Cadastral Map Upgrading and Layers Harmonization for the Spatial Data Infrastructure in Friuli Venezia Giulia, Italy

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SUMMARY

The cadastral map represents an essential layer of any spatial data infrastructure, as well emphasized by the European directive INSPIRE. In this context, each cadastral parcel assumes a fundamental role, since it constitutes one of the key elements for carrying out an interoperable information system. The parcel represents the link among the legal domain information, the public restrictions, the private taxes, and further layers. The cadastral map, therefore, enlarges the required interoperable links to the complete available geo information tools like networks, plans, services and others.

To fulfil this function, the cadastral map must satisfy a high level of accuracy, not reachable at the time of its implementation, often more than one century ago. Furthermore, the harmonization of a digital cadastral map into a spatial information system is complicated by further problems like fragmented reference systems, inaccurate upgrades, distorted and discontinuous representations.

Accordingly, the cadastral map updating requires appropriate interventions. Sometimes the corrective actions prove to be empirical, not reproducible and of costly maintenance. Furthermore, the diversity of solutions hinders the database harmonization of the various administrations.

This paper analyses the problems inherent in the Italian cadastral map, describes the methodology developed to update the digital map and recover the original geometric accuracy. Furthermore, the paper shows the results of a global and qualified set of interventions carried out by the Friuli Venezia Giulia regional administration, in cooperation with INSIEL Spa and the University of Udine, that make the cadastral data base fully harmonized and interoperable within the regional spatial data infrastructure.

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1. INTRODUCTION

A frequent request to the public administrations and agencies providing territorial services is to connect their spatial data bases, relating to urban plans, transport networks, distribution networks and so on, to the real estates reported on the cadastral maps. The most popular method to connect the different layers is based on the geometrical overlapping of the corresponding digital maps, and on the use of GIS spatial analyses tools. In order to obtain a successful result it is necessary to use a structured mapping, updated, and with a high metrical quality according to the formal scale of the GIS.

In Italy and in other countries, the use of the cadastral digital mapping in a GIS, with enough precision and truthfulness, is often a problem for the less than optimal properties of the available maps. If, for more than one century, the Italian cadastral map has satisfied its documental function, today, according to the digital use, it shows many limits due to the historical origins and to the various procedures of preservation and transformation adopted over time. The most common inconveniences are: inhomogeneous and fragmented coordinate systems, incomplete and inaccurate cartographic upgrading processes, deformation and geo referencing problems, lack of congruence for the common sides of contiguous sheets.

For some years, the Italian cadastre administration, namely Agenzia del Territorio (AdT), is deeply involved in the solution of these problems. Unfortunately, the dimensions of the digital archives require too much time, not acceptable by GIS managers that are prompted to search for independent empirical approaches. This praxis leads to patchy solutions that make difficult the geometrical alignment of the cartographic basis among different GIS implementations.

To satisfactorily solve the problem, the Friuli Venezia Giulia regional administration developed an univocal solution to facilitate the integration of the cadastral databases within its own regional GIS. With this aim, in 2005 this regional administration established with the national Agenzia del Territorio a three years agreement, containing a series of actions with the purpose of upgrading and aligning the digital cadastral archives. The execution of the technical activities was committed to Insiel S.p.A., in house company of the regional administration, with the scientific support of the University of Udine (Italy).

The complex upgrading of the cadastral mapping was developed according to the following four action lines:
- the completion of the vectorization of the cadastral maps till in raster format;
- the map updating with the most recent acts not yet registered;
- the geometrical strengthening of the network of the cadastral fiducial points;
- the realization of a continuous cadastral cartographic database, referenced in the national Gauss-Boaga/Roma Monte Mario 1940 and UTM/ETRS89 coordinate systems.

This paper describes the main phases of this complex experience, deepening on the methodology adopted for the strengthening of the fiducial points network, on the analytical approach used to reference the cadastral maps in the national cartographic datum, and on the employed solutions to satisfy the automatic correspondence between the cadastral map, managed by the Agenzia del Territorio, and the corresponding map upgraded in the GIS of the regional administration.

