# IMAGE REGISTRATION OF HIGH RESOLUTION REMOTE SENSING BASED ON STRAIGHT LINE FEATURE

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**ABSTRACT:**

Aim at registration of high resolution remote sensing images, a image registration algorithm based on line feature is described in this paper. First, the lines in both images are extracted, Next a modified iterated Hough transform is introduced to develop the correspondence of lines . Finally, the parameters of affine registration transformation functions were calculated ,based on the Similarity Measure of the distance of corresponds straight line segments. Experimental results have verified this algorithm high accuracy and reliability with the registration of images with affine geometric distortion.

## 1. INTRODUCTION

Image registration is fundamental to remote sensing. With the ever increasing number of remote sensing satellites advances in data fusion, use of multi-image spatial information products is swiftly becoming the norm. However, in order to meet the requirements of the user, each individual image making up the multi-image product needs to be expressed in the same geometric reference frame. This means the images have to be accurately registered to each other and preferably expressed in a local geodetic co-ordinate system. Manual image registration is well established, but the procedure can lead to inaccurate results, and can be slow to execute, especially if a large number of images need to be registered. The subject of automatic image registration addresses, and in many cases solves, the problems associated with manual image registration. However, there still exist a number of scenarios where automatic image registration is not well developed and robust paradigms have not been established for multi-source image registration and image-to-map registration. This paper addresses the problem of automatic registration of multi source images, and proposes an innovative, robust model that is shown to produce reliable and accurate results.

## 2. REGISTRATION OF MULTI-SOURCE IMAGES

### 2.1 Definition of registration

Image registration can be defined as a mapping between two images both spatially and with respect to intensity. If we define these images as two 2-dimension arrays of a given size denoted by $I_1$, $I_2$ where $I_1(x, y)$ and $I_2(x, y)$ each map to their respective intensity values, then the mapping between images can be expressed as:

$$I_2(x, y) = g(I_1(f(x, y)))$$

Where f is a 2D spatial coordinate transformation, i.e.,

$$(x, y)' = f(x, y)$$

And g is 1D intensity or radiometric transformation. The registration problem is the task involved in finding the optimal spatial and intensity transformation. The intensity transformation is frequently not necessary, except, for example, in cases where there is a change in sensor type or where a simple look up table determined by sensor calibration techniques is sufficient. Finding the spatial or geometric transformation is generally the key to any registration problem.

### 2.2 Registration methods

According to the nature of features used, existing image registration can be generally grouped into area-based and feature-based d methods. In the area-based method, a small window of points in the first image is statistically compared with windows of the same size in the second image. The measure of match is usually the normalized cross-correlation. The centers of the matched windows are control points which can be used to solve for the transformation parameters between the two images. However, area-based methods like this are not well-adapted to the problem of multi-sensor image registration since the gray-level characteristics of images to be matched are quite different. Feature-based methods, which extract and match the corresponding features from two images, have been shown to be more suitable for this task. The three fundamental and most commonly used spatial domain features are points, lines and homogenous/areal regions. In the image, they include edges, contour, surface, other salient features such as corners, line intersection, and points of high curvature, statistical features such as moment invariants or centroids, and higher level structural and syntactic descriptions. Because the features are invariant to image orientation and are not sensitive to image

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noise and image resolution, Compared with the area-based method, the feature-based methods has the ability to extract a large number of features and greatly reduces the burden on the correspondence step that follows feature selection. So the feature-based methods are particularly suited to multi-source image registration.

## 3. IMAGE REGISTRATION BASED STRAIGHT LINE FEATURE

At present, registration of imagery remains challenging for several reasons. First, images are usually acquired using different sensor types, each having its inherent noise. Furthermore, radiometric as well as geometric properties of the same object in the involved imagery might differ as a result of changes in the sensor view point, imaging methodology, imaging conditions, and spectral sensitivity of the implemented imaging systems. Finally, the registration process can be complicated by changes in object space caused by movements, deformations, and urban development between the epochs of capture associated with the involved images. Although a vast body of research has dealt with automatic image registration, we still do not have a methodology that meets the current challenges posed by image registration. This paper proposes a feature-based method for semi automatic, accurate and robust image registration between high resolution satellite images. An effective automated image registration methodology as well as the method in this paper must deal with four issues, namely registration primitives, transformation function, similarity measure, and matching strategy (L.G.Brown, 1992). In the following subsections, each component of the registration method in this paper is described briefly.

