CASA-F – A Software for Image Registration

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Abstract — **The image registration is a fundamental operation for applications in Image Processing and it is based on identification of control points on images involved in the process. In this paper it is described a semi-automatic method based on graphic computation for control points acquisition from aerial and satellite images, using the feature matching technique. A C++ program which implements the above method is also described and it performs the process in a friendly manner from images acquisition till the image registration, including the image matching. This program enables control point acquisition in an iterative manner, in despite of the image condition limitations, granting satisfactory results by an analytical model described in this work. Results are presented. So are the registrations. The effective performance of the developed software assumed to be proved.**

Key-Words — **Image Processing, Software for Image Matching, Geographical Information Systems.**

I. INTRODUCTION

Image registration is a decisive task in image processing applications [1,2] and it is used in several situations: multi-temporal analysis, combination of different sensors images from the same area [3], image justaposition, spatial and spectral resolution combination, mosaics elaboration, integration of an image to the existing data base in a Geographic Information System (GIS) and others [7, 8].

The control point collection is a primordial step in image registration in order to obtain the polynomial transformation of the image to be registered.

There are several approaches in control point acquisition [4]. The manual process is hard and exhaustive, since the annalist should be judicious in the search of, for example, road crossings, bridges and bifurcations. Besides that, control points are not easily found on images obtained with a lot of noise, or from extensive areas. On the other hand, the automatic methods have a limited scope, making difficult sometimes control points localization between radar and optics. They are generally applied to a group of images with similar statistical properties.

Therefore, one search for methods and interfaces more friendly and that make the work less boring and more pragmatic. Not forgetting that due to its importance in the final result, the image registration accuracy should be persecuted to any cost, independently of the technique applied.

The objective of this paper consists of the development of a semi-automatic algorithm to support control point localization and extraction. Specifically, methods were developed and implemented based on graphic computation to obtain control points through features matching. In addition, an option was developed for image registration of different resolutions for tests and elaborated a friendly interface to get control points.

II. USED METHODOLOGY

A. Control point Extraction Methods

In the task of getting control points to register two or more images, with or without geocodification, it is important to get a big number of points. But, as not always this is possible, mainly in extensive areas, the extraction of control points from features matching comes to meet this necessity.

It is emphasized at this point the feature definition: geometric place of topographic attributes, generally narrow, from a scene like roof ridge, valleys, borders, etc., or rivers, roads. There are several ways of extraction and or acquisition of these features: through border detection [5], through importation of vectorial layers, generated by dynamic GPS [3] or through the user's free hand drawings on vectorial features of interest.

In this work, it has been adopted the acquisition through drawing tools, made available by the developed application program.

This modeling synthesizes the basic formulation, derived from Analytical Geometry and Vectorial Algebra (corresponding to the operations of rotation, translation and scale), which permits the image orientation.

Consider a vector V_B in the base-image (I_B) defined by points: P_{B1} (X_{B1}, Y_{B1}) and P_{B2} (X_{B2}, Y_{B2}), and the corresponding vector V_A in the adjusting-image (I_A): P_{A1} (X_{A1}, Y_{A1}) and P_{A2} (X_{A2}, Y_{A2}), as illustrated in Fig. 1.
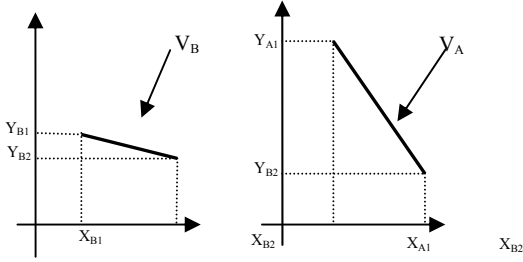

Fig. 1 – Vectors V_B and V_A, graphically represented.

