A MULTIRESOLUTION FEATURE BASED METHOD FOR AUTOMATIC REGISTRATION OF SATELLITE IMAGERY BASED ON DIGITAL MAPS

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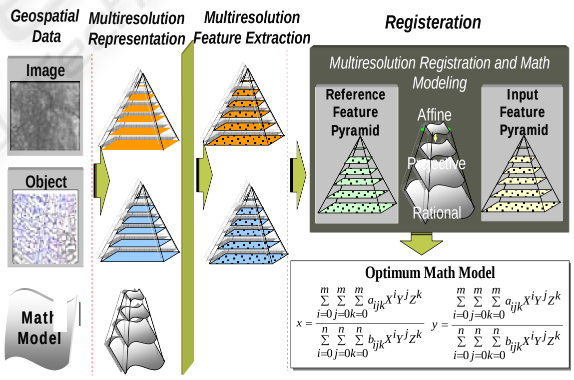
Abstract: The registration of satellite imagery based on object information such as digital vector maps is one of the main key tasks in most of remote sensing applications. Due to the tremendous complications and complexities associated with the natural scenes appearing in satellite imageries and vector maps, fully automatic registration process have faced serious obstacles and thus, only in a relatively simple imaging environment a reliable result is normally expected. In the proposed procedure of this paper, Genetic algorithms (GAs) are used to detect and match the corresponding key features in the satellite image and object data based on a multi-resolution representation of information and math models. The present approach is designed to be completely independent from the sensor type and any a prior information on the exterior orientation. A first successful application of proposed approach is demonstrated for automatic registration of IKONOS imagery and GIS map.

1 INTRODUCTION

With the ever increasing number of remote sensing satellites, advances in data fusion and the functionality of modern geographic information systems, the use of multi-image spatial information products is swiftly becoming commonplace. 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 geodetic co-ordinate system (e.g. maps) (Dowman and Dolloff, 2000; Heipke, 1997; Smith and Park, 1999).

This paper, introduces a novel multiresolution method for automatic image to map registration based on key point features consideration. The overall strategy for our proposed registration method may be expressed by the following interrelated three phases: 1-Multi-resolution Representation, 2-Feature Extraction, and 3-Feature Based Registration (Figure 1). In the following, the main components of the each phase will be described with more detail.



$$x = \frac{\sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=0}^{m} a_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} b_{ijk} X^i Y^j Z^k} \qquad y = \frac{\sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=0}^{m} a_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} b_{ijk} X^i Y^j Z^k}$$

Figure 1: proposed automatic registration method.

2 MULTIRESOLUTION REPRESENTATION

One of the m+ain requirements needed for most of registration algorithms is approximate values of two corresponding points which is related to the interrelation mathematical model of images and object (i.e. digital vector map). The best known solution to derive these approximations is to construct multi-resolution representation of

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information and start the matching process at a low resolution level (i.e. from the top of the image and object pyramids). This can provide rough approximate values for the successive levels of image pyramids.

2.1 Multiresolution Representation of Image Space

Construction of image pyramids in this project is carried out according to wavelet transform. The wavelet transform features are used because wavelet transforms convey spatial and spectral characteristics and their multi-resolution representations enable efficient hierarchical searching.

2.2 Multiresolution Representation of Object Space

In proposed method, construction of object pyramids, involves three stages of Partition of map objects, Mesh simplification and Polygon merging. In the first step, the vector map is separated to the polygon classes by the major and minor roads network. Mesh simplification principles are used to construct vector pyramid levels for reasons of combination and simplification of polygons. In order to merge polygons (third step), neighbouring polygons can be found in the data set by Delaunay algorithm. In this step, by checking the bounding of the polygons, neighbouring objects with or with out common edges are detected and merged (Cecconi et al., 2000).

2.3 Multiresolution Representation of Mathematical Models

Most of high resolution satellite vendors (e.g. Space Imaging) do not intend to present their sensor models and precise ephemeris data. This means that a large number of parameters are unknown, and will not be able to be determined from the imagery alone. So, in this study the tests are conducted based on a multi-resolution representation of Generic Sensor Models, i.e. Rational functions in the form of: Direct Linear Transformation (DLT), 2D Projective, and 3D affine models (Madani, 1999; Dowman, 2000; Tao and Hu, 2001; Grodecki, 2001).

