THE IMAGE REGISTRATION TECHNIQUE FOR HIGH RESOLUTION REMOTE SENSING IMAGE IN HILLY AREA

Gang Hong, Yun Zhang

Department of Geodesy and Geomatics Engineering
University of New Brunswick
Fredericton, New Brunswick, Canada E3B 5A3
Email: v5z78@unb.ca
yunzhang@unb.ca

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ABSTRACT:

Image registration is one of the important image processing procedures in remote sensing; it has been studied and developed for a long time. However, until now, it is still rare to find an accurate, robust, and automatic image registration method, and most existing image registration methods are designed for particular application. At present, high resolution remote sensing images have made it more convenient for people to study the earth; however, they also bring some challenges for the traditional research methods. In terms of image registration, there are some problems with using current image registration techniques for high resolution images, namely: (a) precisely locating control points is not as simple as with moderate resolution images; (b) manually selecting the large number of control points required for precise registration is tedious and time consuming; (c) high data volume will adversely affect the processing speed in the image registration; and (d) local geometric distortion can not be removed very well using traditional image registration methods even with enough control points. Based on these reasons, the need for an image registration approach that will resolve these problems is urgent.

This paper proposes a new automated image registration technique, which is based on the combination of feature-based and area-based matching. Wavelet-based feature extraction technique and relaxation-based image matching technique are employed in this research. Local distortions caused by terrain relief can be greatly reduced in this procedure. IKONOS and QuickBird data are used to evaluate this technique.

1. INTRODUCTION

Image registration is a fundamental image processing technique in remote sensing application. It has been widely used in change detection, image fusion and other related areas. In order to integrate different kinds of sensor data and different temporal data, image registration is an indispensable preprocessing tool in integrating multi-source and multitemoral images. In change detection process, the image registration accuracy directly influences the accuracy of change detection result. Theoretically, the image registration accuracy should be limited to half or one pixel in change detection; otherwise it will later affect the change detection accuracy. Townshend et al. (1992) indicated the need to achieve high values of registration accuracy, or substantial error will be induced when comparisons between images are made for the purposes of reliably detecting land cover changes. In image fusion process, the image registration accuracy will affect the final fusion result; if the panchromatic image and multispectral image has been registered very well, final fusion image appear one whole image although it is be integrated by two images, otherwise, the fusion image appears blur or edge phenomena because of misregistration.

Image registration technique is also a classical problem and has been studied and developed for a long time. However, until now, it is still rare to find an accurate, robust, and automatic image registration method, and most existing image registration methods are designed for particular application, the performance of a methodology is always limited to a specific application, or sensor characteristics and the terrain characteristic of the imaged area. At present, more and higher resolution remote sensing images have made it more and more convenient for people to study the earth; however, they also bring some challenges for the traditional research methods. In terms of image registration, there are some problems with using current image registration techniques for high resolution images, namely: (a) precisely locating control points is not as simple as with moderate resolution images; (b) manually selecting the large number of control points required for precise registration is tedious and time consuming; and (c) high data volume will adversely affect the processing speed in the image registration. Based on these reasons, the need for an image registration approach that will resolve these problems is urgent.

Traditionally, the image registration process consists of the following steps: 1) Feature extraction - identifies the relevant features in the two images (reference image, sensed image), which include edges, intersection of lines, regions, etc. 2) Feature matching - establishes relationship between the features in the two images. 3) Mapping function building - determines transformation parameters of the mapping functions using the features being matched. 4) Image registration - geometrically transforms and resamples the sensed image according to the mapping function established. In fact, the image registration problem can be divided into two parts, namely selecting accurate control points and interpolating the image. For the control point selection, the existing automated image matching techniques can be broadly classified into two categories: area-based matching (ABM) and feature-based matching (FBM) techniques.

