

Automatic Registration of Images with Simulated Rotation and Translation Estimation Using HAIRIS

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Abstract—Image registration is the most important fundamental phenomenon in the image processing system. In which Automatic image registration is a challenging aspect. Although enormous methods for automatic image registration have been developed and implemented in ancient days, it is still a broad use in plenty applications, such as in remote sensing. In my work, I have proposed a method for automatic image registration through histogram-based image segmentation (HAIRIS). This new approach is designed by combining several segmentations of the pair of images to be registered, according to a relaxation parameter based on the delineating histogram modes, following the characterization of the objects extracted —via the objects area, axis ratio, perimeter and fractal dimension—and a statistical procedure for objects matching is applied to each object. Finally, the simulated rotation and translation are illustrated for this proposed methodology. The first and foremost dataset consists of a photograph and a rotated and shifted version of this photograph is developed, with different levels of added Gaussian white noise. This can also be applied to satellite images which are in pair, with different spectral content and simulated translation and rotation is estimated, and also for various remote sensing applications comprising of different viewing angles, different acquisition dates and different sensors. Histogram-based image segmentation allows the registration of pairs of multitemporal and multisensor images with their differences in rotation and translation parameters, with small spectral content differences whereas, leading to sub pixel accuracy.

Index Terms—Histogram, Image registration, Automatic Image registration, image segmentation, matching, wiener filter, second- order Butterworth LPF

I.INTRODUCTION

IMAGE registration is the process of matching two images by transforming different sets of data into one coordinate system. This data may comprise of multiple photographs, data from different sensors, from different times, or from different viewpoints. For the analysis of two or more images of the same scene often requires registration of images. Hence the main goal of image registration is to establish the correspondence between the two images taken by different sensors, images taken by same sensor at different times and determine the geometric transformation that aligns one image with the other. It becomes a classical problem in various image processing applications where it is necessary to match images of same scene.

With remote sensing applications, the registration process is usually carried out manually which is not suitable in the places of processing bulk amount of data. Hence, there is a need for automated techniques which require little or no manual operation. An important issue in automated registration of multi-sensor/multi-spectral images is due to increase in number of images acquired every day from different sensors.

Automatic image registration (AIR) is the most challenging aspect in image processing related remote sensing applications. Further research on AIR methods is carried out in the emerging fields of remote sensing applications. Under this scope, with limited performance and particular difficulties, that AIR methods are more suitable for many computer vision applications. One challenging problem of registering remote sensing images can be the determination of translations and a small rotation parameter.

In relation to computer vision applications, the rigid-body model may be a simple problem to be solved. However, in remote sensing applications, the most challengeable problems is connected to the radiometric content due to multisensor or multispectral pairs of images.

Over the last few decades, a plenty of articles has been published related to image segmentation and their application in several fields such as military, medicine, remote sensing, etc. Image Segmentation is the process of partitioning the digital image into multiple regions that each element in the region satisfies some predefined criteria. IS plays a vital role in identification of objects on a scene.

Classifying image segmentation methods based on their nature: feature based approaches, region-based approaches, histogram thresholding, edge detection approaches, fuzzy approaches, physics-based approaches and any combination of these. Image segmentation is used as a step in image registration whose methods are used to transform any image to a binary image: objects and background.

Typically, HAIRIS comprises of three stages:

- 1) identifying modes of the histogram,
- 2) finding the valleys between the identified modes and
- 3) finally applying thresholds to the image based upon the valleys identified.

Most of the well known methods are subjected to unimodal, bimodal or multimodal histogram thresholding technique for segmenting the images, where it is analyzed that each of the object corresponds to a certain class of objects. However, this is not appropriate for remote sensing applications.

The work by Liang *et al.* deals with a robust multiscale segmentation algorithm for automated registration of images related by rigid-body transformations. This algorithm comprises a new region-based similarity segmentation technique, where minimization of the metric is carried out by Powell direction set optimization method to find the peak. The images taken here do not include additive noise neither remote sensing images, which are widely associated with particular difficulties in registration process.

The work done by Goshtasby *et al.* presents a major contribution to a region-based approach where an algorithm is designed to refine region boundaries so that similar corresponding regions are obtained. Here centers of gravity of corresponding regions are determined, which are used as control points, up to subpixel accuracy. Automatic registration is carried on TMS and MSS images in this region based approach. The work from Dare and Dowman is another example, where the authors state that the image registration method handled is fully automatic, but in practice the method requires a manual alignment initially to remove gross differences in scale and rotation. Moreover, the segmentation methods proposed by Dare and Dowman are more adequate to images containing homogeneous objects such as larger water bodies, but with limited performance on datasets such as satellite images used in remote sensing applications.

The work by Hui Li represents a method known as contour- based approach to multisensor Image registration where two methods are described which use region boundaries and strong edges as matching elements. These methods work well on collection of contour information and accurate contour locations of images such as optical images with SAR images from Landsat and Spot satellites.

