Automatic Registration of SAR and Visible Band Remote Sensing Images

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***Abstract*-Image registration is one of the basic image processing operations in remote sensing. With an increasing number of images collected every day from different sensors, automated registration of multi-sensor/multi-spectral images has become an important issue. A wide range of registration techniques exists for different types of applications and data sources, however no algorithm is known that can accurately register multi-source images consistently. This research addresses this problem by investigating the development of a fully automatic registration system for synthetic aperture radar (SAR) and optical remote sensing images.**

The development of this new automatic image registration method is based on the extraction and matching of common features that are visible in both images. The algorithm involves the following five steps: noise removal, edge extraction, edge linking pattern extraction and pattern matching.

The application of the developed automatic image registration model to SAR and optical image pairs showed that accurate ground control points (GCPs) could be identified automatically.

***Index Terms*—SAR, Feature extraction, Automatic image registration.**

I. INTRODUCTION

Image registration is one of the important preprocessing steps for studying changes of a scene over time. It is often used with satellite images for environmental studies and with medical images for pathology analysis. Registration algorithms attempt to recover the transformation parameters that describe how one image maps to another. Technological developments in digital image registration have advanced from traditional area-based to feature-based and structural image registration.

The problem in creating a layered product from different sensors based on different parts of electromagnetic spectrum (say RADARSAT and Landsat) is in assuring pixel to pixel registration, else the resulting image's registration is difficult. For this process to be automatic, the comparison of the two images must depend only on their content and not require operator selection of features. Thus the essential problem is automatic feature extraction and matching.

There is a large variation in response of different sensors to the same surface. SAR images can be bright where optical images are dim and vice-versa. Topography is prominent in RADARSAT but not Landsat, while Landsat depicts roads and rivers well but RADARSAT does not. Thus feature extraction must be very discriminating to compare images captured by different sensors. Rignot *et al*. [1] have shown that some classification schemes can segment images from different sensors into comparable regions. Similarly, edge detection algorithms that are insensitive to the SAR speckle noise in SAR, will produce linear features that compare well between images.

Following selection of common features, their locations must be geometrically matched to determine the optimal registration correction. This can be done in a number of ways. The features can be represented as binary images and area correlation applied to find the misregistration shifts. Other methods, known as distance transform and chamfer matching [2] (curve matching using distance functions), use a generalized distance to measure the mismatch between features. Optimizing this distance as a function of shift determines the correction. These methods work well if the features are close in shape and orientation. For more severely mismatched features, dynamic programming [3] and autoregressive model methods may be tried. However, the matches are found between patterns of the different images through certain constrains [1][4]. Techniques for automated multi-sensor image registration are still in their infancy. Techniques are at present *ad hoc* and selectively applied as required by the data under consideration.

Although the images to be registered are acquired from the same scene, there are two important differences between them: the characteristics of the sensors (stretching and sheering) and a possible noticeable translation, rotation and scaling of the scenes due to the different positions of these sensors. However SAR and optical images of the same scene appear quite different as seen in Fig. 1. Therefore the first step in trying to register them is to extract just the common features in both of them. In this paper, the development of this new automatic image registration method is based on the extraction and matching of common features that are visible in both images. The algorithm involves the following five steps: noise removal (Section II), edge extraction (Section III), edge linking (Section IV), the pattern extraction using controlled region growing and pattern matching (Sections V and VI). A discussion and some concluding remarks are given in Section VII.

II. NOISE REMOVAL

A. SAR preprocessing

SAR image products are corrupted by speckle noise, which compromises the radiometric quality of the image and hence reduces the signal to noise ratio. In SAR imagery, speckle is generally modeled as a multiplicative noise. SAR images are useful, but the corupting speckle makes the interpretation difficult. To improve the interpretability, and therefore the usefulness of SAR images, it is essential to try to remove or reduce the speckle. A very large number of speckle reduction filters have been developed over the years [5]. Some of the groups of speckle reduction filters are simple filters, rigorous adaptive filters, non-rigorous adaptive filters and modified traditional filters. However, selecting the best SAR filter depends on features of interest. In this application, features must have closed boundaries and they must not be too small, since small features are difficult to match. Therefore the ideal speckle reduction filters for this application can remove or reduce the speckle while retain features with strong edges. The Kuan filter was selected for this task [6].