3 FEATURE EXTRACTION

By construction the multi-resolution representation of image and object, key points are extracted from both of image and objects in all of pyramid levels.

3.1 Feature Extraction in Image Space

Based on the generated image pyramids, the implemented system extracts and constructs feature pyramids by applying a modified Moravec operator to each layer of the image pyramids. In addition to point features the Moravec operator is also modified to detect corners, intersections and centres of gravity. The constructed feature pyramids therefore include the feature attributes. These attributes will greatly contribute to the Genetic algorithm as described in section 2.3.1.

3.2 Feature Extraction in Object Space

Referring to the vector structure of digital maps, basically it is just need to identify the proper key nods of line intersections or polygons vertexes with a threshold for extraction of key nods.

4 FEATURE BASED REGISTRATION

By construction of image and feature pyramids, in this stage, for each feature in the feature pyramid of image, based on corresponding mathematical model, a search area is constructed on the corresponding feature pyramid of object. Now to identify the conjugate features the Genetic algorithm is employed. The main advantage of Genetic algorithm is its fast rate of convergency compared to the other searching methods.

The Genetic algorithm starts with the selection of population of features which followed by the determination of a so called criterion function which can comprise different similarity measures (e.g. feature attributes) and geometric constraints (e.g. affine transformation parameters). Using this criterion function a new population is constructed by decomposition of the old population using a so called Cross-Over operator. The procedures are repeated until a small subset of the population with a specific pattern best satisfies the criterion function.

4.1 Image Matching with Genetic Algorithms

John Holland and his colleagues formally introduced genetic algorithms (GAs) in (Holland, 1975). GAs are based on the natural concept of evolution, suggesting that diversity helps to ensure a population survival under changing environmental conditions.

Chromosome Encoding: Using a bit string encoding scheme for chromosome string, the validity of conjugate pointes is encoded (Figure 2). A *1-bit* field is used to represent the possible situation of individual conjugate point validity in data set. The aim of coding is to create a representation of conjugation (value *1*) or non-conjugation (value *0*) of each pairs of points. This allows any combination of points to be modified.

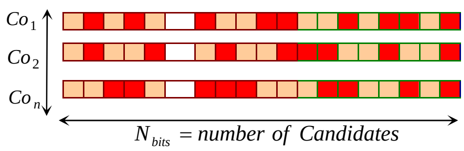

Figure 2: Encoding of *n* conjugate candidate into *n* bit chromosome string.

Objective Function and Selection: The objective function in image registration is to minimize the RMSE of modelling residuals and maximize the correlation between the image space and object space. The correlation function between two images *A* and *B* is given as

$$C(A,B)=\frac{\sum_i (A_i-\bar{A})(B_i-\bar{B})}{\sqrt{\sum_i (A_i-\bar{A})^2}\sqrt{\sum_i (B_i-\bar{B})^2}} \quad (1)$$

For individual selection, we select highly fit individuals with higher correlation (fitness) values based on deterministic sampling. The mating is then performed randomly using the crossover operation. Finally, using the mutation rate of *0.05*, each selected individual is mutated by randomly altering one bit in the chromosome string. The crossover used in this research is the single-point uniform crossover. The termination condition is to stop the GA search after the solution converges or a pre-specified number of generations are reached (Chipperfield 1996; Husband 1990; Goldberg 1989).

5 EXPERIMENTS AND RESULTS

The potential of the proposed method is evaluated using IKONOS imagery was acquired on 2004 and corresponding digital map of the city of Tehran, Iran (Figure 3). The maps have been produced in 2002 from 1:4000 aerial photographs. During these two years time lapse between the generated map and the IKONOS image acquisition, considerable changes have also occurred in the city.

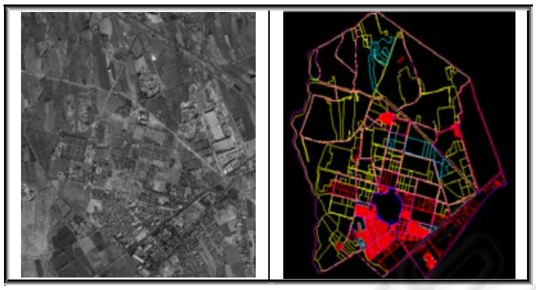

Figure 3: IKONOS image of TEHRAN (left) and corresponding map (right).

