binary Pattern etc. [12]. For improving the SIR outcomes, a suitable hybrid combination of descriptors are undertaken for this experimental analysis. After employing hybrid feature descriptors, the common point sets among source and referenced satellite pictures are determined [13, 14]. Then, a suitable transform scheme is applied for transforming the source satellite pictures to be aligned with respect to reference satellite pictures. Whereas, numerous number of IR transform schemes are available such as, Affine Transform, Local Weighted Mean etc. [15]. The combination of hybrid feature descriptors with suitable transform method eliminates the false matching points. By eliminating more number of false matching points the accuracy of SIR improves in an effective manner. In this paper, hybrid feature descriptor increase the inliers ratio and decrease the outlier's ratio effectively then improving the satellite image registration.

The manuscript is organized as follows. The sectionII, discusses about several existing technique of SIR using various descriptors. In section III, the proposed methodology for SIR is presented. The experiment analysis is carried out and discussed for comparing proposed SIR method over various existing SIR method in section IV. Lastly, the research is conclude with future research direction.

II. LITERATURE SURVEY

This section carryout survey of various existing satellite image registration technique. Zhao, et al. [16] evaluated the multi-date or multispectral images with related patterns, low overlapping areas, or high transformation using dual graph based matching technique. Primarily, the normalization of gradient orientation and increasing the scale ratio similarity of all matching points using scale invariant feature transform was presented. Next, Delaunay graphs (DG) were used for elimination of outliers, after that the respective outliers is chosen using or checking DG formation differences. So as for obtaining the rejected/eliminated inliers into the DG triangulation matching iterative process and for rejecting the outstanding outliers, the improvement approach prepared using the bi-graph of DG was discovered. Parmehr, et al. [17], for improving SIR reliability presented a window size selection method. The advanced technique establishing the superior window size for calculation of probabilistic density function. Along with, for examination of the connection among the identicalness estimate parameters of the information. This majorly focuses on the element of Mutual Information complexities for carrying out transformation. Further, moderately the Mutual Information element that was not related to transformations like noisiness. The advanced method registration performance of satellite image data to LiDAR point cloud was scrutinized and investigational outcomes were evaluated with feature based registration process.

Xu, et al. [18] proposed a Jeffrey's divergence (JD) the, the resemblance calculates in practical multimodal IR tasks. Here, the statistical evaluation is done for examining the causes that limits the usage of mutual Information when handling the inadequate section overlapping picture pairs. Experiment analysis of satellite IR includes different kinds of images. Along with, carryout comparative analysis of JD and MI. The outcome shows JD was proficient of giving the better search space. The result obtained are encouraging for discovering optimal transformation outcome. Yufeng, et al. [19] illustrated a hybrid satellite IR model combining both genetic algorithm (GA) FCM (Fuzzy C Means). This technique applied in image registration, which taken two similar region based images but various instance utilizing SIFT and Harris operator. Here, initial image differences are estimated with the help of combination of ratio and logarithmic approach. Moreover for reducing the image dimension purpose Principal Component Analysis (PCA) algorithm was utilized, later hybrid feature technique was used to improve the classification accuracy, these outcomes have been matched for respective target satellite picture. Yang, et al. [20] presented an IR for using affine method and invariant feature extraction methods. The advanced technique localize the features efficiently in Synthetic Aperture Radar (SAR) using extraction technique as Salient Image Disks (SIDs). An unstable features are removed with the help of multi resolution search method. The experimental results indicated as an advanced scheme was outperforms the exiting SID technique in terms of stability of feature points as well as localization accuracy. The proposed method was less sensitive but high outlier ratio this effect the IR.

III. PROPOSED METHODOLOGY

In proposed methodology, the hybrid feature descriptor is (combination of BRISK and FAST) extract the local as well as global features from the input image. Moreover, the local and global features are extracted through BRISK, which is finding the key point orientation and rotation finds of features in image. The most promising feature descriptor FAST is computationally efficiency and later it is utilized for extracting the feature points, also helps to track and map objects. The proposed descriptor increases the inliers ratio and reduce the outlier's ratio due to improve the satellite IR. Experimental derivation of hybrid feature descriptors are explained in Fig. 1.