Following Spiegel [6], the distance (d) between any two points (x_1,y_1) and (x_2,y_2) is given by:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (1)$$

And the incline angle (θ), determined by respective points is computed by:

$$\theta = \arctan\left(\frac{y_2 - y_1}{x_2 - x_1}\right) \qquad (2)$$

In the modeling of CASA-F, after determining the vectors V_A and V_B inclination angle, it computes the relative angle between them in relation to the horizontal direction. This is the rotation of the adjusting-image in relation to the base-image, or

$$\psi_{RAB} = \theta_A - \theta_B \qquad (3)$$

It computes also the scale factor $E_{x,y}$, which is given by the ratio between the modules of the respective vectors, that is,

$$\begin{cases} E_x = (V_A)_x / (V_B)_x \\ E_y = (V_A)_y / (V_B)_y \end{cases} \qquad (4)$$

The control point selection by CASA-F will determine the point P (X_P, Y_P). Next, through (1), (2) and (4), it determines the distance (d_{B-P}), the angle (θ_{B-P}) and the scale factor (E_{B-P}), between the points P_{B1} and P.

Thus, the predicted point coordinates, which will be exported to the adjusting-image (Fig. 1) are defined by:

$$X_{PA} = X_{A1} + d_{B-P} * E_{B-P} * \cos(\psi_{RAB} + \theta_{B-P})$$
$$Y_{PA} = Y_{A1} + d_{B-P} * E_{B-P} * \sin(\psi_{RAB} + \theta_{B-P}) \qquad (5)$$

B. Description of CASA-F Implemented Methods

Two images are selected: the base-image I_B and the adjusting-image I_A.

In the features drawing in I_B and respective prediction, or drawing, in I_A, it is reiterated the computation above for each selected point in I_B (through mouse click).

It should be noted that after the prediction and orientation of a point, it may be used polynomials of first, second and third degrees which will allow a better accuracy on the predicted points in I_A contributing also in superior definition in the mapping function.

When one works with features, manual adjusting (orientation) may occur so, in this case, only the points for prediction are computed, once the orientation was manually determined.

B.1 Point to point Method

The Point-to-Point (PtoP) method consists of acquiring a point on the base-image and its corresponding point on the adjusting-image. As the points are acquired the residual computation is done. The PtoP is a classical control point extraction method which is available in most of the software which perform the image registration process.

B.2 Vector on Image Method

(A.1)

The Vector on Image method (VonI) consists of features acquisition through drawing tools. Thus as in PtoP method it is necessary to acquire a feature on the base-image and its corresponding on the adjusting-image, but the significant difference is that the drawn feature on the base-image is imported to the adjusting-image. After the importation, it should suffer modifications in order to be adjusted on the corresponding feature on the adjusting-image. The feature modifications are executed by the translation, rotation and scale tools available. Once the adjustment is done the central point of the feature involving rectangle is used as control point.

B.3 Image on Image Method

The Image on Image method (IonI) is similar to the previous one; with the difference that now we are interested on parts of the image. By mean of a mouse click on the or near of the feature of interest, one obtains a part of the image, 100×100 pixels, that as for the VonI method should be exported to the adjusting-image and to suffer translation, rotation and scale transformations in order to be adjusted to the corresponding feature in the adjusting-image. Thus, like in the previous method, the feature involving rectangle central point is used as control point.

III. RESULTS

Four sets of images have been used to test the functionalities of CASA-F.

The first set, CE1, is composed by the base-image: B1 (from São Paulo region, CIBERS-1, 6850 x 6720 pixels size and resolution of 20 m) and by the adjusting-image: A1 (from São Paulo region, sensor LandSat 7, 7910 x 7199 pixels size, and resolution of 10 m). The set presents punctual, linear and curvilinear features and it is illustrated in Fig. 1.

a)   b)

Fig. 1. CE1 Images: base- (a) and adjusting-image (b).

The second set, CE2, is composed by the base-image: B2 (from Machadinho region, coloured in red and blue, RADARSAT, 3846 x 3196 pixels size and 2,75 x 2,77 m resolution) and by the adjusting-image: A2 (from Machadinho region, coloured in green, SPOT, 2785 x 2265 pixels size, and resolution of 5 m). The set presents punctual, linear and curvilinear features and it is illustrated in Fig. 2.
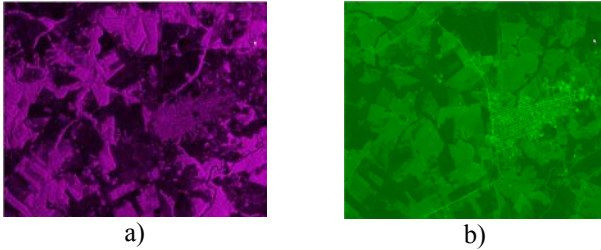

| a) | b) |

Fig. 2. CE2 Images: base- (a) and adjusting- image (b).