In my remarkable work, I have proposed an excellent method for automatic image registration of pair of multi-spectral/multi-temporal images with different values of added White Gaussian noise through histogram-based image segmentation (HAIRIS), which leaves a way for an accurate image registration rather than the traditional methods. HAIRIS technique involves in estimating the rotation and/or translation parameter between two images (reference and referred)—which could be different because were taken at different times, using different devices (multi modal) and from different angles in order to have 2D or 3D (multitemporal or multisensor)—with small differences in their spectral content.

II. SYSTEM DESCRIPTION

A description of Histogram-based Image Segmentation relies on finding the relationship between two coordinate systems using pairs of measurements taken from the coordinates is a complementary task. The transformation between two Cartesian coordinate systems produces results, thus can be subjected into two operations i.e., a rotation and a translation. Consider a pair of images that have same ground resolution (same pixel size with respect to the scene), and the estimate a translation and/or rotation difference between the two images, where one of the image is “static” (reference image) and the other image is sensed image which is to be registered onto the “static” image. Assuming that (A, B) are the spatial (line) coordinates of the “static” image and (P, L) are the (Pixel, Line) pair of the image to be registered. The transformation is carried out as:

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta \\ \sin \theta & -\cos \theta \end{bmatrix} \begin{bmatrix} P \\ L \end{bmatrix} + \begin{bmatrix} \delta_A \\ \delta_B \end{bmatrix}$$

where the origin is considered to be the upper left corner of the reference image, θ is the orientation difference, and (δ_x, δ_y) be the shift between the two images.

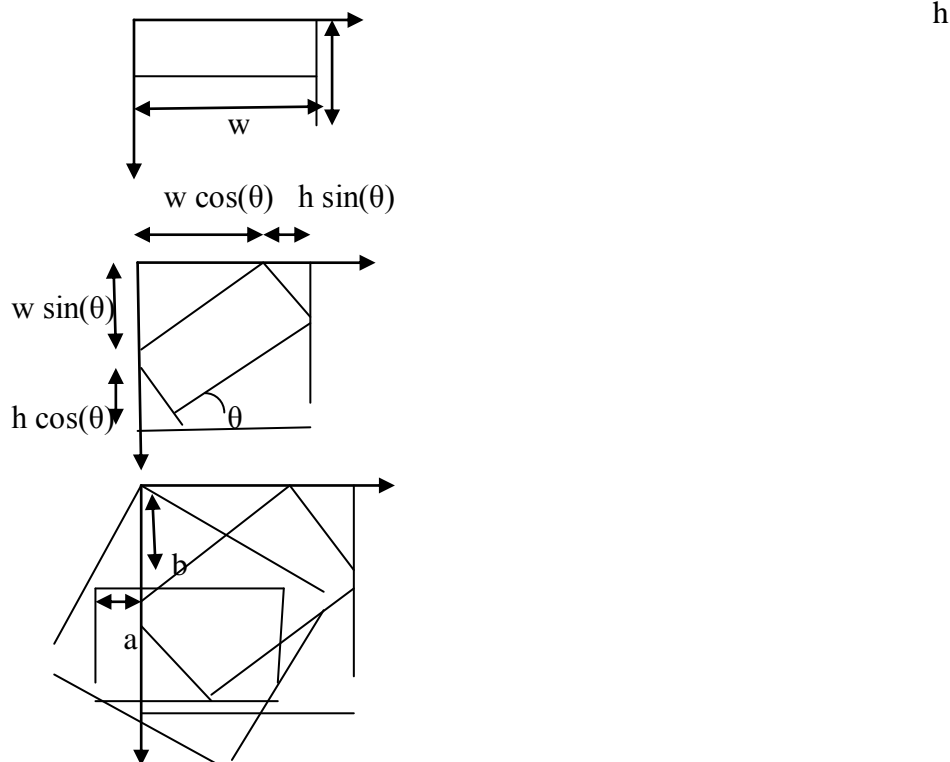


Fig. 1. Translation and Rotation induced by an image

The process begins with a initial processing stage in which the unnecessary detail on the images content are reduced, which includes a relaxation parameter α . Following the segmentation stage, extraction of objects is characterized and matching of the values of object is performed. Finally allows for the estimation of statistic-based rotation and translation parameters.