Area-based matching uses the gray value of the pixels to describe matching entities. In the area-based matching algorithms, a small window of pixels in the sensed image is compared statistically with windows of the same size as the reference image. Usually the normalized cross-correlation or least-squares technique is used to measure the degree of match. The centers of the matched windows are treated as control points, which can be used to solve for mapping function parameters between the reference and sensed images (Li et al., 1995). Area-based matching is the classical method. It is rarely discussed in recent publications. Cideciyan et al. (1992) used Fourier transformation and cross-correlation for image registration. Zheng and Chellapa (1993) used the area correlation in the spatial domain to match the feature points that are extracted by the Gabor wavelet decomposition. On the other hand, feature-based matching techniques do not use the gray values to describe matching entities, but use image features derived by a feature extraction algorithm. These features include edges, contours, surfaces, other salient features such as corners, line intersections, and points of high curvature, statistical features such as moment invariants or centroids, and higher level structural and syntactic descriptions (Brown, 1992). The form of the description as well as the type of features used for matching depends on the task to be solved. There are various methods introduced in feature-based matching. Goshtasby et al. (1986) used the region-based approach in image registration. The corresponding centers of gravity of regions are used as corresponding control points to estimate the registration parameters. Ventura et al. (1990) described feature-based matching using structural similarity detection techniques. Djamdji et al. (1993) used "á trous algorithm" wavelet transformation method for feature extraction. Zheng and Chellappa (1993) used Gabor wavelet decomposition to extract feature points. Flusser and Suk (1994) applied the affine moment invariants principle, a segmentation technique in registering an image with affine geometric distortion. Li et al. (1995) presented two contour-based methods, which used region boundaries and other strong edges as matching primitives. Simhadri et al. (1998) applied the modified "á trous algorithm" wavelet transformation in feature extraction. Dai and Khorram (1999) combined an invariant moment shape descriptor with improved chain-code matching to establish correspondences between the potentially matched regions detected from the two images. Moigne et al. (2002) utilized maxima of wavelet coefficients to form the basic features of a correlation-based automatic registration algorithm.

ABM is simple and has a high precision. The imperfections are also applicable to ABM. The prerequisite of the ABM is that gray level distribution of the sensed image and reference image must be similar because it is sensitive to geometric distortion and radiometric noise. Since gray values contain little explicit information about the object space, as a consequence, area-based matching methods are not reliable enough. Therefore, area-based methods are not well adapted to the problem of multisensor image registration since the gray-level characteristics of images to be matched can vary from sensor to sensor. Compared with AB, FBM is more robust and reliable (Schenk, 1999). First, features are derived properties of the original gray level images and are inherently unique. Second, similarity is based on the attributes and /or relations and thus, it is more invariant to illumination, reflectance, and geometry. Third, features are sufficient for describing image content. However, the worst problem for FBM is precision. Because FBM uses one pixel as a unit, it cannot get sub-pixel accuracy in the registered image, while least-squares matching can do that. Also FBM often requires sophisticated image processing for feature extraction and depends on the robustness of feature detection for reliable matching.

2. METHODOLOGY

A new image registration technique which integrates area-base matching technique with feature-based matching technique is explained in this paper. The principle of this method is listed in Figure 1.

The whole registration process can be generally divided into three major parts (the part number is listed in Figure 1): first, find the corresponding control points in the reference image and the sensed image; second, refine the control points and obtain the fine control point pairs; and third, build the mapping function according to the fine control point pairs and then resample the image.

Because of their high spatial resolution, finding control points precisely for IKONOS and QuickBird images may not be as easy as for moderate resolution images. For example, a road intersection appearing as a point in SPOT or TM imagery will appear as a small area in IKONOS or QuickBird image, thus to locate the precise position of the road intersection in high resolution image such as IKONOS and QuickBird is not so easy and time consuming.