### 3.1 Registration primitives

Registration primitives encompass the domain in which information is extracted from input imagery for the registration process. Hence, to carry out the registration process, the appropriate primitives must be chosen. The three fundamental and most commonly used spatial domain features are points, lines and homogenous/areal regions, in this research, straight-line segments are used as the registration primitives. This choice is motivated by the following facts (Habib, 2001a, 2001b, 2001c): Straight lines are easier to detect than distinct points and areal features. Moreover, the correspondence between conjugate linear features in the input imagery becomes easier. Images of man-made environments are rich with straight-line features. It is straightforward to develop mathematical constraints ensuring the correspondence of conjugate straight-line segments. Free-form linear features can be represented with sufficient accuracy as a sequence of straight-line segments. After selecting straight-line segments as the registration primitives, one has to make a decision regarding on how to represent them. In this research, the line segments are represented by their end points. This representation is chosen since it is capable of representing all line segments in 2-D space. Also, it will allow for a straightforward similarity measure that mathematically describes the correspondence of conjugate line segments. It should be mentioned that the end points defining corresponding line segments in the imagery need not be conjugate.

### 3.2 Similarity measure

Similarity measure mathematically describes the fact that conjugate primitives should coincide with each other after application of the proper registration transformation function. Geometric similarity measure depends on the selected registration primitive (e.g., points, linear features, areal regions) as well as the registration transformation function. In other words, having two datasets, which represent the registration primitives (straight-line segments) manually or automatically extracted from the input and reference images, one should derive the necessary constraints to describe the coincidence of conjugate primitives after applying the appropriate registration transformation function.

The similarity measure formulation depends on the selected registration primitives and their respective attributes. As mentioned before, the registration primitives, straight-lines, will be represented by their end points, which need not be conjugate. In figure 1, assuming that a line segment ab in the reference image corresponds to the line segment cd in the input image, the similarity measure should mathematically describe the fact that the line segment ab will coincide with the corresponding line segment cd after applying the transformation function relating the reference and input images. Such a measure as shown in equation 1 can be derived that the normal distances between the end points of a transformed line segment in the reference image and the corresponding line segment in the input image to be zero.

$$n_1 = \frac{\left|Ax_1' + By_1' + C\right|}{\sqrt{A^2 + B^2}} = 0 \qquad (1)$$

Where （A，B，C） are the parameters of equation which representing the line segment cd in the input image,(x1′,y1′) are the transformed coordinates of point a in the reference image after applying the registration transformation function, Another constraint in the form of equation 1 can be written for point b along the line-segment in the reference image .One pair of conjugate line segments would yield two constraints of the form in Equation (1). Using a given set of “n” corresponding line segments, one can incorporate the resulting “2n” constraints in a least squares adjustment procedure to solve for the parameters of the registration transformation function.

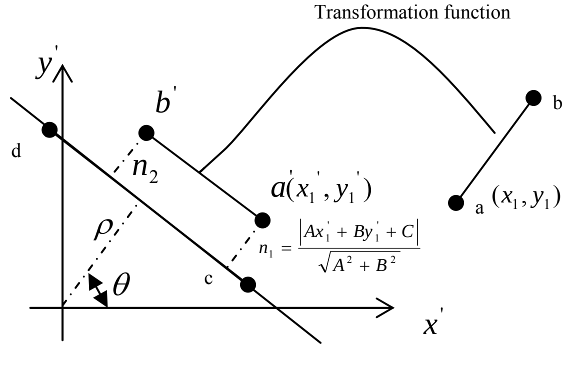


Figure 1 Similarity measure

### 3.3 Transformation function

At this stage, one should establish a registration transformation function that properly aligns the images relative to each other. Given a pair of images, reference and input images, the registration process attempts to find the relative transformation between them. The type of spatial transformation needed to properly overlay the input and reference images is one of the most fundamental and difficult tasks in any image registration technique. Habib and Morgan (2004) showed that affine transformation, Equation (2), could be used as the registration transformation function for imagery captured by satellite imaging systems with narrow angular field of view and long focus. In this paper a 2-D affine will be used to establish the mathematical relationship between conjugate elements of the involved image pair.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \qquad (2)$$