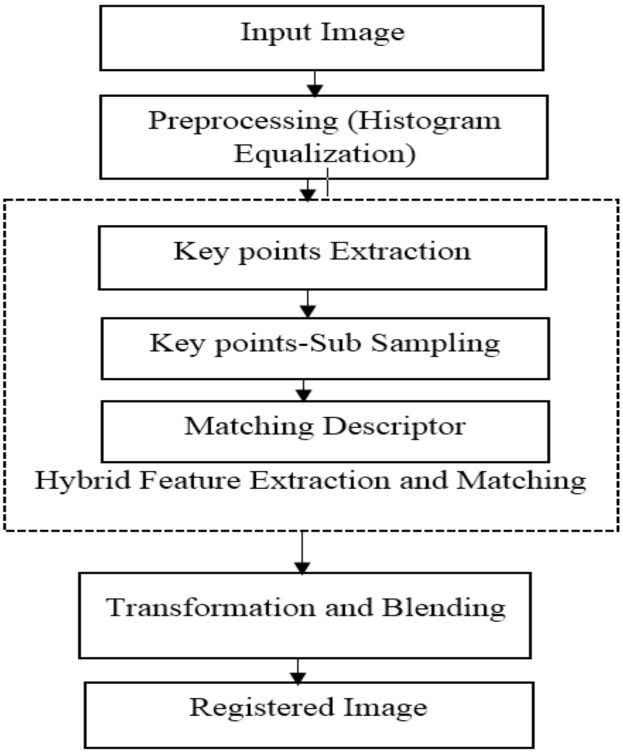


Fig. 1.Proposed Architecture

A. Preprocessing

The Histogram Equalization (HE) preprocessing technique is used in satellite image registration process. HE is a process that changing the distribution of gray scale value in an image so that it becomes uniform. The objective of HE method is acquire the unvarying spread of the histogram as a result every gray scale value has equal number of pixels and mathematically represented in equation (1),

$$s = T(r) \qquad (1)$$

where, s is the new gray scale, T is the transformation and r is the changed gray scale of pixel. Mathematically can be written by the equation r can be recovered from s with inverse transformation as in the equation (2)

$$r = T^{-1}(s) \qquad (2)$$

where, $0 < s < 1$ the equation used to calculate the HE can be written as follows:

$$k_0 = round\left(\frac{C_i(2^k - 1)}{w.h}\right) \qquad (3)$$

where, k_0 is the gray level value from histogram equalization, C_i is the cumulative distribution of i^{th} grayscale from original image, round is rounding to the nearest value, w is the width of the image and $h$is the height of the image. This method is also useful for images with both background and foreground are bright or both dark.

B. Hybrid Feature Combination in Satellite Image Registration

The proposed feature descriptor is consist of BRISK and FAST and extract the relevant features from satellite image. The BRISK is the key point feature and local feature extractor and FAST is the corner detector in image. The following feature descriptors are explained in below section,

BRISK (Binary Robust Invariant Scalable Key) points descriptor: The BRISK is a texture descriptor, which accomplishes essential quality of matching and extract the valuable key points from an input image with limited computation time. In here, we employ the SSP (Symmetric Sampling Pattern) over the sample point of given pixels in the FD (Feature Descriptor), here the image intensity is represented as i_x , later Gaussian with SD σ_x is applied, moreover the Gaussian along with the SD is equal to the distance between the points and circle. In any image k is the key point, which is patterned in accordance with the position and scale and SPP (Sampling Point Pair) is denoted as i_x and i_y. $S(i_x, \sigma_x)$ and $S(i_x, \sigma_x)$ are the smooth value and with the help of these value we compute the local gradients, $G(i_x, i_y)$ is represented as the mathematical term for local gradient and it is depicted through equation 4

$$G(i_x, i_y) = (i_y - i_x).\frac{S(i_{y,}\sigma_y) - S(i_{x,}\sigma_x)}{\|i_y - i_x\|^2} \quad (4)$$

Lets assume the A is set and the SPP(Sampling Point Pairs) is presented through the equation 5.

$$A = \{(i_x, i_y) \in K^2 * K^2 | x < N \wedge y < x \wedge x, y \in N\} \quad (5)$$

Here, N indicates sampling point pair number, later these pixel pairs are divided into the two distinctive sub-set named as long distance and short distance pair. These are denoted as d_2 and d_1 respectively, below given equation 6 and equation 7 represents the sub-set pairings.

$$d_1 = \{(i_x, i_y) \in A | \|i_y - i_x\| < \delta_{max}\} \subseteq A \quad (6)$$

$$d_1 = \{(i_x, i_y) \in A | \|i_y - i_x\| < \delta_{min}\} \subseteq A \quad (7)$$

