Satellite image matching and registration using affine transformation and hybrid feature descriptors

N.S. Anil*

Department of Electronics and Communication Engineering,
East West Institute of Technology,
Bangalore, 91, India
Email: Anilnsg86@gmail.com
*Corresponding author

D.N. Chandrappa

Department of Electronics and Communication Engineering,
SJB Institute of Technology,
BGS Health and Education City, Kengeri,
Bangalore, 560 060, India
Email: Chandrappa.dn@gmail.com

Abstract: Image registration (IR) is an image processing technique to determine geometrical transformation that gives the most accurate match between reference and floating images. In existing IR work, the inliers ratio and outlier's ratios are equal. This reduces the image registration accuracy. So, to avoid the outlier's ratio and increase the inliers ratio, hybrid invariant local features descriptor is proposed. This feature descriptor consists of binary-robust-invariant-scalable-key point (BRISK), speed-up-robust-feature (SURF), and feature from accelerated segment test feature (FAST). The hybrid feature descriptor extracts the relevant features from the image. Then, the feature matching step finds the correct correspondences from the two sets of features. Also, affine transformation avoids the false feature matching points. An experimental analysis shows the inliers ratio and repeatability evaluation metrics performance of individual feature descriptor, combined feature descriptor and proposed feature descriptor. The proposed hybrid feature descriptor achieves inliers ratio of 1.913 and repeatability is 0.121.

Keywords: affine transformation; binary robust invariant scalable key point; feature from accelerated segment test feature; FAST; histogram equalisation; image registration; line blending; speed up robust feature; SURF.

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Biographical notes: N.S. Anil received his BE (ECE) from Canara Engineering College, Mangalore, Visvesvaraya Technological University, Karnataka, India in 2008 and completed his MTech in Industrial Electronics from SJCE, Mysore, Visvesvaraya Technological University, Karnataka in 2010 and since then, he is actively involved in teaching and research activities and he has more than eight years of teaching experience, one year of industry. At present, he is working as an Associate Professor in East West Institute of

Technology, Bangalore Affiliated to Visvesvaraya Technological University. He has good exposure in the field of engineering electromagnetics, signal processing, image processing, analog and digital circuits. He has published number of research papers in the referred international journals and presented research papers in referred international and national conferences.

D.N. Chandrappa is a highly skilful Professor with over 20 years of experience in the field of engineering education. He has been awarded PhD 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.

1 Introduction

Satellite image registration (SIR) is an important part of the national infrastructure-planning-related technologies, including the management and operation of urban planning and its related policies (Jiang and Shi, 2016; Tsai and Lin, 2017). In addition, SIR becomes an essential part of change detection on the earth, forest, and urban monitoring (Shengwen et al., 2015; Lv et al., 2017). Factors including different sensors characteristics, distortion, terrain relief, movement of objects, and high computational complexity affect the registration process and accuracy that makes SIR as a challenging task (Vakalopoulou et al., 2016). SIR technique is classified into two types: area (spatial or intensity)-based methods (ABM) and feature-based methods (FBM) (Sedaghat and Ebadi, 2015). In ABM, intensity of every pixel in images are used to compute some similarity metrics like cost function to determine the optimised transformation. Whereas, for large satellite images the computational time is more in ABM. On the other hand, FBM uses the salient features of images such as points, lines, edges, etc., that are detected and corresponded to find the required transformation parameters (Patel et al., 2016; De Falco et al., 2008). These parameters are sufficient for further image processing tasks like object identification, regional variation detection and image segmentation (Lee et al., 2011).

In feature matching the FBM is employed for image registration (IR). Totally four steps involved in FBM such as, feature extraction, feature matching, transformation and registration (Fan et al., 2013; Lee and Mahmood, 2015). Initially, feature extraction is the action of mapping the image from feature space, which mainly depends on descriptor method. In SIR, several feature descriptor methods are employed such as, speeded up robust features (SURFs), local binary patterns (LBP), histogram of oriented gradients (HOGs), etc. (Safdarinezhad et al., 2017). In order to improve the performance of SIR, a suitable hybrid combination of descriptors is undertaken for this experimental analysis. After employing hybrid feature descriptors, the common points between the reference and sensed images are determined (Yang et al., 2017; Bozorgi and Jafari, 2017). Then, a suitable transform method such as affine transform, piecewise linear (PL), thin plate spline (TPS), etc., is applied for warping the target image to align with the reference image. Many IR transform methods are available such as, affine transform, TPS, PL, local weighted mean (LWM), etc. (Wong and Clausi, 2010). The combination of hybrid feature descriptors with suitable transform method eliminates the false matching points. By eliminating more false matching points the accuracy of SIR improves in an effective manner. In this paper, hybrid feature descriptor used to increase the inliers ratio and decrease the outlier's ratio effectively and also improve the SIR.

