# Simultaneous Georeferencing of Digitised Heterogeneous Map Sheets

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**ملخص :**

من المراحل المهمة في عملية وضع نظام للإعلام الجغرافي مرحلة استرجاع المعطيات الموجودة و وضعها في شكل متناسق. هذه المعطيات آتية من مصادر مختلفة بوسائل متنوعة و لقد تم اقتناءها بتقنيات ميدانية و/ أو فوتوغرامترية مختلفة.
يجب عرض هذه المعلومات في نظام متناسق و مرجعي في نفس نظام الإحداثيات، لأجل ذلك يصبح من الضروري إدماج وسائل تعديل فعالة.
هذا المقال يصف طريقة من طرق التعديل المتزامن للمخططات المرقمنة، مستوحاة من تقنيات التثليث الجوي الفوتوغراميتري و تطبيقها على مخططات التأريف الرقمية.
هذه التقنية تمكن من الحفاظ على العلاقات بين المعطيات بطريقة دقيقة و ضمان الاستمرارية في اقتناء المعلومات التي يمكن إضافتها لاحقا و التصدي بصفة فعالة للمشاكل المطروحة عند الضبط المنعزل للمخططات مثلا :

- نظام إحداثيات محلي أو غير متواجد.
- مقاييس مختلفة للمخططات.
- دعائم مختلفة.
- نقاط مراقبة غير متوفرة بالعدد الكافي أو غير متواجدة.
- تقسيم غير لائق لهذه النقاط.

هذه المقاربة قد تم تطويرها و تطبيقها في إطار وضع نظام إعلامي عقاري لفائدة مؤسسة تسيير المنطقة الصناعية لأرزيو أقزيا.

## Résumé :

L'une des phases importantes pour la mise en place d'un Système d'Information Géographique est la récupération et la mise en forme de toutes les données existantes. Ces données proviennent de sources diverses, sur des supports différents et acquises par des procédures terrains et/ou photogrammétriques et à des dates différentes. Cette information doit être présentée sous une forme homogène et référencée dans un même système de coordonnées. Pour cela l'intégration d'outils d'ajustements efficaces est primordiale. Cet article décrit une des méthodes d'ajustement simultané de plans digitalisés inspirée des techniques d'aérotriangulations photogrammétriques et son application à des plans cadastraux numériques. Cette technique permet de préserver les relations entre les données d'une manière précise et de garantir une continuité dans l'acquisition d'informations qui peuvent être ajoutées ultérieurement et de répondre efficacement aux problèmes posés par le calage isolé de plans tel :

- Système de coordonnées local ou inexistant.
- Echelles de plans différentes.
- Supports différents.
- Points de contrôle indisponible en nombre suffisant, voire inexistants.
- Répartition non optimale de ces points.

Cette approche à été développée et appliquée dans le cadre de la mise en place d'un Système d'Information Foncier pour le compte de l'entreprise de gestion de la zone industrielle d'Arzew EGZIA.

## Abstract :

One of the most important phases in the set up of a GIS is the recuperation of existing data and putting them under the same and homogeneous form. This data may originate from different sources, various media, and be acquired by various techniques at different scales. To be useful the data must be placed into homogeneous system and referenced on the same co-ordinate system. For this purpose, the application of efficient adjustment techniques is mandatory. The paper describes application of a photogrammetric block adjustment technique (independent model triangulation) for simultaneous georeferencing of digitised map sheets. This technique allows us to establish compatibility between sheets, data homogeneity and continuity for an eventual updating. The technique can resolve problems efficiently which may arise in individual sheets because of : different co-ordinate systems in individual sheets, different scales, different media (paper, film), lack of controls points, and inappropriate distribution of control points. This approach was applied to set up a land information system to identify and indemnify landowners before initiation of an industrial compound construction.

***Key words :*** *Individual map sheet, simultaneous georeferencing, tie points, independent model, linear transformation.*

## 1. Introdduction

The incorporation of cadastral data into a GIS requires that all data must be referenced precisely to the same co-ordinate system (James, G., 1992). When the source data originate from existing map sheets or orthophotos we may be confronted with many problems such as :

1. Different co-ordinate system in different sheets.
2. Different scales.
3. Different media (paper, film).
4. Lack of control points.
5. Inappropriate distribution of control points.