### 3.4 Matching strategy

Matching strategy refers to the concept or overall scheme of the solution of the matching problem. It encompasses the selected primitives, transformation functions and similarity measures for automatically solving the registration problem. In this research the Modified Iterated Hough Transform (MIHT) is used as the matching strategy for automatically deriving an estimate of the parameters involved in the transformation function relating the images to be registered as well as the correspondence between conjugate lines. MIHT has been successfully implemented in several photogrammetric operations such as automatic single photo resection relative orientation, image registration (Habib, 2001, 2004). Such a methodology is attractive since it allows for simultaneous matching and parameter estimation. Moreover, it does not require complete correspondence between the primitives in the reference and input images.

The basic steps for implementing the MIHT for solving the registration problem are as follows: Approximations are assumed for the parameters which are yet to be determined. The cell size of the accumulator array depends on the quality of the initial approximations; poor approximations will require larger cell sizes. Then all possible matches between individual registration primitives within the reference and input images are evaluated, incrementing the accumulator array at the location of the resulting solution, from each matching hypothesis. After all possible matches have been considered, the peak in the accumulator array will indicate the most probable solution of the parameter in question. Only one peak is expected for a given accumulator array. After each parameter is determined, the approximations are updated. For the next iteration, the accumulator array cell size is decreased to reflect the improvement in the quality of the parameters. Then, the above two steps are repeated until convergence is achieved. By tracking the hypothesized matches that contribute towards the peak in the last iteration, one can determine the correspondence between conjugate primitives. These matches are then used in a simultaneous least squares adjustment to derive a stochastic estimate of the involved parameters in the registration transformation function. In fact In order to solve n parameters simultaneously, one must utilize the number of hypothesized entity matches needed to generate the required n equations. However, this approach is not practical. Simultaneous evaluation of all permutations of entities leads to combinatorial explosion. In addition, the memory requirements of an n dimensional accumulator array create another problem. In order to reduce the computational complexity of the problem, an alternative approach is to solve for the parameters sequentially in an iterative manner, updating the approximations at each step. Consequentially, the accumulator array becomes one dimensional and the memory problem disappears. After each iteration, the approximations are updated and the cell size of the accumulator array can be reduced to reflect the improvement in the quality of the approximate values of the unknown parameters. In this manner, the parameters can be estimated with high accuracy. Detailed explanation about the MIHT can be found in references (Habib, 2001, 2004).

## 4. EXPERIMENT AND CONCLUSION

To illustrate the feasibility and robustness of the suggested registration process, experiments were conducted using two real datasets. The dataset 1 is composed of 1551 rows × 1471 columns Resource 2 Satellite of China scene (3m) captured in 2004 and 2022 rows × 2149 columns SPOT scene (2.5m)captured in 2002;The dataset 2 is composed of 503 rows × 455 columns Resource 2 scene (3m)captured in 2004 and 1121 rows × 1205 columns ortho-image (1m) which is created from an aerial image captured in 2000. Figure 2-3 shows sample image patches. These scenes were captured at different times and exhibit significantly varying geometric and radiometric properties. The experiment is conduct as following:

### 4.1 Straight line extract

Afterwards, straight-line segments can be manually digitized or automatically extracted in the available scenes. Manual digitization was adopted in this research. Straight - line segments have been manually digitized in these images. Figure 4 shows partly the digitized segments in the 2004 Resource 2 image and 2002 SPOT5 image, where 55 lines have been digitized in the reference image (2002 Spot) and 51 Lines have been digitized in the input image (2004 Resource 2). Figure 5 shows partly the digitized segments in the 2004 Resource 2 image and 2000 aerial image, where 70 lines have been digitized in the reference image (2000 aerial image) and 75 Lines have been digitized in the input image (2004 Resource 2). In this two figures, one can see that there is no complete correspondence between the digitized primitives in the input and reference images.

### 4.2 Feature match

The digitized segments are then incorporated in the MIHT strategy to automatically determine the correspondence between conjugate line segments as well as the parameters of transformation function. The procedure can be described in the following steps.