III. STEPS INVOLVED IN HAIRIS ALGORITHM

In the following, the several steps involved in HAIRIS are explained one by one, where the main objective of the process is to estimate θ , δx and δy

A. Initial processing

Unwanted detail on the pixel domain may lead to undesirable segmentation results. Hence, an image enhancement step (subjective process) is performed in prior to further processing which results to obtain with less detail than the original image. Since with image segmentation step, it is needed to extract image objects which may have some kind of degradation such as additive random noise. Restoration algorithms may provide removal of such detailed characteristics of an image and its degradation. The Wiener filter is one of the most commonly used filters for restoration and enhancement methods, with the aim of reducing the detail on an image. It is typically a low-pass filter whose frequency response $H(\omega_1, \omega_2)$ is given by

$$H(\omega_1, \omega_2) = \frac{P_f(\omega_1, \omega_2)}{P_f(\omega_1, \omega_2) + P_v(\omega_1, \omega_2)}$$

$P_f(\omega_1, \omega_2)$ – power spectrum of original image

$P_v(\omega_1, \omega_2)$ – power spectrum of additive random noise

Traditionally, in order to overcome differences between the histograms of the images to be registered, a histogram equalization of sensed image using the histogram counts of reference image is performed, prior applying wiener filter. In such way, wiener filtering reduces the detail on sensed image.

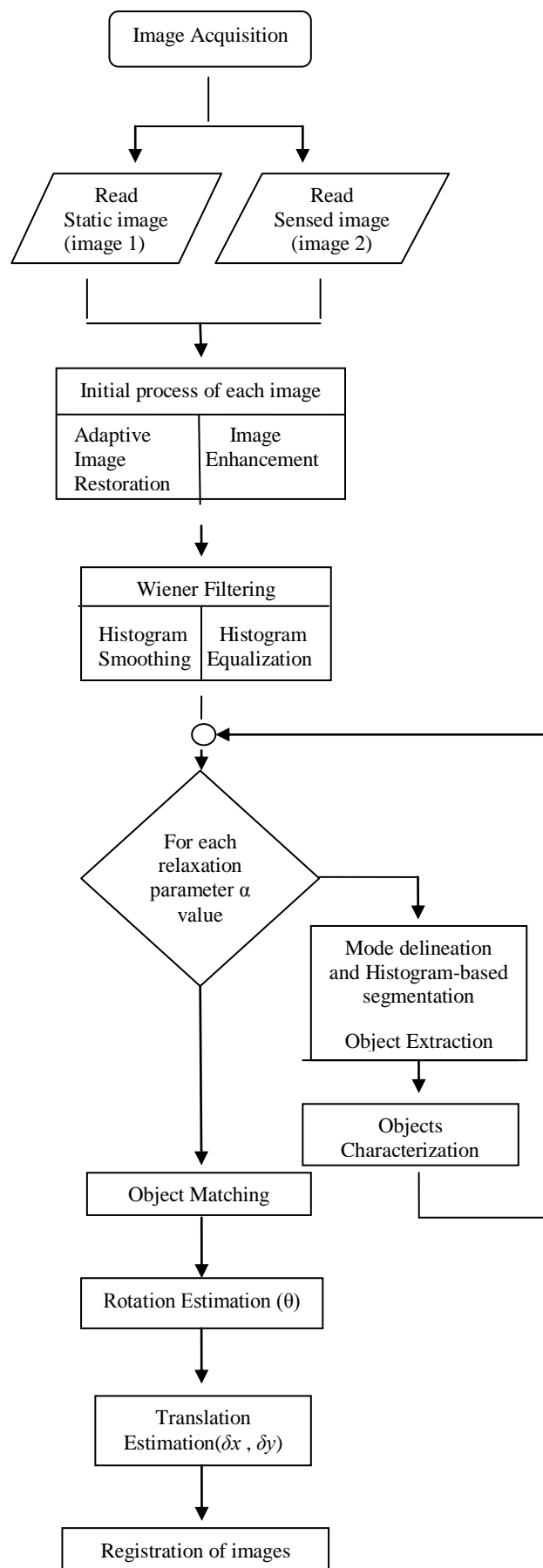


Fig. 2. Flow diagram of the steps in HAIRIS method

B. Mode Delineation and Histogram-based Image Segmentation

Analysis of the consecutive slopes of the histogram leads to mode delineation. An adequate threshold is chosen for this approach, which is characterized by a significant increase and/or decrease on the slopes sequence. The sequence of the consecutive slopes is given by,

$$y(n) = x(n) - x(n-1), \quad n = 1, \dots, M$$

where, the histogram levels is denoted as $M+1$ in which $M=255$ for an 8-bit image. The presence of mode is characterized by extreme positive and negative values of the obtained slope sequences. A fundamental solution for delineating a mode is by obtaining a confidence interval for the slope sequences. Hence, finally the presence of mode is detected by the slopes that are outside the 99% confidence interval.

In order to achieve a proper detection of mode, preprocessing of the slopes should be done, in order to smooth the slope sequence irregularity outside the presence of mode. Such a preprocessing is performed through a second order low-pass Butterworth filter, whose normalized cutoff frequency is 0.25, which is represented in Fig. 3.