In order to register high resolution image accurately, a large number of control points must be selected in the reference image and the sensed image. This is a very tedious and repetitive task if the operator selects the control points manually. Furthermore, this approach requires the operator who is knowledgeable in the application domain, which is not feasible in cases where there is a large amount of data. Thus, there is a need for automated techniques that require little or no operator supervision (Fonseca and Manjunath, 1996).In terms of high resolution, there exists another problem, namely that the high data volume will affect the processing speed for image registration. In order to resolve these problems, this process will develop an automated image registration method using feature-based and area-based matching combination. In order to improve the computation efficient, multilevel matching technique is employed.

In this technique, the wavelet multi-resolution representation property (Mallat, 1989) is used to produce pyramid images from coarse to fine to represent the sensed and reference images. When one image is decomposed into the low level, one approximate image (LL) and three detailed images (LH, HL, HH) can be obtained. Because the LH image only includes the horizontal features, HL only includes the vertical features, while the HH image corresponds, theoretically, to diagonal features, but it also includes the high frequency noise, which affects image matching severely. The LL is the approximation of the actual image, which is always used for image registration. For the HL and LH images, they can form the magnitude image, a series of distinct feature points can be obtained through finding the local maxima of the magnitude image. The feature point's relationship between the reference image and the sensed image can be established using feature-based matching method, in this paper, two methods are tried: one is cross-correlation matching and the other is probability relaxation method (Davis, 1979; Medioni and Nevatia, 1984; Ton and Jain, 1989). Thus, these points can provide the initial value for the next level point matching, and the threshold value is adjusted to get more feature points varying with the image level. That is the first step of the whole image registration process-initial control points selection.

