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Improving the Accuracy of AIR for Remote Sensing Application using Multisensor

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ABSTRACT

Background: A new acquired image must be transformed, using image registration techniques, to match the orientation and scale of the related reference images. Image registration requires intensive computational effort not only because of its computational complexity, but also due to the continuous increase in image resolution. **Objective:** This study presents a method for improved accuracy of automatic image registration (AIR) for remote sensing application using multisensors. **Results:** This method identifies efficient techniques for high-performance automatic image registration for remote sensing. The information used to include hybrid techniques provide a trade-off between speed and accuracy with GA-IRA being the best hybrid technique. **Conclusion:** The sequential and parallel algorithms developed as suitable for a wide range of remote sensing data, as they provide adequate accuracy and embody a great deal of speed (due to reduction of data and search space as well as parallel processing). This makes them also suitable for working with massive remote sensing data has been proposed in this study.

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INTRODUCTION

Many applications in remote sensing rely on image registration. These include three-dimensional mapping of the land and sea surface, identifying and mapping different types of land use, measuring and analyzing natural and agricultural vegetation, matching stereo images to recover shape for autonomous navigation, and aligning images from different medical modalities for diagnosis. With the dramatic increase in data volumes and types of sensors, image registration became also crucial for content-based retrieval of remote sensing data and image data from large data repositories. Image registration is to determine the transformation between a newly sensed image, called input image, and a reference image. In general, image registration is the process of superimposing two images and transforming one of them to find the best transform to make them match (Campbell, 1987; Chipperfield, 1996). Broad range of techniques for image registration has been categorized in (Taleb, 2005). The complexity of the search and similarity measurement in image registration could be computationally intensive.

This section briefly describes and distinguishes among digital image registration, associated transforms, automatic image registration, sub pixel image registration, and high-performance image registration.

Background view:

Digital image registration:

Remote sensed data usually contain two types of distortion: radiometric distortion and geometric distortion [6]. Sources of radiometric distortion are from effects of atmosphere on radiation, effects of atmosphere to remote sensing imagery, and instrumentation errors. These errors can be corrected using the knowledge of the sensor model. Sources of geometric distortion are Earth rotation, panoramic effects, Earth curvature, scan time skew, variation in platform altitude, velocity, attitude, and aspect ratio. There are two major techniques that can be used to correct the various types of geometric distortion. One is to establish correction formulae by modeling the nature of the error sources.

Mathematical modeling can be used to correct these errors. Without the knowledge of sensor sources, an image can be registered to a map coordinate system. This is called image-to-map registration. In this case, the pixels are addressable in terms of map coordinates (latitudes and longitudes or eastings and northings). Using image pixel addresses in terms of a map coordinate base is often referred to as geocoding. If geocoding is not important, the

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image can be registered to a previously related image, called reference image. The resulting output of image registration is a set of transforms or a mapping function that tells us how the input image is different from the reference image. Using these parameters the input image can be transformed to match the reference image. This dissertation concentrates on image-to-image registration techniques without the use of any prior knowledge about the sensor. However, the developed techniques should be feasible to apply to image-to-map registration

Overview:

Automatic image registration:

Automatic image registration is to perform the image registration task without the guidance of incoming satellite images from the Earth Observing System (EOS) program and from new missions with hyperspectral instruments mandate the need for automatic image registration.

One of the well-known techniques for image registration is to use Ground Control Points (GCPs). Ground control points are a set of selected pixels (or regions) that contains important features like intersection of roads or coastlines. They are features that can be located accurately with ease on a map (Bernstein,1987). These control points can be used to identify the transforms between the input image and the reference image shown in fig 1.

An assumption is made that the reference image is geometrically correct (El-Ghazawi, 1994). To relate GCPs in the input image to the grid in the reference image, two Cartesian coordinate systems are used. One describes the location of points in the reference (x,y) and the other defines the location of the GCPs in the input image (u,v). These two coordinate systems can be related via a pair of mapping functions f and g such that u = f(x,y) and v = g(x,y). In practice, *mapping polynomials* are used to relate the GCPs and, thus, the pixels in the input image to coordinates in the reference image.

The mapping functions are generally chosen as a simple polynomial of first, second or third order Least squares solution minimizes the sum of squares of vertical distances between the data points and the curve over the used polynomials. However, there are some practical difficulties that must be addressed. First, the explicit form of the mapping function is not known. Secondly, even if we did know it, the exact pixel in the input image that corresponds to a specific grid location in the reference image may not exist. In such a case, some form of interpolation may be required (Chipperfield, 1996).