Moreover, from the equation it is observed that local gradient might not be as useful as it is global gradient information, hence now we set the threshold distance of value $\delta_{max} = 9.75t$ and $\delta_{min} = 9.75t$ (t is observed as scale of k). Meanwhile the iteration takes place through the L in order to determine the whole pattern direction of particular key point i.e., sk, this is depicted through the given below equation.

$$G = \begin{pmatrix} G_x \\ G_y \end{pmatrix} = \frac{1}{L}. \sum_{(i_x,i_y)\in L} G(i_{x,}i_y) \quad (8)$$

$\alpha = arctan2(G_y, G_x)$ indicates the sample pattern rotation of the given key point, later the intention is to create the binary descriptor denoted as b_k and this is achieved trough short distance pairing followed by that we use the pair in F to compute each and every bit in s b_k. This results in descriptor to be long as 512 bits and collected through the SDD (Short distance Density) on the described binary feature vector and can be represented through the below equation.

$$v = \begin{cases} 1, & S(i_y^\alpha, \sigma_y) > S(i_x^\alpha, \sigma_x) \\ 0, & Otherwise \end{cases} \forall (i_x^\alpha, i_y^\alpha) \in F \quad (9)$$

FAST (Features from Accelerated Segment Test descriptor: A FAST feature descriptor is the corner detection scheme, is identify the every pixel of candidate points using segment test and corner of the candidate pixel as based of computation. For example in Bresenham circle, n is the set of contiguous pixels and radius r, the threshold value t and intensity of candidate pixel is I_p,

Moreover first test gives the outcome of various adjacent response near the interest point, later the extra criteria is implied such that non-maximum suppression can be performed. This in terms gives the authority for precise feature localization. Equation 10 gives the cornerness measure.

$$C(x, y) = max\left(\sum_{j\in S_{bright}} |I_{p\to j} - I_p| - t, \sum_{j\to S_{dark}} |I_p - I_{p\to j}| - t\right) \quad (10)$$

where, where $I_p \to j$ Indicates the pixel which lay on BC (Bresenham circle), and this causes the processing time to be minimized since second test is evaluated on the image fraction points, these image fraction points passes the first test.

C. Feature matching

Moreover in this sub section we discuss about the feature matching, after detecting the feature and sensing the image feature matching takes place. The main aim of feature matching is to determine the particular feature of the reference image that corresponds to the sensed image feature by means of their neighborhood, intensity value. The major two types of feature matching is employed such as area based and feature based. The following feature matching methods are described below.

Sum of Squared Differences: The Sum of Squared Difference (SSD) method is calculate the difference among two image intensity based on pixel by pixel. It estimate the summation of squared product of pixels subtraction between two images. This metric measure the matching point give the location of minimum value in the image. Generally, SSD is directly using the formulation of sum of square error and described in equation (11),

$$\iint_A (f - g)^2 \quad (11)$$

If the above equation is converted into digital form is represented in equation (12),

$$SSD(i, j) = \sum_{i=0}^{M} \sum_{j=0}^{N} \big(f(i, j) - g(i + u, j + v)\big)^2 \quad (12)$$

where Msize of rows in reference is image and N is size of column while u and v are defined variable and shift component in given X and Y direction respectively, depending on variable u and v Term of template is set whether it is constant or not.

Euclidean distance: Euclidean Norm is mainly used for matching the similarity of vector-based features and this is achieved by using the nearest neighbor matching in ED (Euclidean Distance). Moreover, for suppressing the matching member, which can be considered as ambiguous ratio among the next nearest and the distance to the nearest image descriptor, needs to be comparatively less than the given threshold.

Mathematical equation of Euclidean distance as in equation (13),

$$\Delta d = \sqrt{\sum_{i=1}^{n} (|Q_i - D_i|)^2} \quad (13)$$

where Q, and D are the different feature vectors of input images.

In order to measure the similarity index the most common approach is distance matrix in the image retrieval mainly due to its effectiveness and efficiency.

D. Feature matching

The affine transformation is appropriately to match the two satellite images are taken from different position but same viewing angle. It is composed of scaling, translation and rotation. An affine transformation corrects some global distortions in the images to be registered. Given two images needs to registered and it is globally aligned in such a way that anatomical structure should match. Rigid and Affine transformations are global transformations and equations of affine transformation shown in equation (14),

$$P = Ap + t \quad (14)$$

where, A and t are the affine transformation matrix and translation vectors respectively and P is the linear translation. The general 2D affine transformation can be given in equation (15),

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} tx \\ ty \end{bmatrix} + \begin{bmatrix} a_1 & a_2 \\ a_4 & a_5 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (15)$$

Global transformation is said to be one where all pixel suffer from the same transformation and this results in fast and simple computation since less parameters are involved.