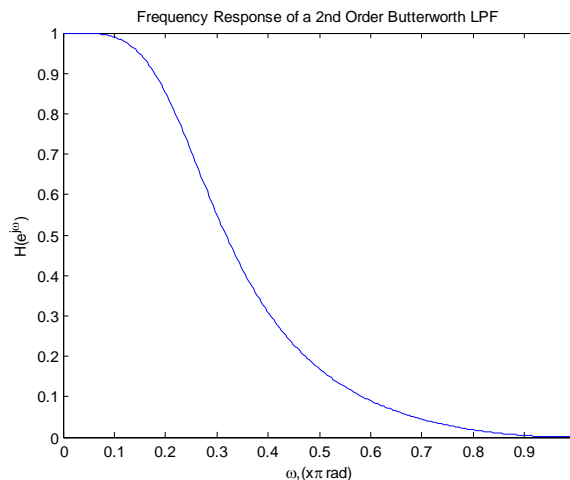


Fig. 3. Frequency response of 2nd order Butterworth LPF

A typical image segmentation approach based on histogram analysis generally carries out three steps:

- 1) Recognize the modes of the histogram.
- 2) Remove the unwanted peaks (too small compared to the biggest peak) in the histogram, suppose i_{\max} is the value of the highest peak satisfying $h_{\max}=h(i_{\max})$. For any peak j , if $h(j)/h_{\max} < 0.05$ then peak is removed.
- 3) find the valley between different two highest modes.

From the image in Fig. 5. (a), the histogram of that image is represented in Fig. 5. (e), where seven modes are visible and the consecutive slopes of the histogram are also shown in the same figure, where the mode on the histogram is obtained by the transition from positive to negative slopes. A relaxation parameter (α) is considered on the mode delineation, which is a continuous parameter, defined in the interval $[0,1]$. This parameter is included to obtain different segmentation results. It corresponds to height of the histogram – considered to correspond to the highest mode. Below this α value, the mode is considered to be a “flat” region. Once the modes and flat regions are identified for each of α value, the image can be segmented by considering each mode or a flat region as a class. This results in the final segmentation of the image.

C. Characterization of the Extracted Objects

The objects extracted at the segmentation stage are normally characterized by the following four attributes: area (A_{rea}), perimeter (P_{erim}), axis ratio (AR_{at}) and fractal dimension (D_b).

Area (A_{rea}):

The attribute area (A_{rea}) is obtained by the number of pixels which form an object, also evaluation of an object with respect to its size.

Perimeter (P_{erim}):

The perimeter (P_{erim}) attribute is obtained by calculating the distance between each adjoining pair of pixels around the border of the region, which evaluates the object compactness.

Axis ratio (AR_{at}):

The ratio between the major and the minor axis length lead to the attribute AR_{at} (axis ratio). The major axis length corresponds to the major axis length of the ellipse that has the same normalized second central moments as the object, from which it may be also obtained the minor axis length. The AR_{at} attribute allows for the characterization of the object according to its narrow or wide nature.

Fractal dimension (D_b):

Although the three previous measures describe the general aspects of an object characterization of both images are calculated by using command region props (REGION PROPERTIES). Therefore, a complementary attribute is considered that describes the particular complexity nature of an object shape: the fractal dimension. Fractal dimension is the one among several notions of dimension proposed by mathematicians. These four previously described attributes are used for object matching.

D. Object Matching

The matching step starts with the evaluation of a cost function, between every possible two-by-two combination of objects which are obtained from the segmentation of the two images, for every possible combination of α values considered for both images. This leads to a matrix with n_1 rows and n_2 columns, where n_1 and n_2 correspond to the number of objects extracted from images 1 and 2, respectively.

The cost function (γ), evaluated for the values of objects from the images 1 and 2 is defined as follows:

$$\gamma = \frac{(A_{rea\ 1} - A_{rea\ 2})}{\overline{A_{rea}}} + \frac{(AR_{at\ 1} - AR_{at\ 2})}{\overline{AR_{at}}} + \frac{(P_{erim\ 1} - P_{erim\ 2})}{\overline{P_{erim}}} + \frac{(D_{b1} - D_{b2})}{\overline{D_b}}$$

where, $\overline{A_{rea}}$, $\overline{AR_{at}}$, $\overline{P_{erim}}$ and $\overline{D_b}$ are the average attribute values for images 1 and 2. A valid matching between two objects is obtained from the lower values of γ .

Boxplots:

In descriptive statistics, a box plot or boxplot (also known as a box-and-whisker diagram or plot) is a convenient

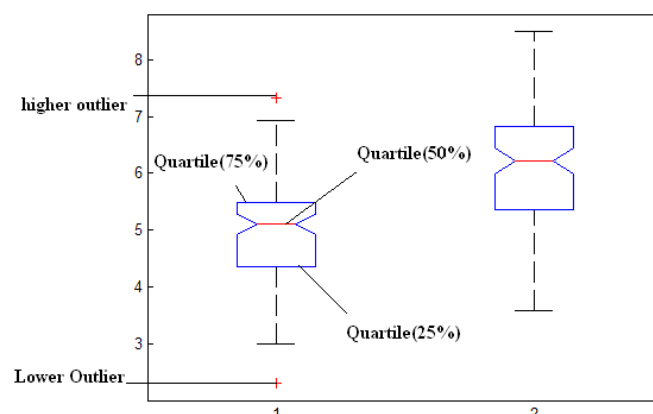


Fig. 4. Illustrates Boxplot For Two Groups Of Data

way of graphically depicting groups of numerical data through their three number summaries: the smallest observation lower quartile (q_1), median (q_2) and upper quartile (q_3) shown in Fig. 4.