2. CARTOGRAPHIC PROBLEM

As mentioned before, the diffusion of large scale GIS in the public administration has evidenced the inappropriateness of the main part of the cadastral digital mapping to represent the extension and the spatial distribution of real estates with the necessary metrical precision. This fact is due to various reasons: the limits of the measurement technology employed for the cadastral map realization, carried out between the end of nineteen century and the first half of the last century, and the way the maps have been stored and preserved, very different from the current needs. The most common problems regard:

2.1. Reference systems fragmentation

The Italian cadastral mapping mainly uses the Cassini-Soldner projection system, and only locally the national Gauss Boaga system is applied. According to reports from the Agenzia del Territorio, the entire national territory is subdivided into more than 818 local reference systems, and 32 systems of "wide dimension". At a local level, a more fragmented situation can be found, particularly in the areas once administered by the former Austro-Hungarian cadastre.

Furthermore, the map digitizing process, carried out in the last two decades, has often produced a total disjunction between the original cartographic coordinates (Cassini-Soldner or Gauss-Boaga) and the vector coordinates. For this reason, many map sheets are referenced into arbitrary independent systems, with consequent difficulties for their proper re-projection within the GIS (Figure 1).

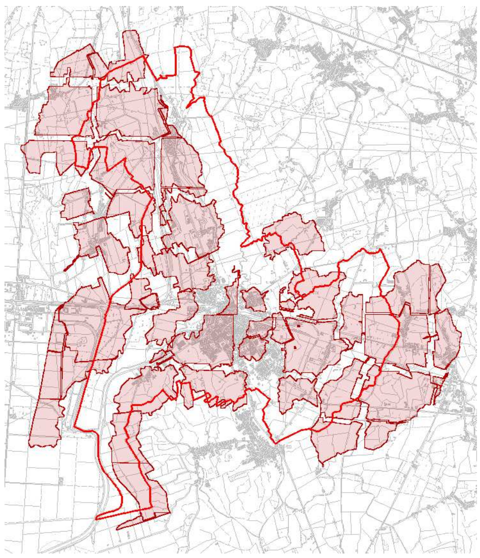

Figure 1 – Cadastral reference system fragmentation

2.2. Map distortions

In origin, the Italian cadastral maps were drown with particular care on heavy paper sheets, transposing with graphical signs the measurements taken on the terrain. Every map sheet was independently surveyed, without a strict graphical continuity with the other sheets, considered not necessary at that time. Although the better surveying techniques employed, the lack of geometrical constraints with the contiguous sheets let the measurement errors accumulate near and along the external perimeter of the maps, making in this way, the common lines of two contiguous sheets not always congruent. This defect was furthermore amplified by the digitizing process of the cadastral maps, carried out not for the original sheets (properly stored against damage) but for the working copies, the only ones to contain the successive updating reports. In this way, to the small initial errors, additional deformations were summed up due to the vectorization procedures and, mainly, due to the deterioration of the long time used paper supports. These cartographic defects, largely widespread, and of a complex modelling, make impossible to accurately georeferencing the cadastral mapping in a global way, and oblige to act sheet by sheet.

2.3 Approximated updating

The cadastral map contains many immaterial geometrical elements, such as the border lines of the parcels, that are rarely reported in the field in concrete way. The only certain physical elements represented by the cadastral mapping are the building perimeters, without roof protrusions. These entities are also represented in the technical maps of the regional administration, and on the photogrammetric images, and can furnish referenced geometrical elements for matching different cartographies. Normally, the insertion of new buildings in the cadastral map is done according to good topographic practice rules, satisfying the prescribed tolerances, but not always this could happened for technical reasons or for contingent necessities. Therefore, there are several cases of map updates carried out in an approximated way, that do not satisfy the precision of the original map, and that must be recognised and treated in a proper way.