The problems appear especially often in countries in transition, The simultaneous adjustment of the adjacent sheets into the same and unique co-ordinate system is then a suitable solution. It allows precise establishment of the relations between sheets and guarantees the continuity of data acquisition. The technique is based on the well-known photogrammetric independent model adjustment. We only substitute a photogrammetric model by a sheet. The adjustment is based on successive transformations of adjacent sheets into common co-ordinate system and then transformation of that common system into a official land co-ordinate system. The technique has been proven in photogrammetric practice and can be easily integrated into a GIS .

## 2. Georeferencing techniques

### 2.1 Individual sheets

Georeferencing of individual sheets is based on individual transformation of a local sheet co-ordinate system into an accepted state plane co-ordinate system.
This approach does not guarantee a correct edge matching. The edge matching between adjacent sheets may become bad because of different characteristics of each individual sheet (scale, medium, precision , control points, maintenance).

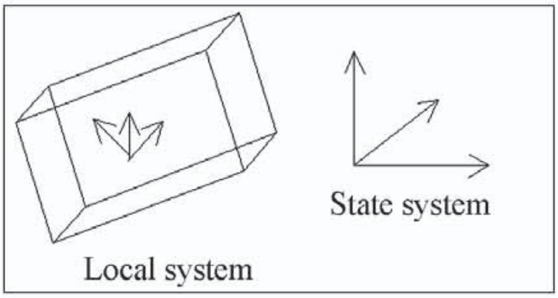


**Fig. 1 :** Local and state co-ordinate system - individal sheet.

Each sheet must have a sufficient number of control points for the determination of the transformation parameters. It may happen that a point appearing in several sheets, shows co-ordinate discrepancies in each sheet. By using a non linear transformation this approach can be applied to derive approximate solution for the global adjustment.

### 2.2 Simultaneous sheet adjustment

This procedure is based on simultaneous treatment of all neighbouring sheets taking into account common points on sheet overlaps (tie points, junction points). On one hand it takes care to adjust neighbouring sheets relatively with each other by minimising tie point discrepancies and on the other hand it adjusts the whole structure absolutely into the state co-ordinate system by minimising the discrepancies on control points. This approach requires overlap between adjacent sheets.
The advantages of the approach are:

1. Control points are not required in every sheet.
2. Best fit among neighbouring sheets is guaranteed .
3. Unique co-ordinates of the points are guaranteed even if they appear in different sheets.

This technique can be employed with help of different kinds of transformation depending on the type of the co-ordinate system ( two dimensional, three dimensional ), nature of deformations, precision of observations, geometry of the area, existence of other data, etc.

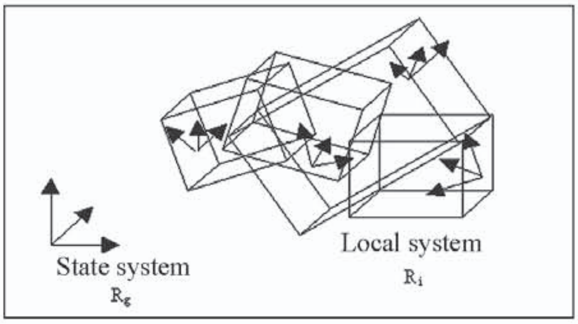


**Fig. 2 :** Local systems and state co-ordinates.

### 2.3 Principles of simultaneous adjustment

Let $R_i$ be a co-ordinate system of the sheet i (where every point of this unit has a known co-ordinates x, y) and $R_g$ a state co-ordinate system. We pass from $R_i$ to $R_g$ by applying a co-ordinate transformation defined by parameters $p_i$. The transformation $T_i$ can be linear or non linear (Radwan 79) :

$$R_i \xrightarrow{Ti\ ,\ Pi} R_g$$
$$(\underline{X})_i \longrightarrow (\underline{X})_g$$

The simultaneous adjustment minimises the relative discrepancies at tie points and the absolute discrepancies at control points. The result provides simultaneously the parameters $p_i$ of the transformations $T_i$.