This paper is organised as follows: Section 2 surveys several existing techniques in SIR. The proposed hybrid feature descriptors are explained in Section 3. Section 4 illustrates the registration performance of proposed method on various types of satellite image pairs. Finally, the conclusion of the research work is explained in Section 5.

2 Literature review

Zhao et al. (2015) evaluated the multi-date or multi-spectral images with related patterns, low overlapping areas, or high transformation using dual graph-based matching technique. Initially, normalising gradient orientations was used to improve scale invariant feature transform (SIFT)-based matching and increased the scale ratio similarity of all resultant points. Next, Delaunay graphs were used for elimination of outliers, after that the candidate outliers were selected by checking the Delaunay graph structures differences. The experimental results demonstrate the accuracy and robustness of the proposed algorithm for various representative remote sensing images. The developed methodology takes more time for constructing graph in order to identify the differences in remote sensing image.

Parmehr et al. (2016) presented a bin size selection approach to improve registration reliability. The advanced technique established the superior (uniform) bin size for the pdf calculation and an examination of the relationship among the similarity estimate values of the information. This majorly focused on the element of mutual information (MI) sensitive to the transformation, moderately the MI element that was not related to the transformation. As compared with feature-based registration (FBR), superior performance was attained for the intensity-based registration (IBR) of aerial images of LiDAR data. While implementing IBR, the intensity of the image should be very high that was considered as one of the major drawback.

Xu et al. (2016) proposed a Jeffrey's divergence the, the resemblance calculates in practical multimodal IR tasks. Here, the statistical evaluation was performed to examine the sources accounting for the limitation of MI when handling the inadequate scene overlap image pairs. In experimental analysis of IR, includes different kinds of images and compare the performance of Jeffrey's divergence and MI. Results indicated that Jeffrey's divergence was capable of giving the larger feasible search space, which was encouraging for discovering optimum transformation parameters in a superior range. In multi modal registration task, joint histogram was easily calculated in large size images, but it was difficult in small size images.

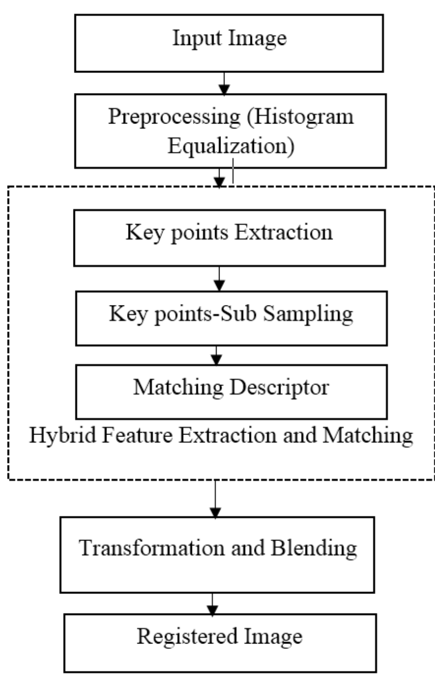
Yufeng and Wei (2017) presented a hybrid genetic fuzzy C means (FCM) algorithm for IR. This technique applied in IR, which taken two same region images but different time using sift operator and Harris operator. Here, initial image differences were estimated with the help of combination of logarithmic method and ratio method. To reduce the image dimension purpose principal component analysis (PCA) method was used. At last, hybrid feature technique was used to improve the classification accuracy and the results were compared with the reference image. As a number of iterations require updating the clustering centre in proposed methodology, it takes more time for IR.

Yang et al. (2014) presented an IR for using affine method and invariant feature extraction methods. The advanced technique localised the features efficiently in synthetic aperture radar (SAR) using extraction technique as salient image disks (SIDs). An unstable feature was removed with the help of multi resolution search method. The experimental results indicated that the proposed method was better than the exiting SID method in terms of stability of feature points as well as localisation accuracy. The proposed method was less sensitive and also high outlier ratio effects the IR.

