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Geo-Imagery Bridging Continents

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Commission 4

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EXPERIENCES IN UPGRADING OF LARGE DATABASES OF SATELLITE IMAGES

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KEY WORDS: Automation, Spatial Database, QuickBird, Spot-5, Eros-A1, Multitemporal, Image Registration

ABSTRACT:

Many technical aspects are involved in the upgrading of satellite image databases: geometric registration, resampling, radiometric adjustment, mosaicking. In this paper, after an overview of all problems, we will focus on the automation of image geocoding. A procedure to perform automatic co-registration of satellite images have been already proposed by the authors (GEOREF), based on an *image-to-image* registration technique implementing the automatic extraction and matching of corresponding points in a robust way. In case one of the pair of co-registered images is already geocoded, the second one will be as well. Recently the implementation of GEOREF algorithms in an operational environment has been completed and its application to upgrade a database of satellite images has become possible. Furthermore, GEOREF is also able to compute the co-registration of images acquired by different sensors, involving also high resolution and multi-resolution imagery. In this paper, tests concerning high resolution and multi-resolution data fusion from Eros-A1, QuickBird and SPOT-5 satellites are presented.

1. INTRODUCTION

In the last years many countries have been carried out an almost complete coverage of satellite images of their own land, in particular at mid scale (e.g. Landsat TM/ETM+). Images are registered to a cartographic reference system (national and/or UTM) and play the role of geographic support for a spatial database, suitable to be integrated by vector layers and by other kinds of raster data.

The availability of this coverage is fundamental to investigate and to detect changes in the use of the soil. An example is represented by the well known CORINE project (Perdigão & Annoni, 1997). The availability of two co-registered remotely sensed images of the same area at two different dates enables the development of studies regarding land cover and landscape dynamics (Forman & Godron, 1986). These are usually based on the development of diachronic land use/land cover maps which are then analyzed with *cross-tabulation* techniques and *landscape metrics*. Multi-temporal maps are also the basis dataset to model future development of the landscape with different techniques such as *cellular automata* or *Markov chains* (Baker, 1989; Sklar & Costanza, 1990). Such application are often based on old aerial photos that have to be scanned and co-registered with recent photo-planes or ortho-photomaps.

Obviously, the spatial database should be frequently updated by introducing new images, either of recent acquisition (to know the current use of the land) and from historical archives (to detect changes with respect to a given time in the past). Frequently, different kinds of images have to be fused together, requiring the availability of geometric transformations which are able to compensate for differences.

Among problems involved in upgrading a large database of images, data geocoding is of great importance, due to the fact that this task is a prerequisite to any other geometric task. The analysis of different techniques and algorithms that have been developed to perform image registration is out from the purposes of this paper. Detailed information can be largely found in literature. Here we would only to make some considerations about operational aspects of image registration, and to propose a solution to this problem.

Geocoding two or more images means to establish a geometric transformation between them in order to perform their reduction to a common reference frame. Obviously, if one of the images is already calibrated to a given cartographic reference system, after geocoding the other image(s) will be as well. In case of small and mid scale satellite imagery (but practically this is generally true), this transformation is estimated on the basis of a set of control points (CPs) which are measured on both images. Usually, the measurement of CPs is carried out manually from a skilled operator, resulting in a largely time consuming task. Nevertheless, to get a high quality on this process, the operator must be very experienced, because in many cases the correct and accurate measurement of homologous CPs is not so ease.

On the other hand, different automatic procedures have been developed, based on image matching algorithms; among the others, methods proposed by Corvi & Nicchiotti (1995), Dare & Dowman (2001) and Goncalves & Dowman (2003) cannot be neglected. Unfortunately, results of these studies have not followed up on the most widespread software packages which are currently used to deal with remote sensing imagery. The consideration which is easily addressed is that the most of the published algorithms have kept a very limited application, which have only concerned a small dataset and have not been implemented in a deliverable release.