Registration process is performed hierarchically using five–layer image pyramids. Each pyramid layer has four times reduced resolution in relation to its previous layer (Figure 4).

Table 1: The number of matched points and the corresponding residual errors on different layers.

Layer	Image Points	Object Points	Match Points	Generation	Math Model	Order
5	12	115	7	100	P2=P4=1	2D-1
4	18	237	11	200	P2=P4	3D-1
3	31	496	20	300	P2=P4	3D-2
2	54	973	32	400	P2=P4	3D-3
1	85	1834	41	500	P2=P4	3D-3

Table 2: The number of matched points and the corresponding residual errors in first layer.

Layer	Match Points	Control Points	Check Points	RMSE on Control		RMSE on Check	
1	41	30	11	0.76	1.09	0.94	1.23

Table 1 shows the independent results for each pyramid layer obtained by the Genetic algorithm process. A comparison between the number of the detected features in each layer and the number of matched points clearly indicates how the Genetic algorithm process has eliminated some of the points in each layer (see Table 1). These are the points for which, the geometric and the radiometric conditions have not been satisfied according to the Genetic algorithm parameters setting (Figure 4). The RMSE values obtained by the GA based method are given in Table 2. As this Table shows the RMSE values for the first layer are *0.76*, *1.09* and *0.94*, *1.23* pixels in the *x* and *y* image coordinate of the check and control points respectively.

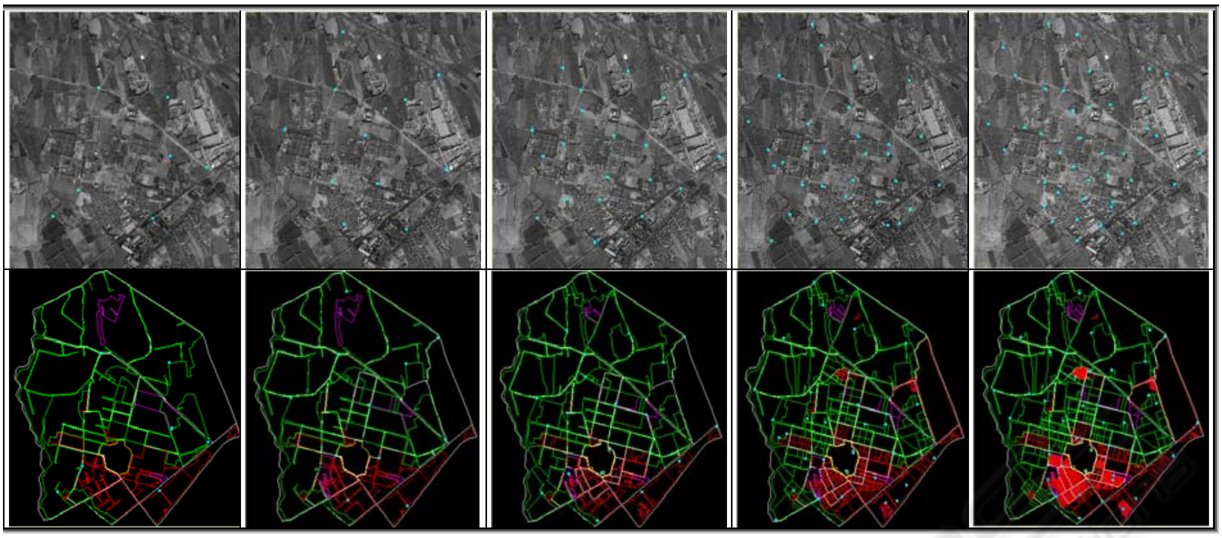

Figure 4: Matched points in each layer of image pyramid (up), Matched points in each layer of vector map pyramid (down).

6 CONCLUSION

The proposed automatic registration method discussed in this paper, has proved to be very efficient and reliable for automatic registration of satellite imageries based on digital vector maps. The implemented methodology has the following characteristics:

- Utilization of a multi-resolution representation of information and mathematical models.
- Employing a Genetic algorithm for conjugate feature identification and modelling.

In spite of the success which is gained in the implementation of the presented method, the topic by no means is exhausted and still a great deal of research works are needed. These research works should be focused mainly on the development of a more sophisticated Genetic algorithm, interest operator and matching strategy. All of these are currently under investigation in our institute.

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