The third set, CE3, is composed by the base-image: B3 (from Tapajós region, RADARSAT, 7844 x 11774 pixels size and resolution of 12,5 m) and by the adjusting-image: A3 (from Tapajós region, RADARSAT, 7844 x 11771 pixels size, and resolution of 10 m). The set presents punctual, linear and curvilinear features and it is illustrated in Fig. 3.
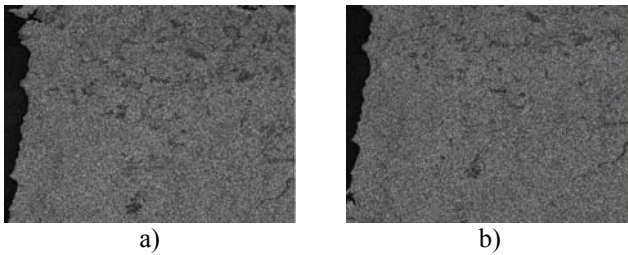

| a) | b) |

Fig. 3. CE3 Images: base- (a) and adjusting- image (b).

The fourth set, CE4, is composed by base-image: B4 (from São José dos Campos region, SPOT, 2886 x 2889 pixels and resolution of 10 m) and by the adjusting-image: A4 (B4 rotated by an angle of 30°). The set presents punctual, linear and curvilinear features and it is illustrated in Fig. 4.
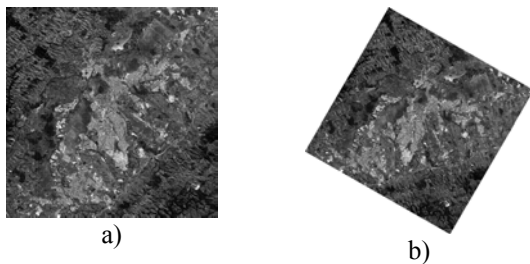

| a) | b) |

Fig. 4. CE4 Images: base- (a) and adjusting- image (b).

Tables I and II group the results obtained by the VonI method in all experimental sets, i. e., CE1, CE2, CE3 and CE4. Tables III and IV, similarly, present the results for the IonI method.

Observing the obtained values in the adjusting-image, it is possible to do a comparative analysis between the two methods. Through the tables analysis, it has been proved the superiority of the VonI method over the IonI one, because the visual adjustment of the vectorial features made available by

that model are less onerous in relation to the IonI, which works with small windows of images.

Should be noted here that the PonP method treated in this paper in Section B.1 it is indirectly incorporated in the VonI method. Therefore, due to the limited space available in this paper, the specific results obtained by the application of this method are not presented.

In the VonI method, it was obtained an average error of 3 pixels for the three first experiments- CE1, CE2 and CE3 - and an error of 0.9 pixels for the last one - CE4. In the first three cases it has been acquired features in images of different resolution, noisy and from extensive areas, resulting in the cited values of the error. On the other hand, in the CE4 experiment it has been treated well behaved images, with control points and features easily detected visually. After the adjusting through the acquired points, suppressing the points with bigger deviations, it has been obtained an average error of 1 pixel in the first three cases and 0.7 pixels in the fourth case, proving the efficiency of the developed tool.

As it was stressed before, it has been obtained better results with VonI method, but it was also possible to improve the accuracy of the acquired points with the IonI method, producing deviations of about 3.5 pixels in the first three experiments and about 2 pixels in the third one after the adjustment.