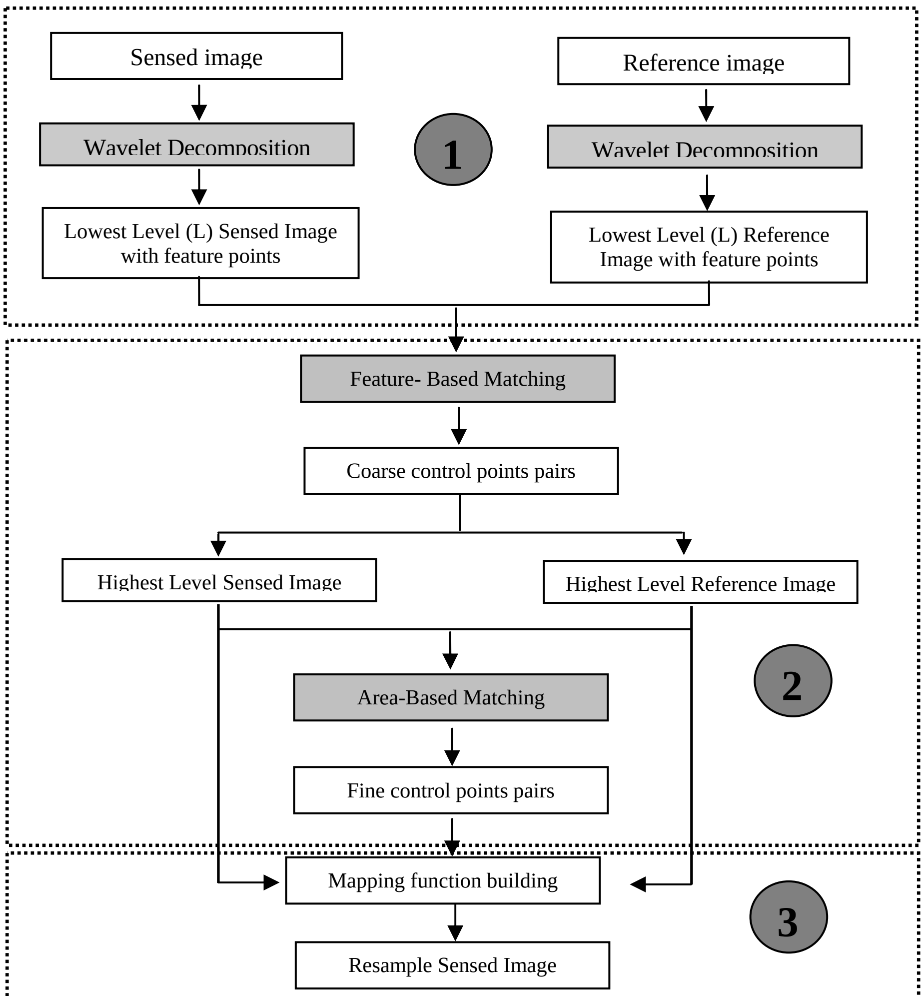

Figure 1. The flow of the image registration

The following task is to obtain the fine control point pairs according to these initial values. In order to achieve a highly accurate registered image, least square matching is employed to refine the control points and to correct for control point errors. In order to distribute the control point evenly, the image is divided into several grids. For every grid, the number of the control points is taken into account.

The third step is to build the mapping function and get the transformation coefficients to resample the sensed image. Traditionally, one set of transformation coefficients is used for the whole image. The shortcoming of this is that it can't resolve the local distortion. The remote sensing satellites, like IKONOS and QuickBird, are closer to the earth compared with other satellites, so the terrain relief affects their images strongly. Especially in mountainous areas, this kind of distortion commonly exists and cannot be resolved by one set of transformation coefficients for the whole image. The method used to resolve this problem is to rectify the sensed image using several sets of mapping function coefficients. Because a large of control points have been selected, the whole image can be divided into a lot of small areas, in this small area, the terrain can be assumed to flat, thus, this method can efficiently reduce the local distortion because of terrain relief.

3. EXPERIMENT

In order to verify this technique, a set of high resolution images have been tested, one is IKONOS panchromatic image (resolution: 1m) and QuickBird multispectral image (resolution: 2.8m). Two image sizes are all 1024 by 1024 pixel. Preliminary and some intermediate results are provided. The terrain characteristic of images is moderate relief.

First, the QuickBird image is resampled to 1m according to the spatial resolution of IKONOS panchromatic image resolution. During the process of finding find control points pairs, three bands multispectral image first is turned into one band gray image. According to the fine control points pairs between panchromatic image and gray form image of multispectral image, three bands are registered one by one. Two levels pyramid structure are built for panchromatic image and gray form image of multispectral image by wavelet decomposition.

Figure 2 is the original image of IKONOS panchromatic image. Figure 3 is the original image of QuickBird multispectral image. Figure 4 is one level wavelet decomposition image of IKONOS. Figure 5 is one level wavelet decomposition of QuickBird gray format image. Figure 6 is the feature extraction points of low level IKONOS image. Figure 7 is the feature extraction points of low level QuickBird multispectral image. Figure 8 is the result of QuickBird multispetral image registered to the IKONOS panchromatic image.