For the evaluation of values of γ , a statistical criteria called the outlier detection used in the boxplots representation is considered, where a point is taken as outlier if it is smaller than $q_1 - k \times (q_3 - q_1)$. Similarly where a point is considered an outlier (regarding the higher values) if it is greater than, $q_1 + k \times (q_3 - q_1)$, where q_1 and q_3 are the first and third quartiles, respectively.

Advantage of Box plot:

The boxplot is a quick way of examining one or more sets of data graphically. Boxplots may seem more primitive than a histogram, but they do have some advantages. They take up less space and are therefore particularly useful for comparing distributions between several groups or sets of data.

E. Rotation Estimation: $\hat{\theta}$

From the given set of matching objects, the histogram of the extracted objects orientation differences is represented. By the procedure outlier detection, the rotation value is calculated from the frequency corresponds to the higher outlier. This leads to the estimation of rotation parameter.

F. Translation Estimation:

Once $\hat{\theta}$ is obtained, only the initial matching candidates which correspond to the obtained rotation are considered.

Then, a similar procedure as that followed in the rotation estimation is considered for obtaining $\hat{\delta}_x$ and $\hat{\delta}_y$. This statistically leads to estimate δ_x and δ_y

III. APPLICATION OF NEW APPROACH

The performance of this new approach is illustrated in the following situations: Simulated rotation and translation, simulated rotation and translation with different levels of added white Gaussian noise to the image to be registered and real examples of remote sensing

applications. Normally, the α values range from 0% to 100% and here the α values are considered through the steps of 20%, 10% and 5% for purpose of analysis.

Medical Image registration (for data of the same patient taken at different points in time such as change detection or tumor monitoring) often additionally involves *elastic* (also known as non rigid) registration to cope with deformation of the subject (due to breathing, anatomical changes, and so forth).

A. Simulated Rotation and Translation

For the illustration of proposed methodology application, it is considered that an 8-bit image of size 768 x 512 pixels which is acquired by the digital camera. For the purpose of analysis, a translation of 60 and 40 pixels on the horizontal and vertical axis, followed by a rotation of $\theta = 30^\circ$ are simulated. As explained, if the rotated image is rotated backward by the same angle θ , there is an additional translational effect on the image. Therefore, the translation values achieved are $\delta_x = 252.0$ and $\delta_y = 292.7$, respectively.

After applying the new approach HAIRIS, the correct value of θ for the three considered resolutions of α (20%, 10% and 5%) along with the subpixel accuracy for these resolutions regarding δ_x and δ_y can be seen in Table I.

B. Simulated Rotation and Translation with added White Gaussian Noise

Several noise levels were considered for the evaluation of HAIRIS in the presence of noise, through the simulation of Gaussian white noise added to the uncorrected image shown in Fig. 5. (b). That the standard deviation of the image in Fig. 5. (b) is given as 45 (excluding the background area induced by the simulated rotation), Gaussian white noise with standard deviation of 10%, 20%, 50%, and 100% of the image standard deviation were simulated. The obtained estimated values for $\hat{\theta}$, $\hat{\delta}_x$ and $\hat{\delta}_y$ through HAIRIS for the four considered noise levels are presented in Table I. For example, the registration of the image with a noise level of 50% for a resolution of 10% is illustrated in Fig. 5. (n).

IV. COMPARISON OF HAIRIS WITH OTHER APPROACHES

To establish a baseline for comparison of HAIRIS with other AIR approaches, three commonly known methods of AIR have been considered: a region-based similarity measure, scale invariant feature transform (SIFT) and a contour-based approach.

Since the former method uses multiscale segmentation algorithm for automatic registration of images. The images used in this approach does not include any type of noise neither remote sensing images. The second one, SIFT method provides a set of conjugate points; the parameters θ , δ_x and δ_y were estimated through the least squares method, that depends on the distance ratio calculation. It is suggested that, this method led to worst results in both photographs and remote sensing images. The implementation of the later method allows for considering the RST transformation (and not merely RT), and the default parameters have been considered. It can be seen that new approach generally outperforms region-based similarity method, SIFT and the countour-based approach, particularly for the remote sensing applications.