3 Proposed methodology

In proposed methodology, the hybrid feature descriptor [combination of binary robust invariant scalable key (BRISK), SURF, and feature from accelerated segment test feature (FAST)] extracts the local as well as global features from the input image. The global features are extracted by BRISK finds the key point orientation and rotational features from an image. The SURF descriptor extracts the local features and it is more robust as well as very faster than descriptor. Also, the most promising feature descriptor FAST is computationally efficient and it is utilised to extract the feature points, also helps to track and map objects. The hybrid feature descriptor increases the inliers' ratio and reduces the outlier's ratio to improve the satellite IR. Experimental derivations of hybrid feature descriptors are explained in Figure 1.

Figure 1 Proposed architecture



3.1 Preprocessing

The histogram equalisation (HE) preprocessing technique is used in SIR process. HE is a process that changes the distribution of greyscale value in an image so that it becomes uniform. The objective of HE method is to acquire the unvarying spread of the histogram, as a result every greyscale value has equal number of pixels and mathematically represented in equation (1)

$$s = T(r) \tag{1}$$

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

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

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

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

where k_0 is the gray level value from HE, C_i is the cumulative distribution of i^{th} greyscale 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.

3.2 Hybrid feature combination in SIR

Several feature descriptors are used in the IR such as HOG, SIFT, gradient location oriented histogram (GLOH), etc. In this research, hybrid feature descriptors like BRISK, FAST, and SURF, extracts the relevant features from satellite image. The BRISK is the key point feature; SURF is the local feature extractor and FAST is the corner detector in image. The proposed hybrid feature descriptor significantly increases the inliers ratio and decreases the outlier's ratio, so it effectively improves the accuracy of SIR. The following feature descriptors are explained in below section.

3.2.1 SURF descriptor

The SURF is a local feature descriptor and it mainly deals with IR, object recognition and 3D reconstruction or classification and also detects the scale plus rotation in an interest point. To identify the SURF point purpose scale space theory and fast hessian matrix (HM) are employed. For deciding, whether a point can be chosen as an interest point or not, that purpose employing the determinant HM. The SURF descriptor is high speed, robust, repeatability, and distinctiveness so it is better than other descriptor. The image I and $X = (x, y)$ is the given point then the HM is identified correspondingly to every pixel position of the image and mathematically derived in equation (4)

$$H(X, \sigma) = \begin{Bmatrix} C_{xx}(X, \sigma) & C_{xy}(X, \sigma) \\ C_{yx}(X, \sigma) & C_{yy}(X, \sigma) \end{Bmatrix} \tag{4}$$

where X is signified as point of image, σ is stated as scale, generally, $C_{xx}(X, \sigma)$ is indicated as the convolution of Gaussian second order derivative of image at the corresponding point with co-ordinates (x, y). Gaussian second order derivative is represented in equation (5)

$$\frac{\partial^2}{\partial x^2} g(\sigma) = \frac{1}{2\pi\sigma^2} e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)} \tag{5}$$

The second order Gaussian derivative for $C_{yy}(X, \sigma)$ and $C_{xy}(X, \sigma)$ are respectively given in equation (6)

$$\frac{\partial^2}{\partial x^2} g(\sigma) \text{ and } \frac{\partial}{\partial x \partial y} g(\sigma) \tag{6}$$

In SURF, the Gaussian second order derivatives smooth the images and it reduces the computational complexity of the operation. To detect the key point in images the determinant of HM is used, which is mathematically represented in equation (7)

$$Det\left[H(X, \sigma)\right] = B_{xx} B_{yy} - \left(0.912 B_{xy}\right)^2 \tag{7}$$

where B_{xx}, B_{yy} and B_{xy} are the box filters of integral images, which are computed in constant time. The 0.912 is constant for HM determinant. The HM determinant determines the several scales as well as non-maximum suppression in neighbourhood is implemented to detect the maxima. Based on maximum value the SURF key point's location and scale σ are obtained. The image size is partitioned into sub-regions and at each space point's horizontal and vertical HW response dx and dy are identified. Here, each sub-region generates dimensional vector by employing HW response and it is given in equation (8)