2. THE GEOREF SOFTWARE

A procedure to perform automatic co-registration of satellite images have been already proposed by the authors (Carrion *et al.*, 2001, 2002; Gianinetto & Scaioni, 2003). The adopted procedure, here referred to as GEOREF, is based on an *image-*

to-image registration technique looking for corresponding points through a gerarchical approach. In the published papers, experiences of registering different kinds of satellite data have been proposed (Landsat TM). Moreover, the procedure has been applied also to data fusion of high resolution satellite images (QuickBird) to a digital photo-plane. In all presented tests, results based on transforming a set of independent check points (ICPs) have shown that the accuracy of image registration is enough good for upgrading maps at scale compatible with the resolution of the used imagery.
Recently the implementation of GEOREF algorithms in an operational software has been completed and its operational application to upgrade spatial databases of satellite images has become possible. GEOREF runs under Microsoft Windows environment and is composed of a main window (Figure 1) divided in three different areas: a workspace on the left side, showing the project structure, a viewing window on the right side and a message window on the bottom.
The main tasks which are performed will be described in next sub-paragraphs.

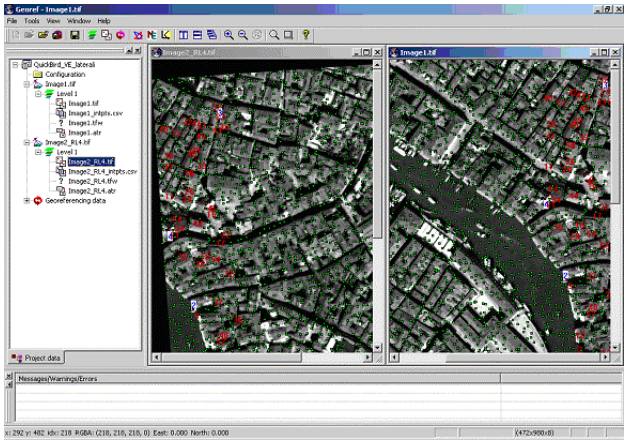

Figure 1. The GEOREF software's main window.

2.1 Data input

Basically the input of GEOREF is made up of the pair of images to be co-registered; the user is let to make the selection about which of them plays as *master* and *slave*.
An external pre-processing stage is needed, consisting in the extraction of both images from larger datasets. In case of multi-spectral imagery, combinations of more than one channel could be used, as done in experimental tests reported in the above-mentioned papers by the authors. The goal of this task is to render both images as similar to each other as possible concerning radiometric aspects; moreover, application of image enhancement techniques to improve contrast (e.g. a linear stretching) is wellcome.
GEOREF accepts images at a radiometric resolution of 8-bit per pixel, being this enough for matching algorithms. All common image formats can be directly read by the software.
In case *master* is already geocoded to a cartographic reference frame, this can be provided to GEOREF by means of an ESRI "*world*" file, containing 6 coefficients of the affine transformation from pixel-to-map.

2.2 Extraction of homologous points

The procedure to automatically extract CPs is based on a standard image registration approach derived from *digital photogrammetry* (see Heipke, 1997) and developing the method proposed by Alparone *et al.* (1995).
Here we do not focus on the implemented algorithms, because these have been already addressed in previous works, but we would like to show some operational issues of GEOREF and the way it can be applied to co-register images.
The registration process, once images have been imported into the project, is based on the following items:

- setup of control parameters;
- extraction of *interest points* (IPs);
- image matching;
- robust estimation of geocoding transformation;
- visualization of resampled *slave* image to overlap the *master*.

2.2.1 Setup of control parameters: Algorithm parameters are available to the user and can be set from the *"Project configuration parameters*" window (Figure 2). All parameters are grouped into five groups:

- interest operator parameters;
- starting affine transform coefficients;
- matching parameters;
- outlier rejection parameters;
- georeferencing parameters.