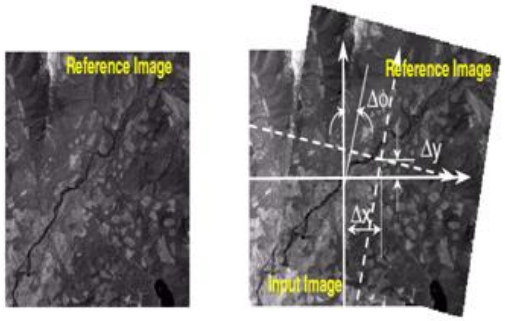

Fig. 1: Shows an example of image registration using three transforms.

Many applications like change detection, passive navigation, feature location. Measurements in remote sensing, image sequence analysis and nondestructive evaluation require registration results with an error less than one pixel, also called super-resolution and subpixel accuracy (Chipperfield, 1996). However, subpixel registration greatly introduces additional computation power and memory space requirement.

Consider the registration of a 32x32 image with subpixel accuracy, A subpixel accuracy of 0.5 pixel requires an interpolated image of the size approximately (32x2)x(32x2) pixels. Likewise, the subpixel accuracy of 0.125 requires a (32x8) x (32x8)-interpolated image. Both the input and reference images are interpolated before performing registration. The extra computational requirement of subpixel accurate registration is another motivation for research.

Using sub images (patches or chips), rather than the whole image, for registration can reduce the amount of search data size and can improve the accuracy of the registration, if the sub images are selected properly. Most practitioners manually select the chips before performing the registration [9]. The sub images can be selected based on the features obtained from binary edge detection described. Although multi-resolution techniques can dramatically reduce computations, substantial parts of the computations are in the high resolution.

Wavelet transform and:

Genetic algorithm:

Automatic selection of subimages:

Using sub images (patches or chips), rather than the whole image, for registration can reduce the amount of search data size and can improve the accuracy of the registration, if the sub images are selected properly. Most practitioners manually select the chips before performing the registration (Akansu, 1995). The sub images can be selected based on the features obtained from binary edge detection described in (Dasgupta, 1992).

Although multi-resolution techniques can dramatically reduce computations, substantial parts of the computations are in the high-resolution level close to the full resolution and experimental result

assessing the benefits.

Wavelet-based image registration:

The wavelet transform generates a multi-resolution representation of image data. Using such multi-resolution data, the size of the search data can be reduced by initially searching at lowest resolution images (smallest data size) and then proceeding to higher resolution images where the search results are only refined (Bernstein, 1987; Berthod, 1994).

Wavelet-based multi-resolution preserves most of the important features of the original data even at a low resolution. It also eliminates weak features in higher resolution while highlighting strong image features (Campbell, 1987). LeMoigne *et al*. presented a cross-comparison of automated registration algorithms for multiple source remote sensing data.

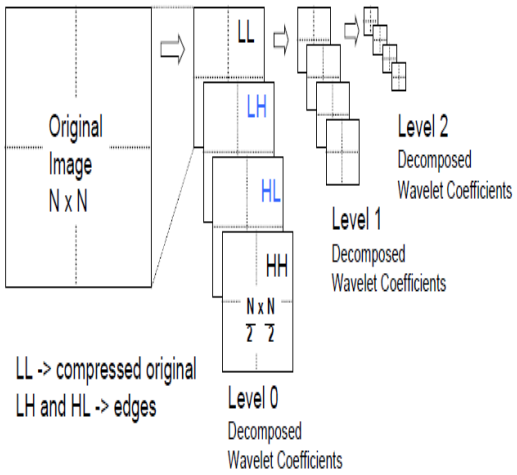

Fig. 2: Wavelet transform.

A multi-resolution wavelet-based (MRW) image registration was used shown in fig 2. The algorithm requires no a priori knowledge in order to perform automatic registration. The similarity measure is based on the normalized cross-correlation. The work in (Flynn, 1972; Horn, 1987) proposed automatic wavelet based image registration based on point matching techniques. Unlike LeMoigne's technique, the similarity measure is based on automatically extracted control points from the wavelet-compressed images. The registration result is determined by matching these control points. However, using similar test data as in (Fitzpatrick, 1984) poor registration accuracy results were reported. The drawback of their work is that the algorithm must have a sufficient number of Control points that are sufficiently distributed in space. In the presence of clouds, the algorithm is noticeably unsuccessful. The translation invariant wavelets and their application were explored in (Lazaridis, 2005; Li, 1995).

An image registration algorithm using translation invariant wavelets was developed. However, the study produced poor results and concluded that the translation invariant wavelets have limited applications in image registration.

Fonseca and Manjunath presented a multi-resolution registration that relies on the grey level information content of the images and their local wavelet-transform modulas maxima (Gonçalves, 2009).

The proposed algorithm consists of five major steps:

1) smoothing the image,
2)Decomposing the image using wavelet
3) Extracting the feature points
4) Matching the feature points
5)refining the matching in higher resolutions.