$$v = \left(\sum dx, \sum dy, \sum |dx|, \sum |dy|\right) \tag{8}$$

3.2.2 BRISK points descriptor

The BRISK is a texture descriptor, which accomplishes essential quality of matching, and extracts the valuable key points from an input image with limited computation time. Here, it employs a symmetric sampling pattern over sample point of smooth pixels in feature descriptor. The intensity of the image is represented as i_x and then employ Gaussian smoothing with standard deviation σ_x, which is equivalent to the distance between the circle and points. The key-point k in an image is patterned according to its scaling and position, the sampling-point pairs are denoted as (i_x, i_y). Respectively, the intensity of smoothed values of points is denoted as $S(i_x, \sigma_x)$ and $S(i_y, \sigma_y)$ that helps to determine the local gradients. Mathematically, the local gradients $G(i_x, i_y)$ are represented as in equation (9)

$$G\left(i_x, i_y\right) = \left(i_y - i_x\right) . \frac{s\left(i_y, \sigma_y\right) - s\left(i_x, \sigma_x\right)}{\left\|i_y - i_x\right\|^2} \tag{9}$$

Assuming, the set A of sampling point pairs indicated in equation (10)

$$A=\left\{i_x, i_y \in \Re^2 \times \Re^2 \left| x<N \wedge y<x \wedge x, y \in N\right.\right\} \tag{10}$$

where N is mentioned as the number of sampling point pairs, partition the pixel pairs into two sub-sets such as short distance pairs and long distance pairs and it is mentioned as d_1 and d_2 respectively. The following equations (11) and (12) represent the distance pairing of sub-sets

$$d_1=\left\{\left(i_x, i_y\right) \in A \mid \left\|i_y-i_x\right\|<\delta_{max}\right\} \dot{\subseteq} A \tag{11}$$

$$d_1=\left\{\left(i_x, i_y\right) \in A \mid \left\|i_y-i_x\right\|<\delta_{min}\right\} \dot{\subseteq} A \tag{12}$$

Analysis, the local gradient in long distance pairs and not necessary in the global gradient information. The threshold distance is set as δ_{max} = 9.75t and δ_{min} = 9.75t (t is the scale of k). Hence, the point pairs are iterated through L to identify the complete pattern direction of key points k, which is given in equation (13)

$$G=\begin{pmatrix} G_x \\ G_y \end{pmatrix}=\frac{1}{L} \cdot \sum_{\left(i_x, i_y\right) \in L} G\left(i_x, i_y\right) \tag{13}$$

Sampling pattern rotation of orientation is mentioned as α =arctan 2(G_y, G_x) of the key-point. The binary descriptor b_k is generated by utilising short distance paring and each bit in b_k is calculated from a pair in F. Hence, the descriptor is 512 *bits* long and it is gathered by performing short distance intensity at every binary feature vectors v, it is mentioned as follows in equation (14)

$$v=\begin{cases} 1, & S\left(i_y^\alpha, \sigma_y\right)>S\left(i_x^\alpha, \sigma_x\right) \\ 0, & \text{otherwise} \end{cases} \tag{14}$$

3.2.3 Features from accelerated segment test descriptor

A FAST feature descriptor is the corner detection method, identify every pixel of candidate points using segment test and corner of the candidate pixel are calculated. 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, as the first test produces many adjacent responses around the interest point, an additional criteria is applied to perform a non-maximum suppression. This allows for precise feature localisation. The FAST feature measure the corner of the image, which is mathematically represented in equation (15)

$$C(x, y)-max\left(\sum_{j \in S_{bright}}\left|I_{p \rightarrow j}-I_p\right|-t, \sum_{j \rightarrow S_{dark}}\left|I_p-I_{p \rightarrow j}\right|-t\right) \tag{15}$$

where $I_p \rightarrow j$ denotes the pixels laying on the Bresenham circle. In this way, the processing time remains short because the second test is performed only on a fraction of image points that passed the first test.

3.3 Feature matching

Once the features from the reference and sensed image are detected the very next step is the feature matching. The feature matching step is to find that which feature of the reference image is corresponding to which feature of the sensed image by means of their neighbourhood, intensity value. Feature matching consists of two type's technique: area-based and feature-based. The following feature matching methods are described below.

3.3.1 Sum of squared differences

The sum of squared difference (SSD) method calculates the difference among two image intensity based on pixel by pixel. It estimates 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 (16)

$$\iint_A (f-g)^2 \tag{16}$$

If the above equation is converted into digital form is represented in equation (17)

$$SSD(i, j) = \sum_{i=0}^{M} \sum_{j=0}^{N} \left(f(i, j) - g(i+u, j+v) \right)^2 \tag{17}$$

where M size of rows in reference is image and N is size of column while u and v are variable, shift component along x-direction and y-direction respectively. The value of SSD is constant and is not constant where it depend on variable u and v.