Computationally SIFT is a powerful method under the scope of computer vision applications, but its performance is quite limited for remote sensing images. Since, it depends upon the parameter associated to the ratio of distances, it provides undesirable property under the scope of fully AIR methods. On the other hand, even though the contour-based approach is quite a fast method, it has worst performance. Hence, it is not able to handle with more

complex situations such as presence of noise or multisensor pairs of images. Compared to these approaches HAIRIS had accurately registered complex pairs of images. It is clear that HAIRIS have been implemented with the help of MATLAB, whereas the contour-based approach implementation is based upon C++ which is faster. Moreover, HAIRIS is able to register pairs of images associated with multitemporal, multisensor, and images in the presence of noise.

V. DISCUSSION AND CONCLUSION

A large variety of applications depend on automatic image registration methods, where the registration is carried out on satellite images. In this paper, a new approach for automatic image registration through histogram- based image segmentation (HAIRIS) is proposed for images with added white Gaussian noise, where HAIRIS does not require any search interval either for rotation or translation, it is a fully automatic procedure. As shown in Fig. 2. With the filtering step—an important initial processing stage of the proposed methodology—the objective is to transform the original image. The most commonly used filter for this stage is Wiener filter.

For restoration step, an adaptive restoration algorithm provides easy computation and better performance than non-adaptive algorithms. In particular, it was impossible to find the set of parameters for all the considered examples. The use of other methods, such as wavelets, is not compatible with automatic image registration methods. In this new approach, calculating the mode delineation from the consecutive slopes sequence of the histogram is a robust method regarding an accurate delineation of the modes present on a histogram.

Despite of the known segmentation methods work well, with images for certain applications such as remote sensing applications, will exhibit a lower performance. This aspect leads to consider the relaxation parameter α proposed in HAIRIS, which allows for an efficient histogram-based segmentation. Although, the image segmentation methods based upon histogram thresholding are simpler methods, may present some limitations. One of the strengths of HAIRIS is that the segmentation method using histogram thresholding has the advantage of being less dependent upon the choice of parameters. Another advantage is that a pair of images with completely different histograms can be accurately registered. The modes which are detected at segmentation stage lead to a set of extracted objects, which are combined at the subsequent stages, results in accurate registration of images in pair. Another, important characteristic of HAIRIS is considering a range of values for the relaxation parameter α during segmentation.

Thus, the comparison of HAIRIS with most popular, commonly known methods for automatic image registration such as region-based similarity measure, SIFT and a contour-based in terms of accuracy and computational time are stated. Here, in this new approach HAIRIS was applied to single-band images at a time, which leads to better results, even in the presence of considerable amount of added Gaussian White noise. The proposed methodology of image registration is more suitable for registration of remote sensing images. And also HAIRIS method correctly register the pair of images (including multitemporal and multisensor) with subpixel accuracy.

VI. EXPERIMENTAL RESULTS

In this section, the experimental results for automatic registration of single-band remote sensing images using histogram-based image segmentation are demonstrated.

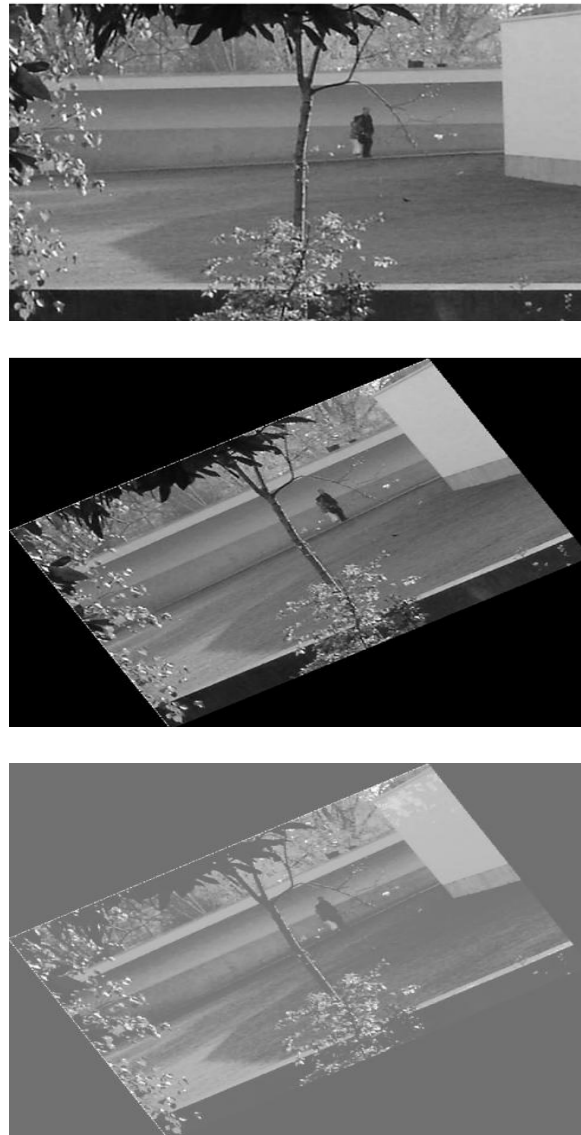


Fig. 5. (a) 8-bit original image (image 1) with size 768 x 512 pixels, extracted from larger scene, acquired by a digital camera. (b) Rotated and shifted version of original image (image 2). (c) Histogram equalization of image 2