3. RESEARCHES ABOUT CADASTRE DIGITAL MAPPING IN ITALY

It is obvious how the described questions hinder the functional connection between the cadastral database and the other GIS layers. The problem is not recent nor only Italian, but is shared by other countries still using an historical cadastral database. Making use of the experience of other countries is not always simple for the different technical norms adopted by each country. Although it is easy to modify a map without any limit so to satisfy the graphical congruence, actually, legal, metrical, geometrical and topological constraints of the map contents strongly reduce this possibility.

In Italy two opposing views are compared: those that propose a total remaking of the cadastral map, neglecting the high costs and time needed, and those suggesting a progressive upgrading according to the specific applications. The second way is the most adopted, and is proposed by universities, public administrations, and the same Agenzia del Territorio.

A concise overview of the research lines carried out in Italy includes the analytical models and the techniques to geo-referencing, updating and fixing the coordinates of the fiducial points network (Di Filippo et al., 2005; Ferrante et al., 2005; Sossai, 2005; Crespi e Reina, 2004; Beinat et al., 2004b; Conia et al. 1992), the automatic definition of corresponding elements on different cartographies (Brovelli e Zamboni, 2003; 2004; Brovelli et al., 2007; Beinat et al. 2003; 2004c; 2004d), the required algorithms for the general coordinate transformation from cadastral systems to the national ones (D’Urso et al., 2009; Cina, 2008;

Bendea et al. 2009; Di Filippo, 1995; 1996; 2003), and the recovery of the cartographic geometrical deformations (Garnero e Ferrante, 2009; Sossai, 2006; Beinat e Crosilla, 2002; 2003; Beinat et al. 2005b).

The scientific literature presents a set of proposals that allow, in different cases, to appropriately amend the cadastral map, avoiding or postponing its costly rebuilding. A sound opportunity was proposed by the Agenzia del Territorio, thanks to the development of a software tool, called Pregeo, for the updating of the cadastral database, and a series of supplemental topographic and cartographic norms. Among these we mention the cooperation of professional figures for the cartographic updating, the request of topographic surveys in the field, the institution of a wide and dense fiducial point network, the formulation and the telematic delivery of the cadastral updating acts by charged technicians. Since the nineties, by the Pregeo procedure, the Agenzia del Territorio has gathered a considerable archive of topographical surveys (more than 8 millions) that represent, although not continuously in space, the most precise and updated elements of the current cadastral map. This is a resource not yet completely exploited, that must be used instead for new effective solutions.

4 THE ACTIVITIES CARRIED OUT BY THE FRIULI VENEZIA GIULIA REGION

In this context, the administration of the Friuli Venezia Giulia region started specific initiatives to upgrade and to adapt the cadastral databases so to guarantee their correct use and full interoperability within a GIS, according to three phases of intervention:
1. upgrading and adaptation of the cadastral data base;
2. strengthening of the fiducial point network, and coordinate conversion into a unique reference system;
3. realization of a continuous digital cadastral cartographic data base.

While in the first case the procedures are largely experimented, for the two remaining points the matter is still argument of study and practical testing. For this reason, what described in the following, represents one of the largest and most significant experiments carried out in Italy.

4.1 Fixing the coordinates of the fiducial points network

The national network of the fiducial points (FP) was established in 1987, to guarantee a stable point location in the cadastral reference system, easily accessible and very dense, with vertices located at a mutual distance of some hundreds meters. Initially, for most of the cases, the coordinates of the fiducial points were estimated on the map, and for this reason they have a very poor accuracy.

The cadastral norms, relating to the Pregeo procedure, oblige the professionals to locally constrain to the fiducial network every updating topographic survey, and to determine, in the meanwhile, the mutual distances between the involved fiducial points (Figure 2). In this way, with the years passing, the activity of the professionals has permitted to determine with redundancy the main part of the fiducial vertices, through the repeated measurement of the elements of such a network.