3.3.2 Euclidean distance

The nearest-neighbour matching in the feature space of the image descriptors in Euclidean norm can be used for matching vector-based features. To suppress matching candidates for which the correspondence may be regarded as ambiguous, the ratio between the distances to the nearest and the next nearest image descriptor is required to be less than some threshold. Mathematical equation of Euclidean distance presented in the equation (18)

$$\Delta d = \sqrt{\sum_{i=1}^{n} \left(|Q_i - D_i| \right)^2} \tag{18}$$

where Q and D are the different feature vectors of input images. This distance metric is most commonly used for similarity measurement in image retrieval because of its efficiency and effectiveness. The hybrid feature descriptors extract the relevant features from the satellite image. After feature extraction, SSD and Euclidean distance-based feature matching methods are used for calculating the similarity between the two feature sets from the reference and sensed image. A Euclidean distance provide the information of pixel distances and this information is needed for image matching and registration.

3.4 Affine transformation

The affine transformation is appropriately to match the two satellite images are taken from different position but same viewing angle. It consists of scaling, translation and rotation. The affine transformation is suitable to describe the mapping between the image pairs as the simplest non-rigid transformation. After the affine transformation corrects global distortions in the images registration happened. On one hand, the two images to be registered can be globally aligned so that the main anatomical structures match. Rigid and affine transformations are global transformations and equations of affine transformation shown in equation (19)

$$P = Ap + t \tag{19}$$

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 (20)

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} tx \\ ty \end{bmatrix} + \begin{bmatrix} a_1 & a_2 \\ a_4 & a_5 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{20}$$

Global transformation is the one in which all pixels suffer the same transformation, which often results in simple and fast computation due to its small number of parameters

3.4.1 Linear blending

The linear blending scheme helps to combine the same satellite as a pre-processing for the registration process. Dyadic (two input) operator is the linear blend operator given in the equation (21)

$$g(x) = (1 - d) f_0(x) + \alpha f_1(x) \tag{21}$$

where $f_0(x)$ and $f_1(x)$ are the two source images of the same type and size. Then, calculate the weighted two arrays is in equation (22)

$$dst = \alpha f_0(x) + \beta f_1(x) + \gamma \tag{22}$$

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.

This hybrid feature combination attains a significant 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 describes the experimental result and discussion of the SIR.

4 Experimental result and discussion

In this section, the experimental results have been characterised in detailed. All experiments were implemented on PC with 1.8 GHz Pentium IV processor by employing

MATLAB (version 2017A). However, the satellite IR was calculated in three different ways, such as standard, with noise and with attack. Here, the two satellite image database of the same scene in different time period was given as the input and it is publicly obtainable database. The input image is taken from Massachusetts Geographic Information System (MassGIS). The sample input satellite image is mentioned in Figure 2.

Figure 2 Input satellite images of the same scene at different time period

Standard SIR

The standard two SIR were matched by applying BRISK, SURF and FAST feature. These features are correctly detected and extracted the important features and objects from images. The features extracted from images could be local or global where a local feature is an image pattern which differs from its direct neighbourhoods are usually represented by points, edges, corners and contours or by other features. Here, BRISK and SURF features are point detection in the image and FAST feature was corner detection in the image. The matching point using BRISK, SURF and FAST features with inliers and outliers, inliers and registered images are described in Figure 3.

Figure 3 indicated as BRISK, SURF and FAST feature image matching performance. In this feature extraction, the points were detected and matched by computing the pair-wise distance between the feature vectors and it was 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 match all key points of images, in second part only correct matching key points are mentioned and remove the outliers. Similarly, in SURF feature, the corresponding points were matched by utilising SSD. Matching point using the SURF feature, with the combination of (inliers and outliers), finally registered image is noted and likewise FAST feature performance is addressed in above Figure 3.