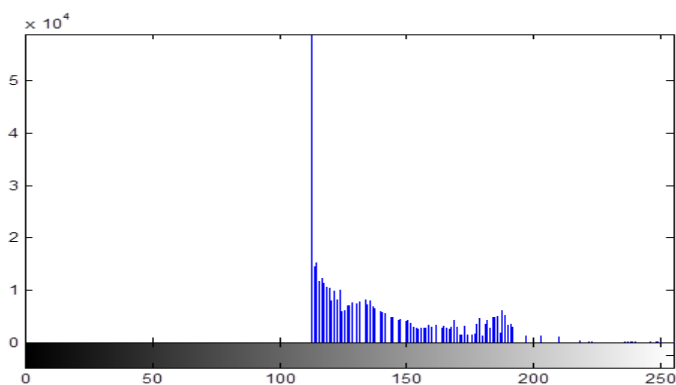


Fig. 5. (d) Histogram plot of fig. 5. (c)

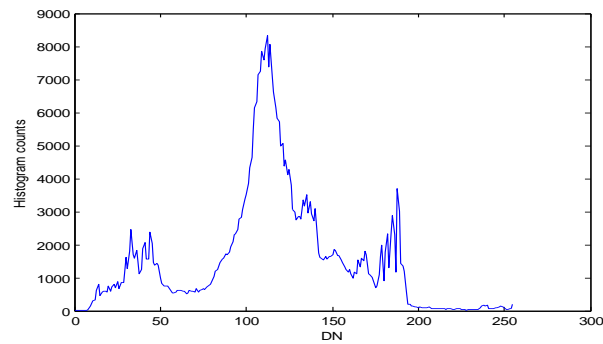


Fig. 5.(e) Histogram of image presented in fig. 5.(a)

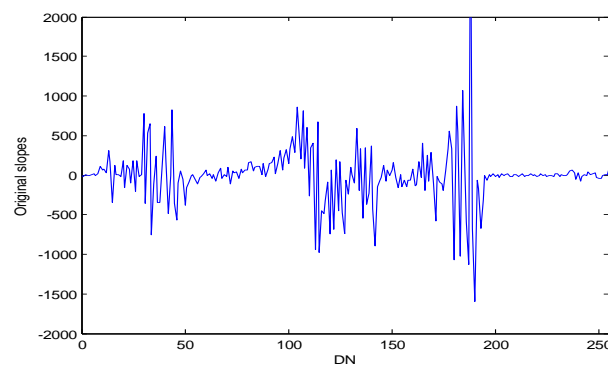


Fig. 5. (f) Slope sequence of image in fig. 5. (e)

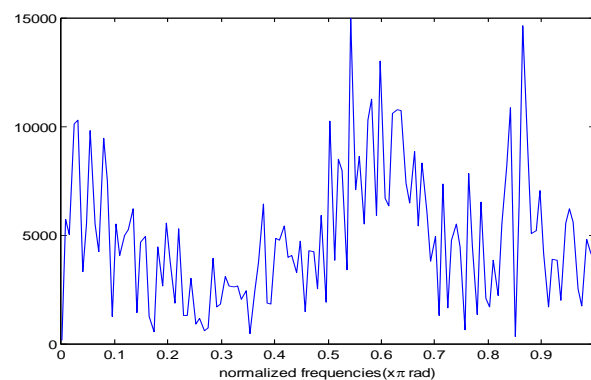


Fig. 5.(g) Frequency domain representation of slopes sequence shown in fig. 5. (f)

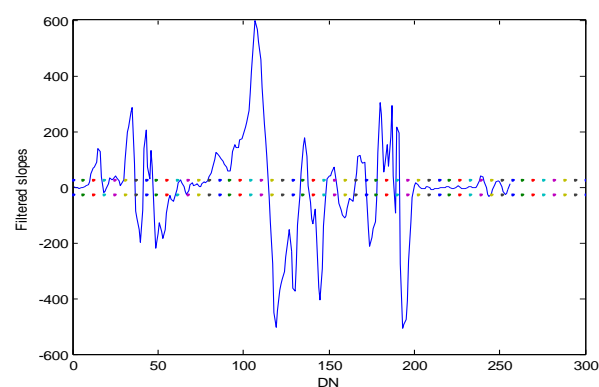


Fig. 5. (h) Filtered slopes sequence corresponding to the histogram in fig. 5. (e)