For a control point j of the sheet i, the observation equation is :

$$\underline{X}_j = T_i\,(\underline{x}_j)_i \qquad (1)$$

where $\underline{X}_j$ is a known co-ordinate vector $(X\ Y\ Z)_j^T$ of the point **j** in the state system and $\underline{x}_j$ is a known co-ordinate vector $(xyz)_j^T$ of the point **j** in the local system **i**.

For a tie point j appearing in sheet i, the observation equation is:

$$\underline{X}_j - T_i\,(\underline{x}_j)_i = 0 \qquad (2)$$

where $X_j$ is a unknown co-ordinate vector of the point **j** in the state system.

The observation system (Amer) can be set as :

$$\mathbf{Ap + Bc = e} \qquad (3)$$

Generally the system is overdetermined and a least squares solution is applied . The normal system is given by :

$$\begin{aligned} &\mathbf{A^T Ap + A^T Bc = A^T e} \\ &\mathbf{B^T Ap + B^T Bc = B^T e} \\ &\text{Or} \\ &\mathbf{N_{11}p + N_{12}c = f_1} \\ &\mathbf{N^T_{12}p + N_{22}c = f_2} \end{aligned} \qquad (4)$$

where **p** is the parameter vector of the different transformations and c is the unknown co-ordinate vector of all tie point in the state system $R_g$. **p** is obtained by :

$$\mathbf{p} = (\mathbf{N}_{11} - \mathbf{N}_{12}\mathbf{N}^{-1}_{22}\mathbf{N}^{T}_{12})^{-1}(\mathbf{f}_1 - \mathbf{N}_{12}\mathbf{N}^{-1}_{22}\mathbf{f}_2) \tag{5}$$

and **c** is obtained by :

$$\mathbf{c} = \mathbf{N}^{-1}_{22}\mathbf{f}_2 - \mathbf{N}^{-1}_{22}\mathbf{N}^{T}_{12}\,\mathbf{p} \tag{6}$$

After the parameters are calculated the new co-ordinates of the all points **n** of each sheet **m** may be obtained in the common system $R_g$ by :

$$\underline{X}_n = T_m(\underline{x}_n)_m \tag{7}$$

## 3. Application

### 3.1 Practical considerations

Since we consider only a planemetric adjustment, we used two kinds of points. Control point, it is a point **j** appearing in a sheet **i** having a measured coordinates in the system **i** $(x_j, y_j)_i$ and a known ( X j , Y j ) on the reference system. Tie point , it is point **j** when it s appear in a system k and a system l , it has a measured co-ordinates $(xj, yj)_k$ in the system k and a measured co-ordinates $(xj, yj)_l$ in the system l . The tie point has as many number of vector co-ordinates as the number it appear in the whole structure but a unique position in the reference system ( Xj , Yj ) which is unknown.
We used an affine plane transformation after a serie of test which make in evidence the existence of global deformations caused by paper deformation.

Every point j appearing in the sheet i give us an equation :

$$\begin{pmatrix} X \\ Y \end{pmatrix}_j = \begin{pmatrix} a & b \\ c & d \end{pmatrix}_i \begin{pmatrix} x \\ y \end{pmatrix}_{ji} + \begin{pmatrix} CX \\ CY \end{pmatrix}_i \tag{8}$$

or in the form :

$$\begin{pmatrix} X \\ Y \end{pmatrix}_j = \begin{pmatrix} x & y & 0 & 0 & 1 & 0 \\ 0 & 0 & x & y & 0 & 1 \end{pmatrix}_{ji} \begin{pmatrix} a \\ b \\ c \\ d \\ CX \\ CY \end{pmatrix}_i \tag{9}$$

or in the implicit form : $A_{JI}\,P_I = F_J$ for control point and for a tie point : $A_{JI}\,P_I - IX_J = 0$.
For every map sheet i , we have to determine the set of the unknowns $P_i$. $(a,b,c,d,cx,cy)^T_i$.
The user can change and apply an other type of transformation model which depend in the kind of his application ( spatial, linear plane, polynomiale... ) taking care about the signification of every coefficient.