Figure 3 Matching point using BRISK, SURF and FAST with inliers and outliers, only with inliers and registered image (see online version for colours)

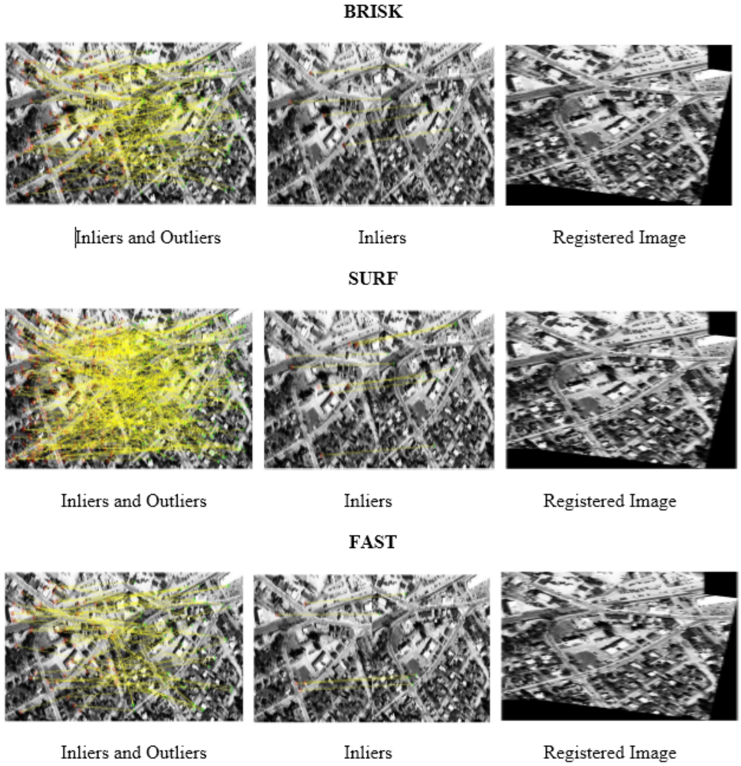


Figure 4 represents feature matching point of combined features of BRISK and FAST, BRISK and SURF, SURF and FAST with inliers and outliers, only inliers and registered image. The BRISK and FAST feature combination matches the related features of two images. It represents the inliers and outliers, after that represents the only inliers and removes the outliers. Finally, registered image is noted. Likewise, for the feature combination of BRISK and SURF, the matched points were combined. Matching the point using (BRISK and SURF feature combination) is specified with the combination of (inliers and outliers) and only with inliers. Similarly, SURF and FAST combined feature represents an effective matching result in registration of an image shown in Figure 4.

Figures 5 and 6 shown as inliers and outliers and only inliers of satellite image using proposed features like combination of BRISK, SURF and FAST feature respectively. In Figures 3 and 4 the efficiency of inliers ratio very limited so it is difficult to improve the IR accuracy. Here, the proposed feature increases the inliers ratio and decrease the outlier's ratio efficiently and improve the SIR accuracy.

In this experiment, the quality of SIC is based on affine geometrical transform. While comparing, the geometrical transforms for BRISK, SURF and FAST provides a comparable result. But, the combination of BRISK, SURF and FAST delivers an effective matching result in registration of an image. The final output of combination of BRISK, SURF and FAST is shown in Figure 7. Figure 8 indicated as more than two IR using proposed features.

Figure 4 Matching point using BRISK and FAST, BRISK and SURF, SURF and FAST with inliers and outliers, only with inliers and registered image (see online version for colours)

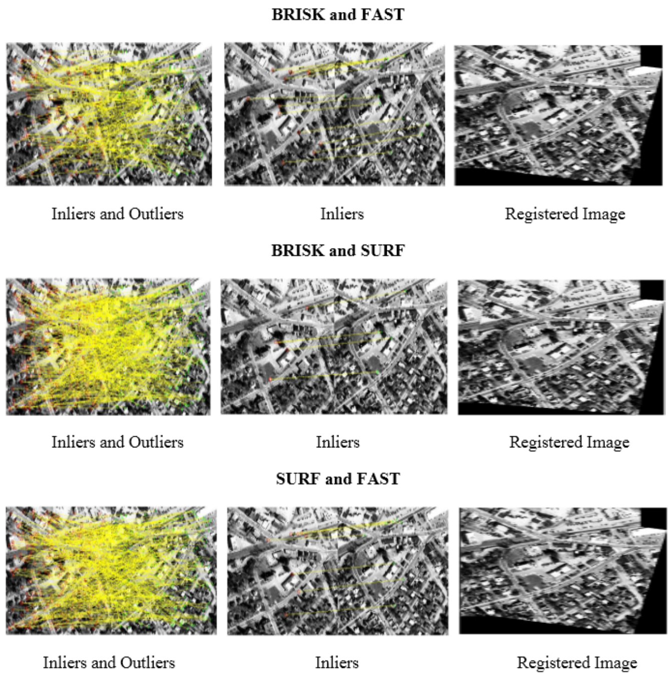


Figure 5 Proposed inliers and outliers (see online version for colours)