At the beginning the AdT forecasted the use of these surveys to progressively improve the coordinate values of the fiducial network and the metrical quality of the cadastral mapping, as soon as the measurements reached enough consistency. Today, except some experimental activities (Conia et al., 1992; Ferrante et al., 2005), the Pregeo surveys are only used for updating the existing mapping, without considering its distortions, while the measurements between FPs are only marginally used to improve the fiducial network. This remains weakly joined to the cadastral datum, and the main part of its coordinates are heterogeneous, not accurate and subjected to changes in time.

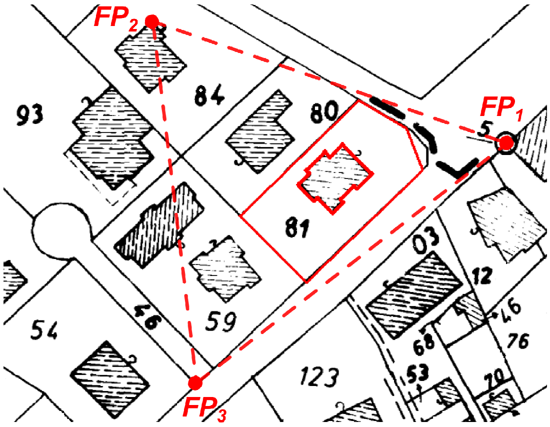

Figure 2 – *PREGEO* survey of a cadastral parcel referred to the Fiducial Point network.

In this context, the FVG Region wanted to benefit of the opportunities offered by the largest amount of topographic observations gathered by the AdT, to better fix the position of the FP located on its territory. A stable fiducial network, integrated with the Pregeo surveys, although allows to reconstruct only a partial and fragmented map, is instead well suited to furnish correspondences and constraints to improve the geometrical precision of the current cartography (Figure 6 a,b,c).

However this situation is different among the various Italian regions, and strictly related to the cadastral activity carried out by the professionals. In the FVG Region, already in 2004, an investigation on the data available in the digital archives of AdT, evidenced that the regional fiducial network was largely interconnected, and covered the most significant areas in terms of management and planning of the regional territory (Beinat et al., 2004a). There were the premises to fix the definitive values of the point coordinates.

To consolidate the geometry of the fiducial network, it is necessary to constrain the measurements to a certain number of FP topographically determined. According to the shape of the network, the interconnections among the nodes, and the required precision, the percentage of the constrained points is of the order of 10%, as reported by the authors (Beinat et al., 2002; Sossai, 2005).

For the FVG network, constituted by more than 34000 FP, the selection of the 3538 constrain FP was carried out by a GIS that handled all the data, the characteristics of the

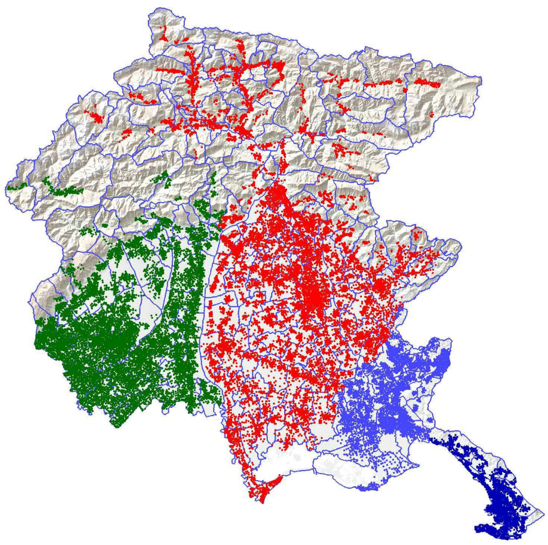

Figure 3 – Spatial distribution of the 28355 Fiducial Points surveyed or adjusted. The network covers the territory of major cadastral interest.

regional PF and all the mutual distances contained in the AdT archives.