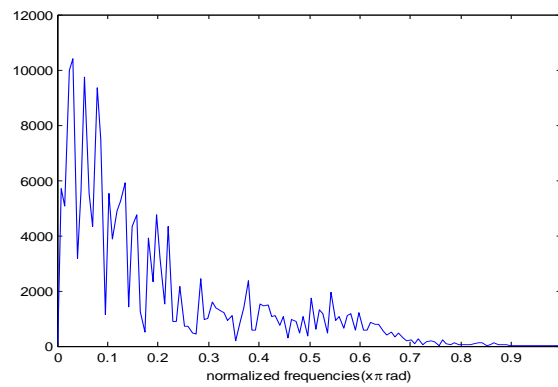


Fig. 5. (i) Frequency domain representation of slopes sequence shown in above figure

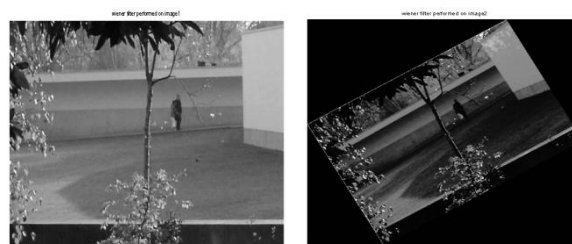


Fig. 5. (j) Wiener filter performed on image 1 and image 2

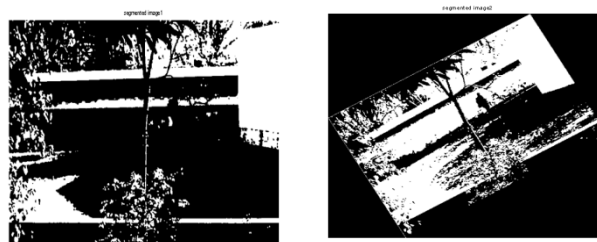


Fig. 5. (k) Segmented image of original and shifted image

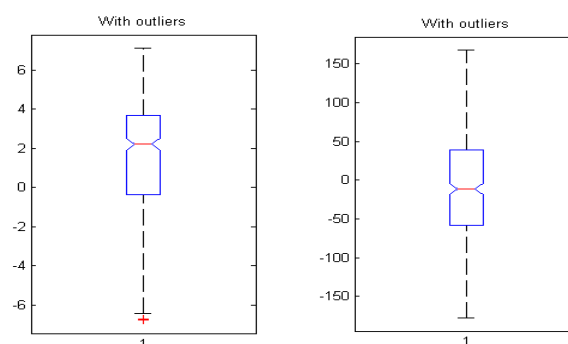


Fig. 5. (l) Boxplot for cost function and rotation estimation

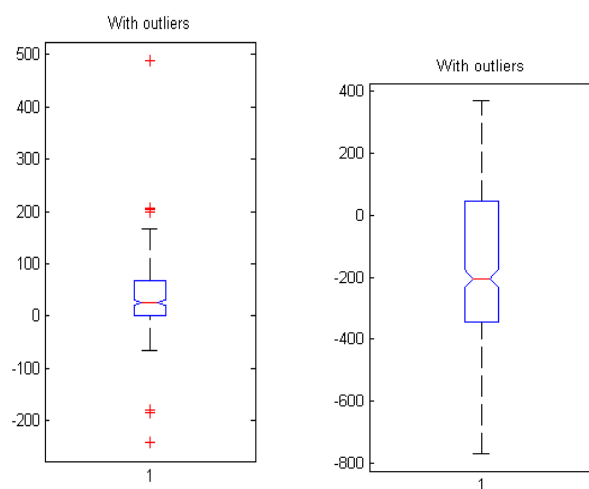


Fig. 5. (m) Boxplot for translation estimation



Fig. 5. (n) Registration of original image with added noise



Fig. 5. (o) Registering original image with unregistered image (final matching)

TABLE I

Tabular column indicates rotation, translation and computation time with different alpha and added noise of four types of images.

Alpha steps		III-A	III-B				III-C		
			10%	20%	50%	100%	Pair 1	Pair 2	Pair 3
20%	Theta	30°	30°	30°	30°	30°	0°	0°	0°
	Translation in x	60	60	58.53	59	59.7	59.4	59.9	60.43
	Translation in y	41	39.12	39.52	40.1	40.8	38	40.2	41.11
	Time(sec)	151	110	120	157	173	60	145	68
10%	Theta	30°	30°	30°	30°	30°	0°	0°	0°
	Translation in x	60	59	59	60	60	59.4	59.9	60.42
	Translation in y	41.0	40	39.52	40.6	39.16	38	40.2	41.11
	Time(sec)	77.5	132.7	117.2	115	176.2	32.8	142	125.5
5%	Theta	30°	30°	30°	30°	30°	0°	0°	0°
	Translation in x	60	59.72	60.4	61.2	61.30	59.4	59.9	60.43
	Translation in y	41.0	41	40	40	41.04	38	40.2	41.11
	Time(sec)	78.6	93.77	116.2	154	181.5	24.1	139	56.42

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