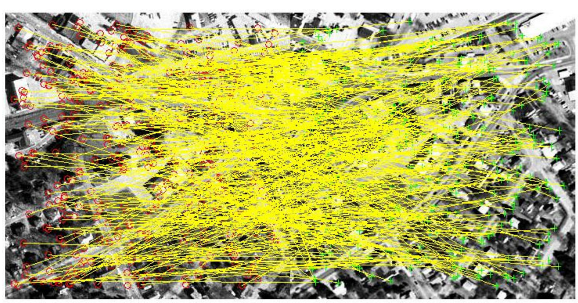


Figure 6 Inliers (see online version for colours)

Figure 7 Registered image using proposed feature

Figure 8 Multi-image registration using proposed feature

Satellite image with noise

Generally, two satellite images are essential to perform SIC. In that, the first image is stationary and the second image is going to register in the first image. In experimental analysis, satellite image with salt-and-pepper noise is taken for measuring the proposed method's IR performance and their noise variance is 0.01. Still, the noise factor did not affect the efficiency of repeatability and inliers ratio rate. The final output of SURF and BRISK combination with noise is mentioned in Figure 9.

Satellite image with attack

In this section, attack indicates that a particular portion of a satellite image is removed. Similarly, the initial satellite image was kept stationary and the attack factor is applied on second satellite image and its range is 32×32. Then, the two satellite images were registered, but still it shows a comparable result in repeatability and inliers ratio. The final output of SURF and BRISK combination with an attack is mentioned in Figure 10.

Figure 9 IR using combined BRISK, SURF and FAST with noise

Figure 10 IR using combined BRISK, SURF and FAST with attack

4.1 Analysis report

The accuracy of IR is based on two factors inliers ratio and repeatability. Inliers ratio determines the correct prediction rate of feature matching and repeatability is determined by the mean of the number of detected key-points. Here, the SIC is demonstrated in three different ways like standard SIC, SIC with noise, SIC with attack. It clearly shows that the combination of SURF and BRISK provides a better registration than other two methods. The performance analysis of features are graphed below in Figures 11 and 12 respectively.

The performance evaluation of following feature combination such as individual feature descriptor as BRISK, SURF, FAST, combined feature descriptor of BRISK + SURF, BRISK + FAST, SURF + FAST and proposed feature descriptor performance was evaluated in Table 1. Hence, it proves that the proposed feature combination is very effective in IR compared to other two individual methods.

Figure 11 Inliers ratio comparison (see online version for colours)

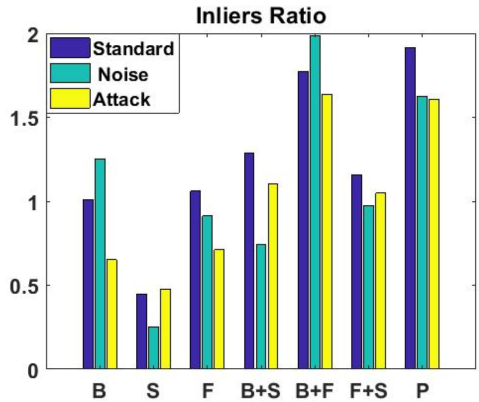


Table 1 Performance evaluation of feature combination

	Methods	*Inliers ratio*	*Repeatability*
Standard	BRISK	1.009	0.0329
	SURF	0.4474	0.0963
	FAST	1.0606	0.0367
	BRISK + SURF	1.2888	0.1018
	BRISK + FAST	1.7725	0.0591
	SURF + FAST	1.1565	0.1147
	Proposed	1.9139	0.1210
Noise	BRISK	1.2527	0.0285
	SURF	0.2532	0.0544
	FAST	0.9123	0.0186
	BRISK + SURF	0.7397	0.0422
	BRISK + FAST	1.9858	0.0409
	SURF + FAST	0.9734	0.0656
	Proposed	1.6271	0.0747
Attack	BRISK	0.6531	0.0206
	SURF	0.4793	0.0976
	FAST	0.7123	0.0273
	BRISK + SURF	1.1048	0.0833
	BRISK + FAST	0.6374	0.0558
	SURF + FAST	1.0483	0.1022
	Proposed	1.6082	0.0996

Generally, the hybrid feature combination provides a better feature matching. While matching several satellite images, it contains both inliers and outliers ratio (inliers represents a correct prediction of features and outliers represents a wrong prediction of features). In standard images the inliers ratio is 1.913 achieved, repeatability is 0.121. In noisy image, the inliers ratio of proposed feature achieved 1.62 and repeatability is 0.07.