- Establish approximations for b0, a1, b1, a2 and b2.
- Determine the range and the cell size of the accumulator array for a0, depending on the quality of the approximations of the other parameters.
- Using the equation (1), solve a0 for every combination of line in reference image with one line in input image. At the location of each solution, increment the corresponding cell of the accumulator array.

- After considering all possible combinations, locate the peak or maximum cell of the accumulator array. That cell has the most likely values of a0.
- Repeat step 1 to step 4 for b0, a1, b1, a2, b2 updating the approximations of the parameters that was determined earlier.
- Decrease the cell size of the accumulator arrays for (a0, b0), (a1, b1) and (a2, b2) to reflect the improvement in the quality of the approximate transformation function parameters. Then, repeat steps 1–5 until the parameters converge to the desired precision.
- Using the estimated transformation parameters and the straight-line segments in the input image, one can computer the corresponding straight-line segment in the reference image, then the correspondence problem is solved. The resulting matches are used in a simultaneous least-squares adjustment to solve the precise transformation parameters and error of registration.

### 4.3 Experiment and result

The estimated parameters for affine transformation functions and their variance components for the abovementioned datasets are listed in Table 1, the estimated variance components, which reflect the quality of fit, reveal two facts. First, they show good registrations between the involved images. Also, the small variance components signify the validity of the affine transformation as the registration transformation function.

Experimental results showed the feasibility and the robustness of the suggested approach that could tolerate possible discrepancies between the imagery due to varying sensor operational principles as well as changes in the object space without the need for approximate registration of the involved imagery. Moreover, the results proved the superiority of straight-line segments which showed its effectiveness in registering among multi-source imagery. The suggested approach in this research has the potential to registration various types of spatial data such as maps and a GIS database with aerial imagery. But the MIHT method is based the principles of statistics, so the disadvantage of this approach is to need enough straight-line segments, or else the parameters fail to converge. Future research will concentrate on automatic extraction of the registration primitives, straight-line segments, from the input imagery. Furthermore, research should be conducted to evaluate the limits for the validity of the affine transformation as the registration transformation function.

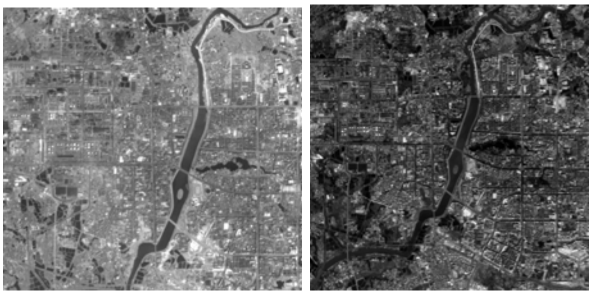

Figure 2 2004 Resource 2 image and 2002 SPOT5 image

Figure 3 2004 Resource 2 image and 2000 aero image

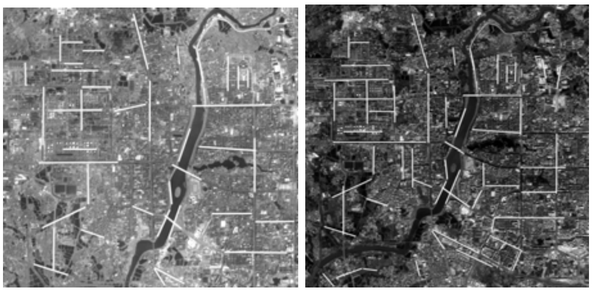

Figure 4 Digitized linear features in the 2004 Resource 2 image and 2002 SPOT5 image

Figure 5 Digitized linear features in the 2004 Resource 2 image and 2000 aero image

| Affine | Resource 2004/ SPOT 2002 | Resource 2004/ aero image 2000 |
|---|---|---|
| $\sigma^2$(pixel$^2$) | 3.467 | 3.289 |
| a0(pixel) | -61.658 | 29.209 |
| a1 | 1.205 | 2.945 |
| a2 | 0.006 | -0.05 |
| b0(pixel) | 64.347 | -130.472 |
| b1 | 0.005 | 0.02 |
| b2 | 1.202 | 3.06 |

Table 1 Affine transformation parameters between the involved datasets

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