The analyses have permitted to identify 620 FPs having a high reliability, connected to the fiducial network by at least two updating surveys, and corresponding to IGM, cadastral vertices, or stable reference points, of which the analytical original coordinates were known in the Cassini – Soldner local system. The remaining 2918 FPs, having only provisory coordinates, were selected among those most widely used by the professionals, in such a way to guarantee an homogeneous spatial distribution not less than 1 FP per square kilometre in the flat areas, and 4 FP per square kilometre in complex morphological areas. For every selected FP, an alternative point was identified in the surroundings.

The topographic surveys were executed with classical and satellite techniques. GPS L1+L2 receivers were used in relative rapid static positioning, with measurement sessions not less than 20 minutes, in double base. All this was facilitated by the presence of 23 permanent stations active in the region, belonging to the “FredNet”, “Marussi” and “ItalPos” GPS networks, to which additional 55 temporary local masters were joined. This permitted to determine 6409 GPS vertices, of which 722 located on the selected PF (20%), while the remaining (80%) constituted off centres for the determination of 2816 FPs not directly occupiable with GPS antennas. Technical reasons and reliability questions have precluded the use of the NRTK technology.

The field measurements started at the end of 2007 and lasted for more than 15 months. At the end of the field work, the testing procedures carried out by the AdT over a sample corresponding to the 5% of the surveyed FPs, furnished fully positive results.

To adjust the fiducial network, a procedure developed by the group of Udine University was adopted. This procedure is conceptually inspired to the photogrammetric bundle adjustments by independent models (Beinat e Crosilla, 2002; 2003; Beinat et al., 2002; 2004b; Sossai, 2005).

Unlike the classical topographic adjustment, that considers the mutual distances computed from the FP difference of coordinates of the Pregeo surveys, in the adopted solution an iterative global least squares similarity transformation model of the various Pregeo fiducial polygons was applied. At each iteration the various fiducial polygons are translated, rotated and eventually scaled in such a way to optimally fit all the other polygons without any anisotropic deformation. The running procedure ends when the variations of the transformation parameters for all the polygons satisfies a minimum condition.

The procedure, derived from the Generalized Procrustes analysis (Beinat and Crosilla, 2003), allows a robust estimate and the capability to model possible systematic effects by an isotropic scale factor, like in the case of the linear deformation module variations between the Cassini Solder and Gauss mapping systems.

The solution equation is given by the well known relationship (Beinat and Crosilla, 2003):

$$S = \sum_{i<k}^{\mathrm{m}} \mathrm{tr}\left(\mathrm{c}_i \mathbf{A}_i \mathbf{T}_i + \mathbf{j}\mathbf{t}_i - \mathrm{c}_k \mathbf{A}_k \mathbf{T}_k - \mathbf{j}\mathbf{t}_k\right)^{\mathrm{T}} \mathbf{D}_i \mathbf{D}_k \left(\sum_{j=1}^{\mathrm{m}} \mathbf{D}_j\right)^{-1} \left(\mathrm{c}_i \mathbf{A}_i \mathbf{T}_i + \mathbf{j}\mathbf{t}_i - \mathrm{c}_k \mathbf{A}_k \mathbf{T}_k - \mathbf{j}\mathbf{t}_k\right) = \min \quad [1]$$

where:

$\mathbf{A}_i$ is a generic matrix containing by rows the 2D or 3D coordinates of the FPs that constitute the survey of the professionals (Figure 4); c_i, is the scale factor; $\mathbf{T}_i$ is the rotation matrix; $\mathbf{t}_i$ is the translation vector of the *i*-th fiducial polygon; $\mathbf{D}_i$ is the diagonal weight matrix relating to matrix $\mathbf{A}_i$; **j** is the unit vector of dimension 1×m; and m is the total number of fiducial polygons to adjust.