On the left side of the configuration window are the *interest operator* parameters and the start affine transform coefficients. The well-known *interest operator* from Förstner (1986) is applied to extract from both images a set of points which are candidate to become CPs. To work out enough points, a set of parameters must be setup, two of them being crucial:

- the *interest window size*; usually, the smaller it is, the higher is the number of extracted IPs; on the other hand, if the window is selected too small, poor contrasted features could be found (default window size is 5x5 pixels);
- the minimun distance between two IPs (usually two times the *interest window size*);
- the minimum *point density*; this parameter allows to check the extraction of a sufficient number of IPs, depending on the image kind, quality and content. By the way, experience of the user is fundamental to properly select minimum *point density*. If the fixed value would not be reached, an adaptive procedure will restart the application of Förstner operator by reducing the *interest window size*.

In the "*GEOREF start affine transform coefficients*" frame, a set of rough initial parameters can be entered (if known). Otherwise, these can be computed by interactively measurement of at least 3 CPs in both images.
On the right side of configuration window we find *matching*, *outlier rejection* and *georeferencing* parameters.
The *matching* process is performed by *Least Squares matching* technique (Grün, 1985); implementation details can be found in Scaioni (1999). The success of this algorithm will depend on the selection of following parameters:

- the *size of searching window* (default size is 9x9 pixels);
- the *size of matching window* (default size is 7x7 pixels);

- the minimum correlation between homologous points (default value is 0.70).

The "*outlier rejection algorithm*" frame is used to specify the method to be applied to remove blunders from the set of computed CPs; an affine or a 2nd order polynomial transform may be selected.
Finally, the "*georeferencing parameters*" frame is used to set a minimum number of valid CPs (default value is 8) and to select the final geometric transformation model (*transformation type*). At the moment, only affine and 2nd order polynomial transformations are available in the GEOREF environment. Anyway, more sophisticated geometric models (higher order polynomials, RFM, splines, *etc.*) can be computed with third parties remote sensing software using GEOREF outputs in ASCII format.
A set of configuration parameters is expected to work well on a set of images which are similar for type, content and size, then it can be saved into a template project to be used at different times.

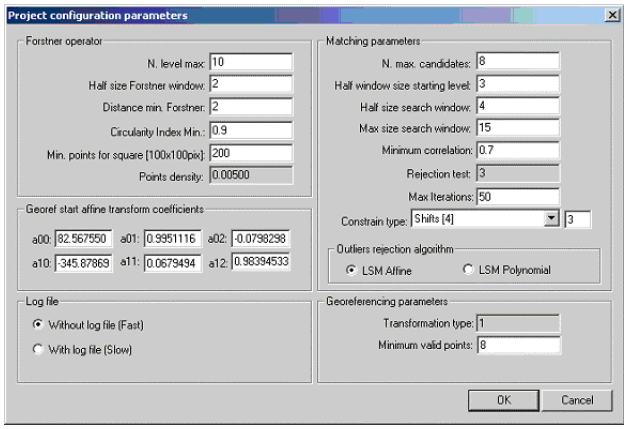

Figure 2. GEOREF configuration parameters window.

2.2.2 Interest point extraction and matching: After setup of parameters, GEOREF proposes an operational workflow to extract CPs:

a) *generation of image pyramids*: this task is implemented to cope with all cases where bad parameters for the starting affine transformation have been computed. However, the current version of the software is provided by a graphical tool which allows to manually measure with ease a minimum set of 3 CPs to compute this transformation. Findings of recent tests have shown that the use of image pyramids could be avoided in the most cases, working directly on the original images;

b) *extraction of IPs*: the user is requested to enter the maximum number of IPs to accept in order to reduce the computing time; in this case, all extracted IPs are ranked according to their *interest value*, and those featuring higher positions are selected (according to the strategy proposed in Forlani *et al.*, 1996). Ohterwise, all IPs can be held;

c) *measurement of the initial affine transformation;*

d) *finding corresponding points*: the initial affine parameters are used to transfer each IP from *master* to *slave* image; around the position found on the *slave*, all IPs falling into a square *searching window* (see 2.2.1) are matched with the point in the *master*. That point featuring the higher correlation after L.S. matching is selected as homologous; however, correlation must be higher than the minimum acceptance threshold. In case not enough points have been found, the process is repeated by enlarging the size of the search window.

e) *outlier rejection*: to cope effectively with blunders in the set of CPs, a robust technique based on *Least Median Squares* (Rousseeuw & Leroy, 1987) followed by classical L.S. estimation and data snooping is applied.