TABLE I The VonI method results for all the experimental sets

	CE1	CE2	CE3	CE4
XRMSE[1]	2.272	0.584	2.093	0.770
YRMSE[2]	2.988	2.885	2.413	0.488
TRMSE[3]	3.754	2.944	3.194	0.912

[1]X Root Mean Square Error
[2]Y Root Mean Square Error
[3] TOTAL Root Mean Square Error

TABLE II Total errors for the VonI (after Table I data adjustment)

	CE1	CE2	CE3	CE4
TRMSE[3]	1.097357	0.850	1.543681	0.715043

[3] TOTAL Root Mean Square Error

TABLE III The IonI method results for all the experimental sets

	CE1	CE2	CE3	CE4
XRMSE[1]	2.984	1.328	1.251	1.476
YRMSE[2]	2.855	2.645	4.030	0.630
TRMSE[3]	4.129	2.960	4.220	1.605

[1]X Root Mean Square Error
[2]Y Root Mean Square Error
[3] TOTAL Root Mean Square Error

TABLE IV Total errors for the IonI (after Table III data adjustment)

	CE1	CE2	CE3	CE4
TRMSE[3]	2.246	1.863	1.863	1.605

[3] TOTAL Root Mean Square Error

The Figures 5, 6, 7 and 8 display the registered images with the control points obtained from the experimental sets CE1, CE2, CE3 and CE4. It must be noticed that there is a great difference regarding to dimensions between base- and adjusting – images related to CE1, CE2 and CE3. Thus, only a portion of the registration is displayed.
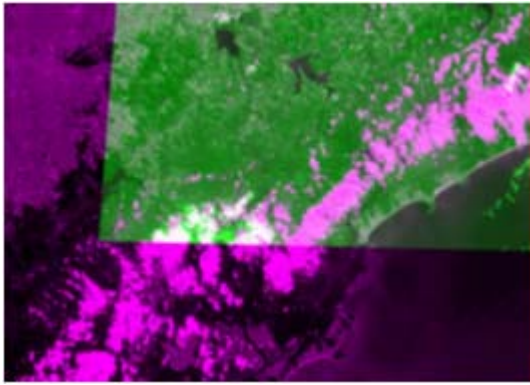
Fig. 5. CE1 registration (base is colored in red and blue, adjusting in green).

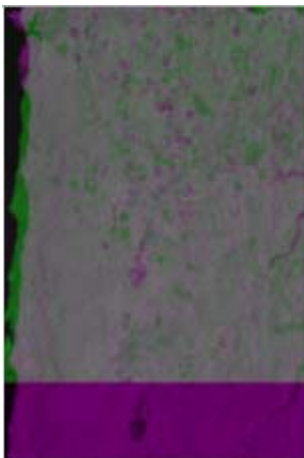Fig. 6. Registration for CE2 set.

Fig. 7. CE3 registration (base is colored in red and blue, adjusting in green).
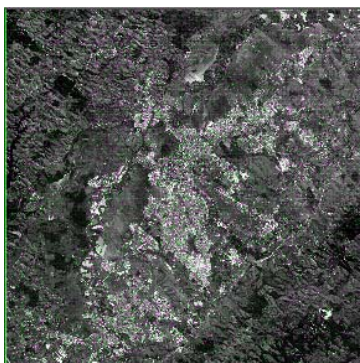

Fig. 8. CE4 registration (base is colored in red and blue, adjusting in green).

IV. CONCLUSIONS

The software CASA-F, as the results proved, permits the selection of control points through features drawing, as well as through selected parts of images, using the IonI method. The results described in Section III have proved accurate and reliable registrations for all the 4 sets of images: CE1 to CE4. However, it should be stressed the superiority of the VonI method over the IonI one, facilitating greatly the user work.

The software CASA-F contributes with the image registration, making easy for the user to extract control points from different sensors images. And, yet, it has an important application even as for images getting from the same sensor, but related to extensive, heterogeneous and noisy areas, and, consequently with different statistical properties.

The interface man-machine, developed to execute the main CASA-F algorithm, has shown to be flexible. The tool allows the extraction of control points for image registration in a friendly operational process. Furthermore, since it is software developed in C++ Builder programming language, it permits addition of new functionalities and integration to hardware devices.

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