The registration error is less than one pixel for noise-free images. However, only clean images were used. The registration might fail if the images contain anomaly.

Genetic algorithm-based image registration:

Image registration involves a search to find the transform that yields the highest similarity between the input and the reference images. While most of the registration techniques employ linear search over the sampling of search scope, some researchers have attempted to apply Genetic Algorithms (GAs) to help search over the complex search scope in image registration (Dasgupta, 1992; El-Ghazawi, 1994; Flynn, 1972). Genetic Algorithms are based on an adaptive stochastic random search.

Preprocessing:

The wavelet transform has been extensively used for compression due to its excellent energy compaction characteristics. In the proposed scheme, By image enhancement (which is itself a largely subjective process), it is intended to obtain an image with less detail than the original version, nearest to the "object" identification which is performed by the human eye. Although typically more mathematical and complex, restoration algorithms may provide the exploitation of the detailed characteristics of an image and its degradation.

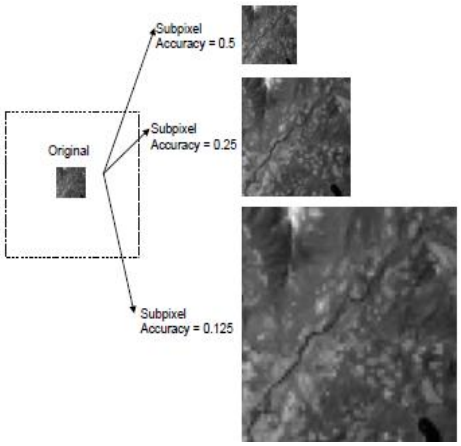

Fig. 3: Improved Accuracy with higher resolution.

A "pixel-by-pixel processing" approach may Become quite computationally expensive, in opposition to a "sub image-by-sub image processing" where we divide the image into a certain number of tiles shown in fig 3. The latter is typically considered for sub images with size between 8x8 and 32x32 pixels . However, since the objective of the Wiener filter employment is different from restoration, it is advisable to consider the conservative smallest possible square tile (beyond a single pixel) size of 3 3 pixels. Although this latter approach might induce the "blocking effect," it may be ignored for images with low SNR.

Segmentation:

A relaxation parameter is considered on the mode delineation, which in theory is a continuous parameter, defined on the space [0,1], in table.1 and has to pass through a discretization process in practice. The inclusion of this parameter leads to the obtention of several different segmentation results, which allows for the subsequent stages of the proposed methodology to be more robust.

Table 1: Automatic selection of sub images.

1	2
3	4

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

Furthermore, for situations where only a single and sharp mode is detected on the histogram, the inclusion of this parameter reveals to be of great importance for the satellite images pair. The relaxation parameter corresponds to the proportion of the height of the histogram—considered to correspond to the highest mode—for which below this value, the mode is to be considered as a "flat" region.

In this way, the method becomes much more useful and adaptable to a large variety of situations. The common methods of merely identifying a mode correspond to selecting the null value .Once the modes and "flat" regions are identified for each value of, the image may be segmented considering each interval (either a mode or a flat region) as a class. Then, for each class, those pixels which are 4-connected are considering as belonging to the same object, resulting in the final segmentation of the image.

Characterization of the extracted objects:

The extracted objects at the segmentation stage are characterized by four attributes which allow for their adequate morphological description: area, perimeter, and axis ratio and fractal dimension. The attribute area is merely obtained by the number of pixels which form an object, whereas the perimeter is obtained by calculating the distance between each adjoining pair of pixels around the border of the region. These two attributes allow for the evaluation of an object with respect to its size and compactness, respectively.

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 ratio between the major and the minor axis length lead to the attribute (axis ratio).

The attribute allows Therefore, in order to allow for the registration of the pair of images, there is the need to have an orientation and positioning indicators. Regarding orientation, for each extracted object, the angle between the x-axis and the major axis of the ellipse that has the same second-moments as the object is stored. With respect to translation, the centroid of each object (the center of mass of the object) is also stored.

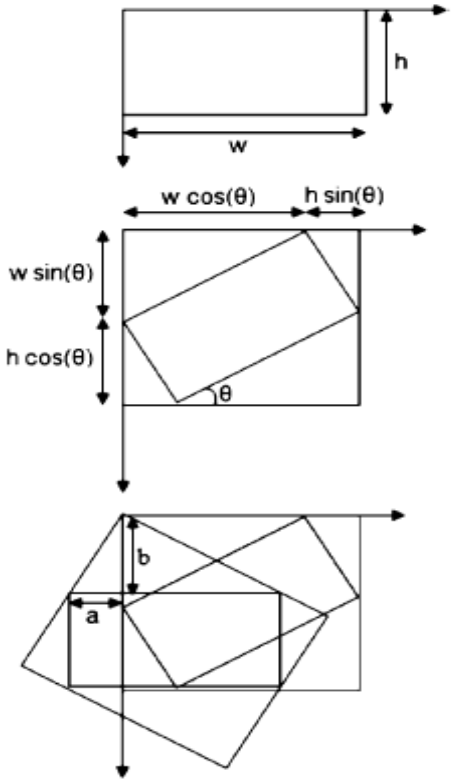

Fig. 4: Rotation and matching with reference image.