Linear Blending: The LB (linear blending) scheme blends as a pre-processing from the same given satellite for registration process, Dyadllic also known as two input operator is on of the linear blend operator and given in the equation (16),

$$g(x) = (1 - d)f_0(x) + \alpha f_1(x) \quad (16)$$

where, $f_0(x)$ and $f_1(x)$ share same size and type and these two are used as the source image, later we compute the weighted sum of two given arrays and depicted in the equation (17).

$$st = \alpha f_0(x) + \beta f_1(x) + \gamma \quad (17)$$

By varying α(weights of the first image) from 0 to 1 this operator can be used to perform a temporal cross-dissolve between the two images. The $g(x)$ will generate an image, assume that $\beta = (1 - \alpha)$ is the weight of the second image.

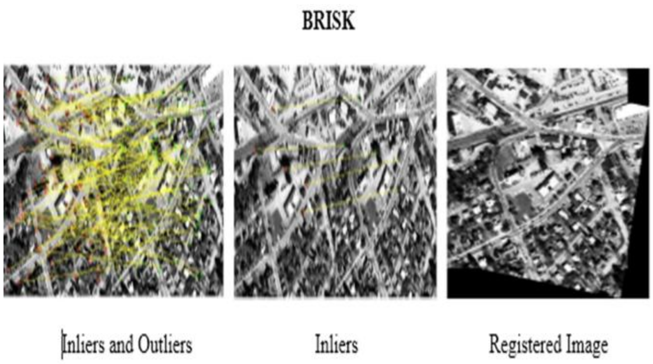
Hybrid feature possesses a marginal rate of inliers and extract the key point in each region. The proposed descriptor only extract inside of the region from input image and the outside regions are ignored. The next section describe the experimental result and discussion of the satellite image registration.

IV. EXPERIMENT RESULT AND DISCUSSION

This section discuss evaluation and experiments results in details, this proposed work has been evaluated under some system configuration such as it uses the Pentium IV process with MATLAB as a programming language with its 2017 A version. Moreover SIR (Satellite Image Registration) have been illustrated in three different ways namely with noise, with attack and standard. Moreover two-satellite image in the various period as its input and the database are publicly available. Input image is taken from Massachusetts Geographic Information System (MassGIS). The sample input satellite image is mentioned in Fig.2

Fig. 2.Input as the satellite images of the same scene in various time period.

Standard Satellite Image Registration: Standard two satellite image registration were matched by applying BRISK and FAST feature. These features are extracted and detected the eminent features as well as objects from the given images. FE (Feature Extracted) from the particular image could be either global or local feature; local feature is the particular image pattern that totally differs from the direct neighborhood. These are presented as contours, corners, edges and points. Here, BRISK features were point detection in the image and FAST feature was corner detection in the image. The matching point using BRISK and FAST features with outliers and inliers and registered images are described below.



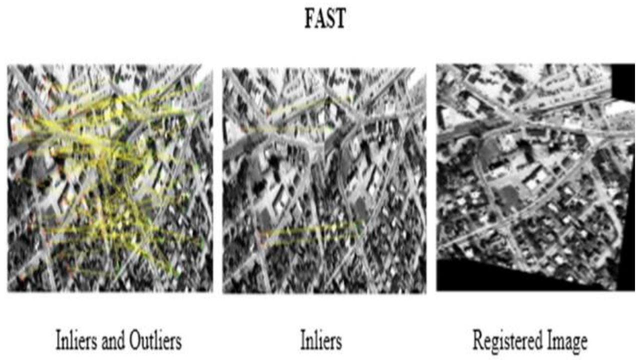
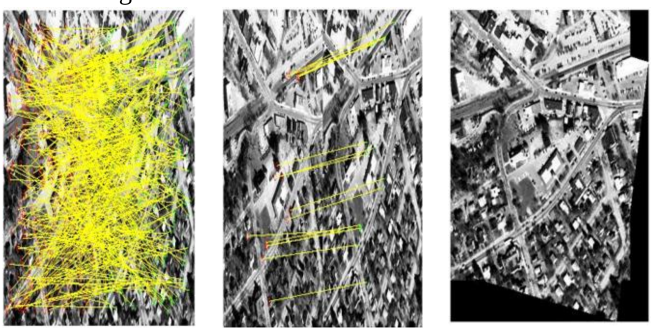


Fig. 3.MP (Matching point) using BRISK and FAST with the outliers and inliners, only with the inliers and Registered Image.