2.3 Visualization of results and data export

In case the georeference has been successfully completed, the user can check results by means of either analytical and graphical tools. The former concern the sigma nought of the estimated transformation (affine or polynomial); the implementation of plotting residuals onto the image is ongoing. Tha latter is given by overlapping the resampled *slave* image onto the *master*, so that the accuracy of the co-registration can be verified. An example of this visualization is presented in Figure 8.
Different kinds of information can be exported from GEOREF. First of all, a file containing coordinate of CPs in both images is available. This file could be then imported into other Remote Sensing data processing softwares, in order to recompute the registration with more accurate algorithm, based on the same CP set found by GEOREF.
In case the *master* image is provided by an ESRI "*world*" file, also that of *slave* is written; this fact enables to directly import the *slave* image into a commercial GIS software, so that a spatial database could be easily upgraded.
Furthermore, all intermediate files and images are available as by-products and can be used independently from GEOREF.

3. DATASET

GEOREF has been tested with data collected by different high resolution image sensors (Eros-A1, QuickBird and SPOT-5 HRG). The images used in this study were taken over the Caselle airport, near the city of Torino, Italy (Figure 3) and the full dataset used is composed of:

- one scene acquired by the QuickBird satellite;
- one scene acquired by the SPOT-5 satellite;
- one stereo scene acquired by the Eros-A1.

The main purpose of the tests has been to show the potential use of GEOREF for HRSI automatic registration and for multi-resolution and multi-sensor automatic data fusion. Therefore, tests have involved:

- 2.5-meter SPOT-5 HRG and 0.62-meter QuickBird PAN image fusion (multi-resolution and multi-sensor data fusion);
- 2.6-meter Eros-A1 stereo coverage (HRSI automatic registration);
- 2.6-meter Eros-A1 and 2.5-meter SPOT-5 HRG image fusion (multi-sensor data fusion).

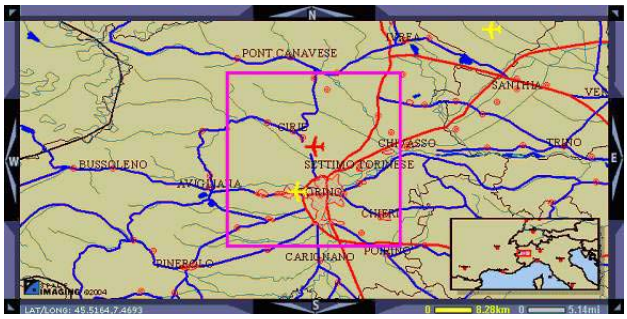

Figure 3. The study area over Caselle airport (Torino, Italy).

Figure 4. QuickBird PAN image (0.62 m GSD) over test area.

Figure 5. SPOT-5 HRG (2.5 m GSD) over test area.

4. IMAGE GEOCODING

4.1 QuickBird PAN *vs* SPOT5-HRG

QuickBird panchromatic (PAN) acquisition has a nominal 0.61 m GSD for nadir viewing and a maximum of 0.72 m GSD for 25° off-nadir viewing, in the range of 450-900 nm wavelength. The BRC60 camera mounted on the QuickBird satellite is a high-resolution pushbroom sensor with linear CCD arrays.
SPOT-5 satellite carries two HRG (*High Resolution Geometric*) sensors for high-resolution panchromatic acquisition in the range of 480-710 nm wavelength. Each HRG instrument acquires images with 5 m GSD, and the ground processing of the data produces 2.5 m GSD images with same viewing geometry of the original images.
A first test involving multi-sensor and multi-resolution registration has been performed using the QuickBird and the SPOT images. The QuickBird PAN image taken over the Caselle airport (Figure 4) and processed by GEOREF has a 0.62 m row GSD and a 0.63 m column GSD, while the SPOT5-HRG image (Figure 5) has a 2.5 m interpolated GSD.
Using GEOREF software, homologous CPs has been automatically extracted and a six-parameter 2D affine transformation computed for image georeference. Image data fusion of QuickBird and SPOT-5 images are presented in figure 6.