Matching:

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

Rotation estimation:

The rotation and translation are determined on a

statistical basis. Given the set of matching objects candidates, the histogram of the extracted objects orientation differences is represented. This allows for the detection of a modal class, restricting the set of possible values for rotation shown in fig4.

Then, among these rotation candidates, a robust strategy of finding is performed, through considering the frequencies of the rotation candidates, and finding the rotation value which absolute frequency corresponds to the higher outlier, according to the procedure of box plot outliers detection previously described. This procedure leads to a robust estimation.

Table 2: Different angle rotation and translation.

Rotation Set	Δ	Angles Used	RMSE
A	1	0^0,1^0,-1^0,2^0,-2^0,3^0,-3^0	0.016
B	2	0^0,2^0,-2^0,4^0,-4^0,8^0,-8^0	0.016
C	4	0^0,4^0,-4^0,8^0,-8^0,16^0,-16^0	0.016
D	10	0^0,10^0,-10^0,20^0,-20^0,30^0,-30^0	0.016
E	30	0^0,30^0,-30^0,60^0,-60^0,90^0,-90^0	0.137

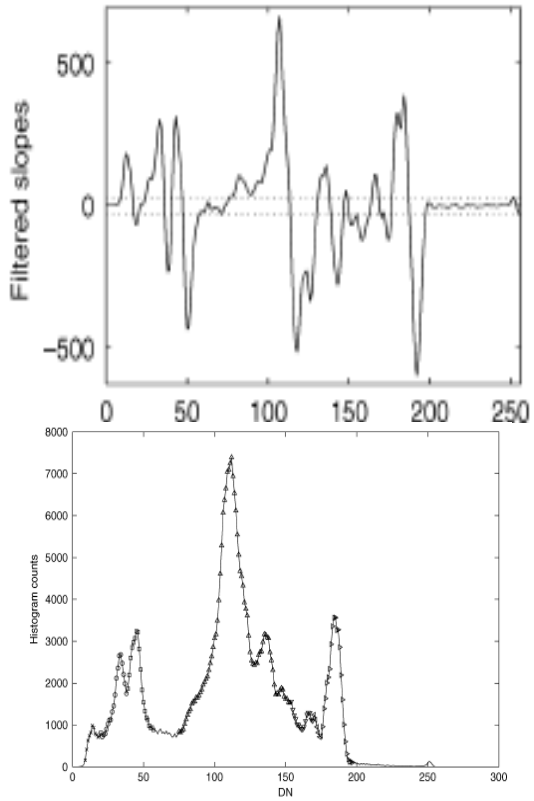

Fig. 5: Noise Filtering And Histrogram Count.

Translation estimation:

Once 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 shown in table 2 under angles and waveforms in fig.5

Conclusion:

This dissertation investigated efficient techniques for high-performance automatic image registration for remote sensing.

Fig. 6: Example for Automatic Image Registration for Remote Sensed Image with Improved Accuracy.

High-performance registration is achieved by seeking reduction in search data and search space as well as parallelism exploitation. Algorithmic analysis of the developed sequential and parallel algorithms for image registration was presented. Each proposed algorithm has been tested using remote sensing images from LandSat TM, AVHRR, GOES8, and SAR. Some digitized photo Images are also used in fig 6..

This Dissertation has reached a number of important findings and made many contributions in the area of high-performance automatic image registration. Provided a new technique that can speed up registration (by reducing data) and improve accuracy by selecting a sub image for the registration process based on its ability to provide accurate result

Determined a faster method (IRA) for implementing multi-resolution image registration.

Implemented and investigated the effectiveness of GAs for registering remote sensing images, and compared them to wavelet-based multi resolution methods (IRA). It was shown that IRA is most accurate and much faster than full- correlation. IRA, however, is slower than GA based techniques.

Hybrid techniques provide a trade-off between speed and accuracy with GA-IRA being the best hybrid technique.

Demonstrated that the sequential and parallel algorithms developed as suitable for a wide range of remote sensing data, as they provide adequate accuracy and embody a great deal of speed (due to reduction of data and search space as well as parallel processing). This makes them also suitable for working with massive remote sensing data.

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