B. Optical preprocessing

In contrast to SAR data, optical data requires very little radiometric preprocessing before feature extraction. Since the signal to noise ratio is typically high, noise does not obscure features and generally no smoothing is required. However, application of histogram equalization making features become much more distinct from their backgrounds and improved the success of optical image feature extraction algorithms.

III. EDGE EXTRACTION

Most remote sensing applications, such as image registration, image segmentation, region separation, object description and recognition use edge detection as a preprocessing stage for feature extraction. Image edges are usually found where there is a sudden change in image intensity. This will result in local minima or maxima of the first derivative of the intensity. Equivalently, this same location will have a zero-crossing of the second derivative.

The edge detector should provide consistent identification of high contrast boundries. A number of different edge extraction schemes have been considered [7]. A modified Canny edge detector was considered suitable[8][9], and this filter is demonstrated in Fig. 2.

IV. EDGE LINKING

Since the contours within the edge map are often incomplete, some forms of edge linking is necessary. Morphological operators are applied to obtain closed contours. The edge map is dilated using a window proportional to the gap size to achieve the closed contours. This operation is necessary for accurate pattern extraction.

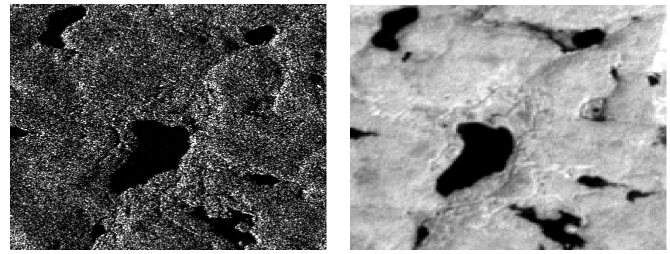

Fig. 1 Middle Ottawa , Canada by different sensors, (a) RADARSAT (b) Landsat

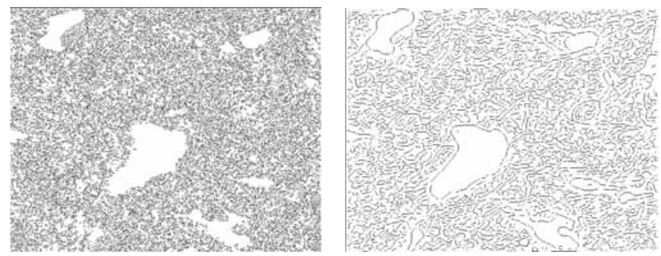

Fig. 2 Edge maps using a modified Canny edge detector

V. PATTERN EXTRACTION

Following edge linking, pattern extraction is performed to identify large homogeneous regions within closed contours. The initial regions are obtained by scanning the edge map with a square window and masking pixels when the window is completely free of edge points. These initial regions are then grown until they meet the enclosing edge contours. This process identifies the large edge free regions while ignoring smaller, less significant features.

VI. PATTERN MATCHING

After region growing is completed, the patterns are assigned arbitrary labels. The final step of the overall algorithm, pattern matching, is performed. This is done by using the attributes of the patterns in SAR and optical images such as perimeter, centroid, area, convex hull, number of pixels above horizontal center line, number of pixels to the right of vertical center line and the area of bounding box of the pattern. The difference between the attributes determine the value of a matching cost function C. The matching function is determined for the first pattern in image 1 and all the patterns in image 2. The combination of patterns which has minimum matching cost is accepted as the best match. Pattern A from the first image and B from the second image are selected as a matched pair if the following conditions are satisfied:

(a) $C_{AB} \le C_{AB'}$ ie. B' includes all the patterns with similar shapes to pattern A,

(b) $C_{AB} < T$ ie. If the minimum matching cost is above the threshold, T, there is no match.

The process is "pairwise exhaustive" ie. repeating for the second, third and all subsequent patterns in image 1 until they have all been matched with patterns in image 2. In the situation where a pattern from image 2 has been matched with two different patterns from image 1, the match with the lowest match function is accepted as the correct one. The result is that all the patterns in image 1 have been matched, but not necessarily all of the patterns in image 2. To ensure that all of the patterns in image 2 have the opportunity to be matched with all of the patterns in image 1, the process is repeated with the order of the images reversed. The first pattern in image 2 is matched with all the patterns in image 1, as is the second, third, and so on. Multiple matches are again eliminated using the value of the matching function. The centroid of the matched patterns are taken as accurate ground control points (GCPs). The application of the developed automatic image registration model to a SAR (ERS-1), SPOT pair images and RADARSAT and Landsat pair images showed that (GCPs) can be identified automatically, as displayed in Fig. 3. Following the GCP recognition, standard methods can be used for registration.