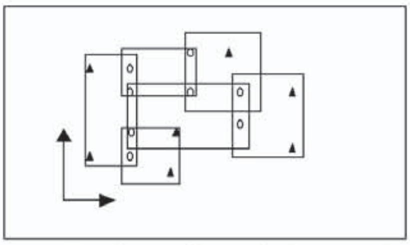

**Fig. 3 :** Example of repartition of planemetric controls, ties points and overlap between sheets.

### 3.2 Practical application

A good preparation ( stefanovic 1975 ) for all the work was initiated :

1- To find points which can be used as ties points and ensure their presence in the different sheet.
2- Looking for the availability and the existence of the control points.
3- Ensure to have a unique identification of the different points.
4- To choose the type of transformation.

Every mapsheet has her proper local system and only some of them have somepoints known in the state system. Because of the type of the maps and their nature ( paper ) we used an affine plane transformation. All the mapsheet were numbered using their proper local system (vector numbering), independently, taking all precautions to ensure the presence of all points with the rules established by the user, function of his needs. The main objective was a construction of a system for managing the landed patrimony of the industrial Zone. The interest area lies on 25 papers map sheets A0 format covering approximately 3000 ha. The approximate scale of the different sheets was 1/4000.

So the approach was implemented for the realisation of a land system, solution of the problem submitting by the EGZIA principal manager of the industrial zone activities.
Once the parameters calculated by our made program, the entire digitised points were determined in the unique system chosen and given by the user.

## 4. Conclusion

The obtained results give us a facility in the manipulation of the data since they were presented in a same and unique system.
The consideration of the "all map" permit to us to avoid duplication or to forget data .The fundamentals relations and the cadastral elements were easily graft, letting us indexing owner propriety. Thanks to the homogeneity of the results, the constraints of bad closing of geometrical figures, junctions between plans and duplicates co-ordinates for the same points disappear.
This approach is not the last one, it is only the first step of the adjustment where the constraints on details (points) have not been used. ( Merrit, R. Ewan, 2000).
Adding these considerations will let surely this approach of adjustment be more efficient.

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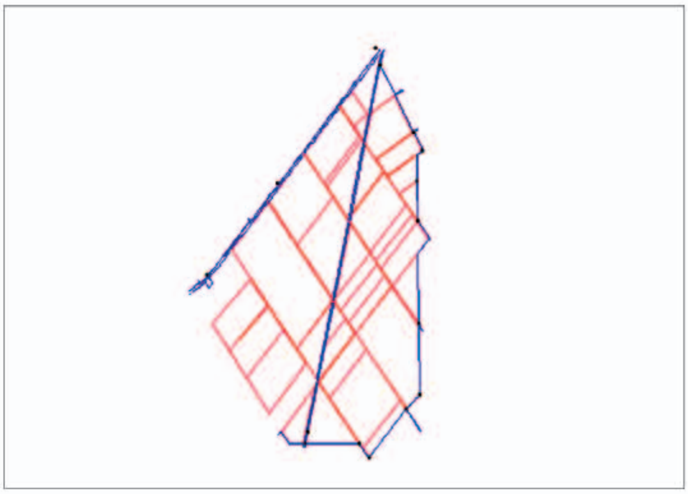

**Fig. 4 :** one of the 25 isolated maps N° 8

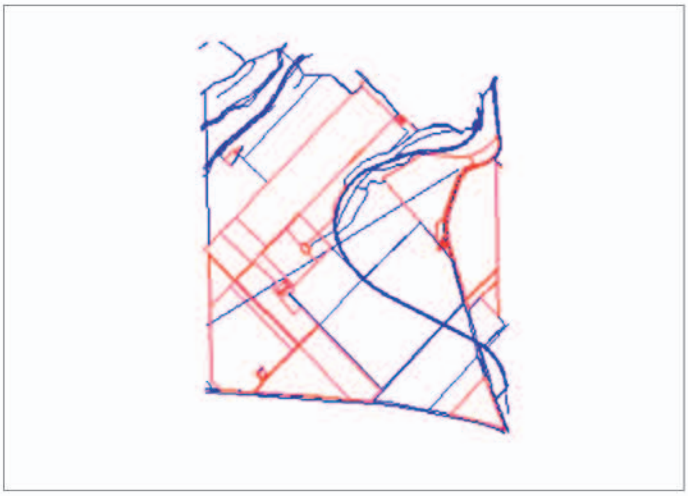

**Fig. 5 :** isolated map n°25

**Fig. 6 :** final result of the adjustment .
All the 25 maps are adjusted in the same reference system