An image with attack of proposed feature achieved 1.60 of inliers ratio and repeatability is 0.09. Here, compare to the individual feature and combination of BRISK + SURF, BRISK + FAST and SURF + FAST the hybrid feature descriptor presents better result. Comparative study of existing research works and proposed work is shown in Tables 2 and 3 respectively.

Table 2 comparative study of existing methods

Methodology employed	*Advantage*	*Limitation*	*Performance measured*
A bin size selection method to improve the registration reliability (Parmehr et al., 2016).	A novel bin size selection approach proposed to improve registration reliability. The proposed method determined the best (uniform or variable) bin size for the pdf estimation via an analysis of the relationship between the similarity measure values of the data and the adopted geometric transformation.	While implementing IBR, the intensity of the image should be very high that is considered as one of the major drawback.	RMSE: 1.08, 0.63, mean: 0.0274, 0.0032 feature and intensity-based respectively.
Local descriptors for multi-spectral remote sensing IR (Ye and Shan, 2014).	The proposed scale registration-SIFT method and LSCC similarity metrics used for multi-spectral remote sensing IR. Here, the pre-registration performed using SR-SIFT and a projective transform to eliminate the obvious translation, rotation, and scale differences between the reference and the sensed images.	This method mainly concentrated on outliers' rejection than the inliers' improvement. The test outcome indicated that the proposed scheme can gain a reliable registration.	RMSE: 1.52, correct match rate: 79.2
A fully automatic registration approach based on contour and SIFT (Ni et al., 2012).	The proposed approach is the combination of contour matching algorithm, SIFT, image blocking and local adaptive matching as a robust matching mechanism. This algorithm helps in automatic IR without any manual intervention.	The proposed method bit lagging in coarse matching of images in texture. So, texture-based feature descriptors are required.	Time complexity: 391 sec, registration precision: 100% in only 22 matching points.

The proposed hybrid feature descriptor improved the IR accuracy and the transformation method reduced the false matching points in satellite image. Moreover, proposed work improved the inliers ratio and reduced the outlier's ratio significantly. The performance was measured using evaluation parameters inliers ratio and repeatability achieved 1.913 and 0.121 respectively.

Figure 12 Repeatability comparison (see online version for colours)

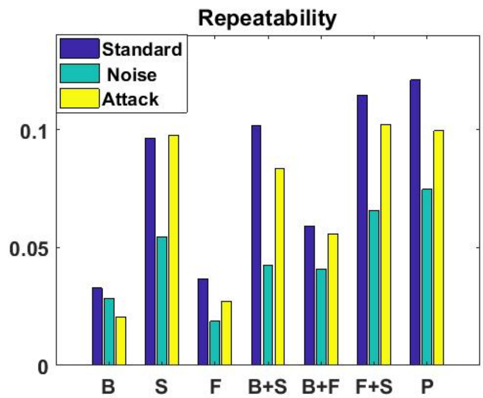


Table 3 Performance of proposed method

Proposed work	*Advantage*	*Performance measure*
Proposed hybrid features such as BRISK + SURF + FAST descriptor is used for IR.	Hybrid feature descriptors with suitable transform method eliminate the false matching points. By eliminating more false matching points the accuracy of SIR improves in an effective manner.	An inliers ratio and the repeatability of proposed combination showed 1.913 and 0.121 values respectively.

5 Conclusions

IR is the technique of aligning the two images. First image is called the reference image, which is fixed and second image is the sensed image, which is to be transformed and then registered over reference image. In this paper, hybrid feature descriptor (SURF + BRISK + FAST) is proposed for improving the SIR and additionally, transformation method avoids the false feature matching points. As a result, the proposed method increased the inliers ratio and decreased the outlier's ratio significantly. Usually, the performance of the IR depends on inliers ratio and repeatability. In this scenario, the standard was illustrated in three different ways, such as standard, with noise and with attack. At standard SIC, the inliers ratio and the repeatability of proposed combination showed 1.913 and 0.121 values respectively. On the other hand, standard image with noise and standard image with attack showed a superior result in terms of inliers ratio and repeatability, which is significantly greater than the other individual methods. In the present research work, the proposed approaches used the single sensor multiple images, but in future work multiple sensor multiple images will be used in satellite image matching and registration.

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