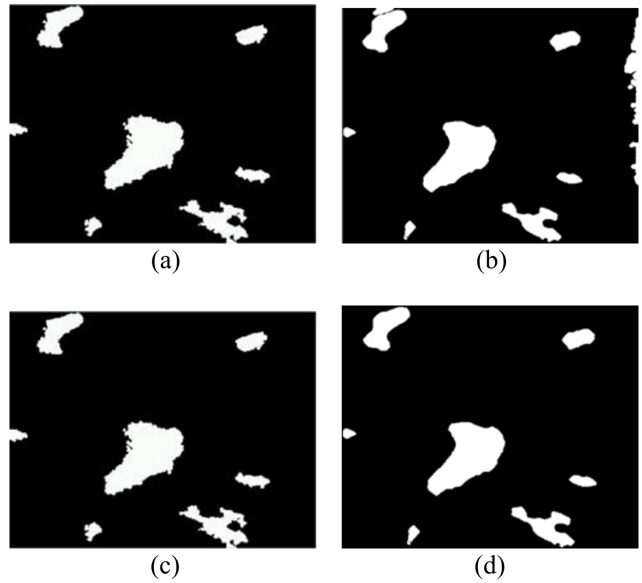

Fig. 3 Extracted patterns from RADARSAT (a)and Landsat(b) images. (c) and (d) are the matched patterns.

CONCLUSION

One of the major advantages of automatic image registration is subpixel accuracy potentially could be achieved for conjugate points. Using the proposed technique, the problem of region growing in SAR images which happen due to the difficulty of obtaining homogenous regions is solved. The region growing controlled by edge map is more accurate than using image segmentation for pattern extraction due to the uncertainty of segmentation boundaries. Implementation of the proposed model has shown that automatic ground control points measurement between pairs of SAR and optical images can be accurately achieved. The model should be tested under more SAR and optical data for accurate evaluation.

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REFERENCES

[1] E. J. M, Rignot, R. Kwok, J. C. Curlander and S. S. Pang," Automated multisensor registration: Requirements and techniques", *Photogrammetric Engineering and Remote Sensing*, Vol. 57, pp. 1029-1038, 1991.

[2] B Gunilla, "Hierarchical Chamfer Matching: A Parametric Edge Matching Algorithm", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* Vol. 10, No. 6, pp. 849 – 865, Nov. 1988.

[3] G. M. Qu'enot, "Image Matching using Dynamic Programming: Application to Stereovision and Image Interpolation" *Image Communication, Bordeaux,* France, 20-22 may 1996.

[4] J. C. Curlander, and R. N. McDonough, "Synthetic Aperture Radar, Systems and Signal Processing," John Wiley & Sons, New York, 1991.

[5] I. McConnell and C. Oliver, "Comparison of annealing and iterated filters for speckle reduction in SAR", in *Microwave Sensing and Synthetic Aperture Radar*, Proc. SPIE 2958 ,pp.74-85,1996.

[6] D. T. Kuan, A. A. Sawchuk, T. C. Strand, P. Chavel, "Adaptive noise smoothing filter for images with signal-dependent noise", *IEEE Trans. Patt. Anal. Machine Intel*, Vol. 7, No. 2, pp. 165-177, 1985.

[7] M. Heath, S. Sarkar, T. Sanocki, and K. Bowyer, "Comparison of Edge Detectors: A Methodology and Initial Study," *Proc. IEEE Conf. Computer Vision Pattern Recognition*, San Francisco, *IEEE CS Press*, pp. 143-148, June 1996.

[8] J. F. Canny,"A computational approach to edge detection," *IEEE Trans. Pattern Analysis and Machine Intelligence*,Vol: 8, pp. 679-698, 1986.

[9] M. Ali, and D. Clausi "Using the Canny edge detector for feature extraction and enhancement of remote sensing images", *Proceedings of International Geoscience and Remote Sensing Symposium*, *IGARSS, Sydney, Australia*, 9-13 July 2001.