Figure 2 IKONOS panchromatic image

Figure 3 Quickbird multispectral image

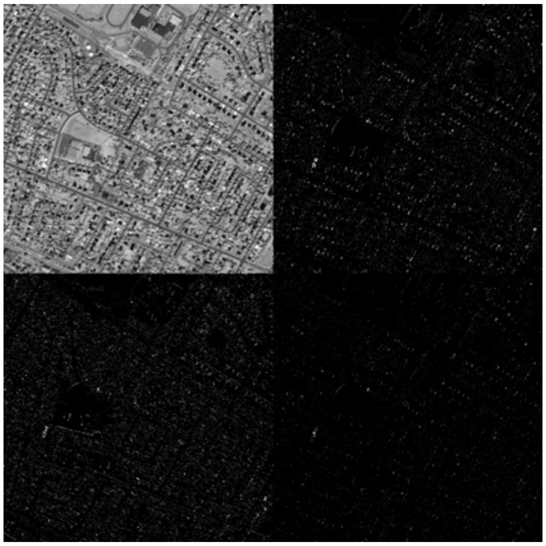

Figure 4 Panchromatic image wavelet decomposition

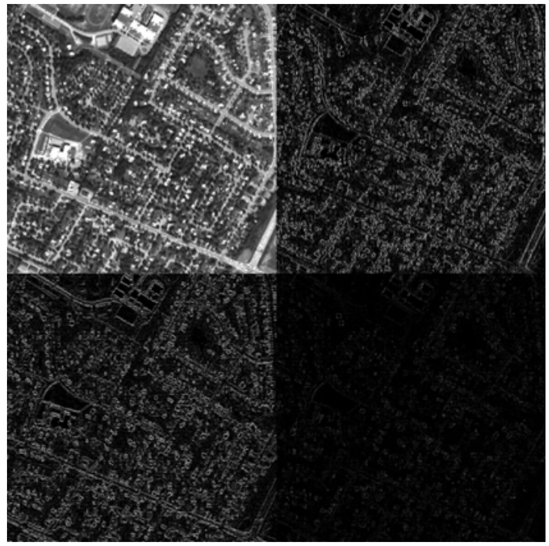

Figure 5 Multispectral image grey form image wavelet decomposition

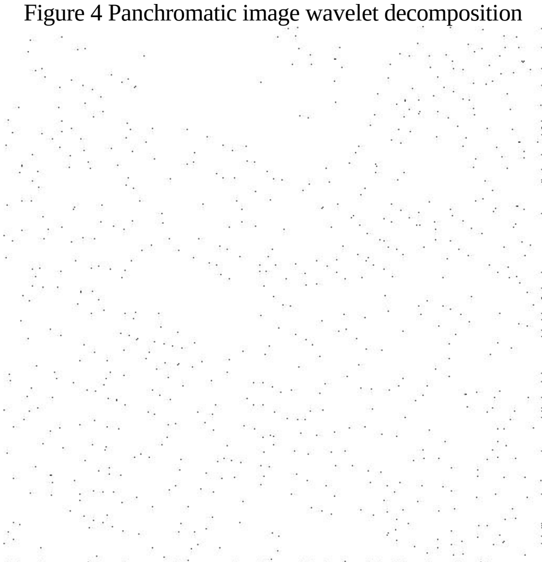

Figure 6 low level feature extraction points of IKONOS

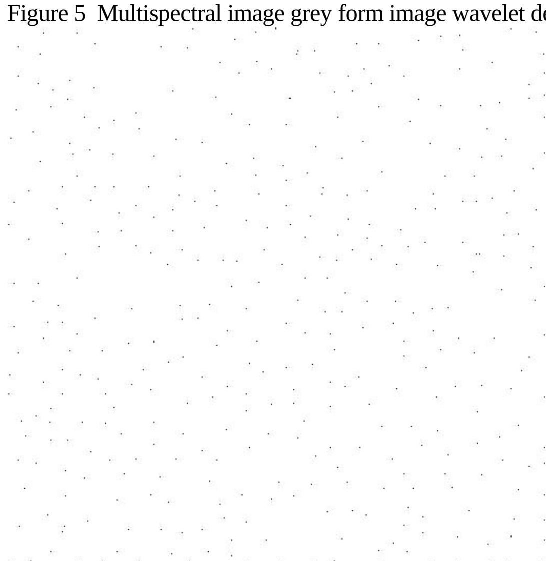

Figure 7 low level feature extraction points of QuickBird

Figure 8 registered Quickbird image

4. CONCLUSION

Because the high resolution remote sensing image is sensitive to terrain relief, the image registration technique in this paper is intended to resolve the following problems existing in registering high resolution images: (1) automatically selecting a large number of control points pairs in the sensed image and the reference image; (2) reduce the computation time because of high volume data; (3) reduce the local distortion existing in different sensors and different temporal images. Basically, this method can meet these requirements. However, it still needs some improvement. The problems existing in this method are: (1) it will take some time to set an appropriate threshold to get idealistic feature points; (2) it will take some time to correspond control points in the sensing image and the reference image using relaxation method.

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