The Fig. 3 indicated as BRISK and FAST feature image matching performance. Here, in this FE (Feature Extraction), the points are matched and detected through the pair wise distance computation among the feature vectors and later it is named as Hamming Distance.

In BRISK feature, the inliers and outliers matching of satellite image, only inliers matching and finally the registered image is noted. Initially BRISK feature matching all key points of images, in second part only correct matching key points are mentioned and remove the outliers. With help of inliers registered the image. Similarly, in BRISK feature, Corresponding points are matched through utilization of SSD. Matching point using the BRISK feature, with the combination of (inliers and outliers), finally registered image is noted and likewise FAST feature performance is addressed in above Fig. 3.



Inliers and Outliers | **Inliers** | **Registered Image**

Fig. 4.Match Matching point using proposed hybrid descriptor with inliers and outliers, only with inliers and Registered Image.

The Fig. 4 shown as inliers and outliers and only inliers of satellite image using proposed features like combination of BRISK and FAST feature respectively. In Fig. 3 the efficiency of inliers ratio very limited so difficult to improve the image registration accuracy. Here, the proposed feature increases the inliers ratio and decrease the outlier's ratio efficiently and improve the satellite image registration accuracy. In this experiment, the quality of SIR is based on affine geometrical transform.

Satellite Image with Noise and Attack Normally the two distinctive satellite image are important for performing the SIR, here first image is the stationary image and the second image is registered in the first image. Moreover, it is observed that second image includes the noise and there has not been any impact on the efficiency and the initial ration rate of inliers. Moreover, the outcome of combination of FAST and BRISK along with noise is presented in Fig. 5

Fig. 5.Image registration using combined BRISK and FAST with noise.

A. Result Analysis

Image registration accuracy is mainly based on the two factor i.e. repeatability and inliers ratio, Inliers ratio helps in finding the absolute prediction rate. PR (Prediction Rate) of repeatability and feature matching is identified through calculating the mean of the number of key points detected. Moreover the SIR is shown in the two type i.e. SIR with Noise and standard SIR, hence it is observed that the proposed IR model outperforms the other two methods namely BRISK and FAST in terms of registration. Moreover, the evaluation of the proposed and other two model and feature combination has been evaluated and tabulated in the given Table I.

Table- I: Performance Evaluation of feature combination

	Methods	Inliers Ratio	Repeatability
Standard	BRISK	1.009	0.0329
	FAST	1.0606	0.0367
	Proposed	1.9139	0.1210
Noise	BRISK	1.2527	0.0285
	FAST	0.9123	0.0186
	Proposed	1.6271	0.0747

Generally, the hybrid feature combination provides a better feature matching, during the satellite matching, both prediction are presents i.e. inliers which represent the correct prediction and outliers which represents the wrong prediction features. Standard image achieve the repeatability value of 0.121, inliers ratio of 1.9139, in case of noisy image the repeatability achieved is 0.074, and inliers ratio achieved is 1.627. Comparison analysis shows that our methodology performs better.

V. CONCLUSION

Image registration is method where two image are aligned, here first image is known as the reference image, second image is known as the sensed image. First image is fixed image and second image is the one that has to transformed followed by that it needs to be registered over the reference image. This research work evaluates the hybrid feature i.e. combination of FAST and BRISK method for improvising the SIR (Satellite Image registration). Image registration performance depends on the repeatability and inliers ratio, hence in this research work SIR has been illustrated in three distinctive ways namely with attack, with noise and standard, moreover proposed approach which is combination of FAST and BRISK achieves the repeatability and inliers value of 0.121 and 1.913 respectively. Standard image with the noise achieves the better result in terms of repeatability and inliers ratio and performs better than these individual model.

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Chandrappa D.N is a highly skillful Professor with over 20 years of experience in the field of engineering education. He has been awarded Ph.D from Visvesvaraya Technological University. He is awarded doctorate for his research in the areas of signal and image processing. He has more than 20 research publications at peer reviewed international journals and conferences. At present, he is working as a Professor in the Department of Electronics and Communication Engineering in SJB Institute of Technology, Bangalore, India. His project consultancies includes in the field of image processing, power electronics and embedded systems.