4.2 Eros-A1 stereo pair co-registration

Eros-A1 Standard Mode acquisition produces panchromatic images, in the range of 500-900 nm wavelength, with a nominal 1.8 m GSD. The NA30 camera mounted on the Eros-A1 satellite is a high-resolution pushbroom sensor with 4 linear CCD arrays. Because of its asynchronous scanning mode (the satellite ground speed is faster than its rate of imaging), images collected by Eros-A1 shows image deformations and very different geometry of the taken.
A second test involving different taken and strong geometrical deformations has been performed using the Eros-A1 stereo pair taken over Caselle airport (Italy). Both image, processed by GEOREF, had a 2.6 m GSD (Figure 7).
GEOREF automatic procedure has leaded to obtain a precise overlapping between the two images. Figure 8 shows this results. In white and blue colours are represented Eros-A1 original images, and in yellow is represented the overlap between them.

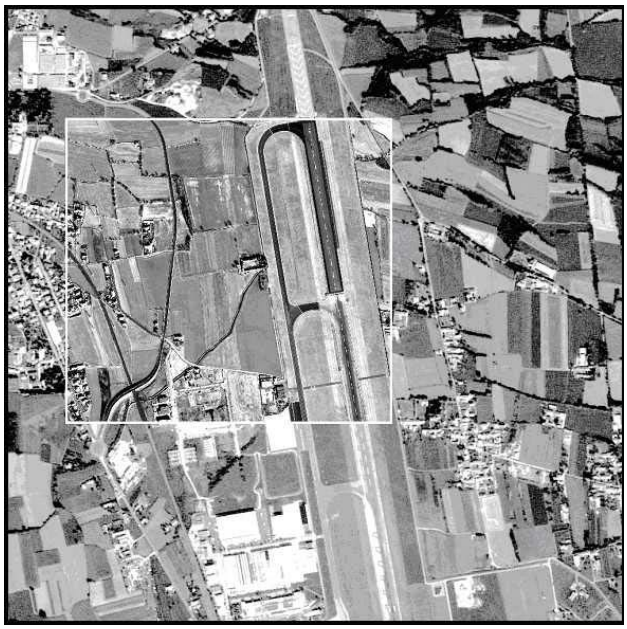

Figure 6. Result of SPOT-5 HRG (larger image) and QuickBird PAN (image inside the box) multi-resolution data fusion.

Figure 7. Eros-A1 stereo coverage (2.6 m GSD) over test area.

4.3 Eros-A1 *vs* SPOT-5 HRG

A final test involving multi-sensor with similar geometric resolution was performed using the 2.6 m Eros-A1 image and the 2.5 m SPOT-5 HRG image over the test area.
As in the previous examples, homologous points have been automatically extracted with the GEOREF software from both images, and on the basis of the computed CPs a 2D affine transformation has been estimated for image data fusion. Figure 9 shows the resulting fusion of the original Eros-A1 and SPOT-5 images.

5. THE GEOREF SOFTWARE DISTRIBUTION POLICY

The development of GEOREF SW has been carried out for research and technology transfer purposes. All people, institutes and companies having the same interests are encouraged to contact the authors which will provide to send a fully operational demo-license. All GEOREF's users are invited to share results of their activities and to cooperate to the development of this project.

6. CONCLUSIONS

The availability of a fast procedure, such as that implemented in GEOREF, for the co-registration of multitemporal remotely sensed images enabled an easier development of landscape change detection analysis. Such kind of spatial information are of basic importance to support land management decisions, especially within the framework of a more sustainable use of natural resources and for the analysis of man-induced landscape changes.

Figure 8. Result of Eros-A1 (2.6 m GSD) stereo coverage data fusion.

Figure 9. Result of Eros-A1 (lower image) and SPOT-5 HRG (upper image) image fusion.

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