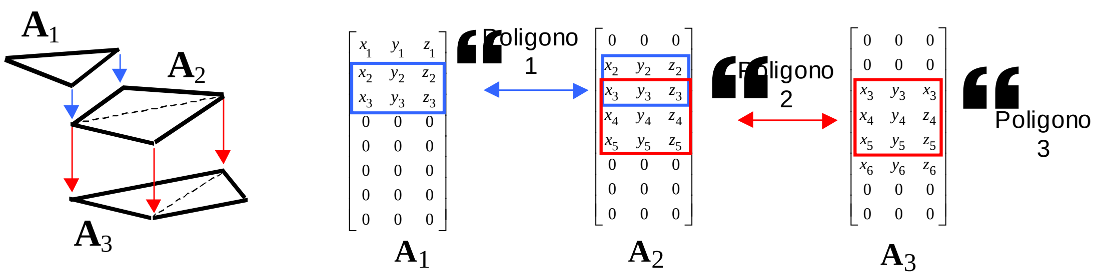

Figure 4 – Matrix representation of the Fiducial Point polygons surveyed by the professionals

The Procrustes solution, that is the final optimal configuration of the fiducial network A*, is given by:

$$\mathbf{A}^* = \left(\sum_{k=1}^{m} \mathbf{D}_k \right)^{-1} \sum_{i=1}^{m} \mathbf{D}_i \left(c\mathbf{A}_i \mathbf{T}_i + \mathbf{j}\mathbf{t}_i \right) \qquad [2]$$

This activity permitted to compute the adjusted coordinates of 28355 FPs, nearly the 87% of the whole regional fiducial network, with the exclusion of those not joined by a sufficient number of measurements (Figure 3). For details about the topographic field work, and the adjustment of the fiducial network, see Basso et al. (2009a).

4.2 Cadastral map recomposition

The cadastral map recomposition aims to unify the cadastral reference system, and to restore the geometric continuity without gaps or overlaps between contiguous sheets. Like other Italian research groups, the University of Udine developed and experimented different solutions on this topic, all based on a common analytical model. These techniques can be distinguished according to the smaller map elements on which they operate:

- recomposition by sheets, both raster and vector, performed by geometric transformations of the entire maps so to fit them in the cadastral datum and adapt each sheet with the others;

- recomposition by parcels, where the map sheet is first exploded in its parcels and buildings, and then reassembled with further constraints and updates by means of a new adjustment of the individual geometric elements. The format, in this case is vector only.

The second solution yielded excellent results (Beinat et al 2005a; 2005b) but the costs of implementation and the reduced availability of the required data, limited its use.

For the upgrading of the cadastral map in the FVG Region, the adopted approach was by sheets, because of the reduced timing and favourable cost-benefit analysis. The planned goal was to achieve a level of agreement of the order of 1 – 2 meters between the cadastral map and the technical digital map (RTDM) of the FVG Region. According to the regional laws, the RTDM is the base map for the realization of urban and land planning instruments of the regional authorities and municipalities. RTDM accuracy is equivalent to that of a map at a nominal scale 1:2000. The 1:1000, 1:2000, 1:1440 and 1:2880 cadastral maps, despite their often larger scale, generally reveal a much lower accuracy.

Because of the different cadastral systems, and the lack of reliability of the coordinates frames of the various cadastral maps, it was considered appropriate to define the transformation parameters of the individual sheets through the identification of a series of double points of various kind, like constraints of consistency and continuity between two sheets. The analytical model adopted for the upgrading of the map sheets was the block adjustment by independent models (Figure 5). The block size corresponds to the number of sheets covering the total area of the municipality, and ranges from several tens to several hundreds units. For each sheet of the block, specific transformations can be applied: rigid, conformal or affine.
The implemented procedure is articulated as follows (Basso et al. 2009 b):

- at the computer screen, a hundred correspondence points between the cadastral map (in a proprietary format CXF) and the RTDM are interactively identified. The redundancy can statistically attenuate the problems related to the different cartographic properties of the two sheets. Depending on the transformation model adopted, the operator can progressively verify the reliability of the correspondence points selected through the analysis of the residuals;

- in addition, some constraint points given by the fiducial points topographically determined, and those stabilized with the analytical procedure described in the previous paragraph, are introduced;

- finally, the greatest number of perimeter bindings, detectable between the contiguous sheets of the block are automatically joined (Sossai 2006).

A weight empirically defined is then assigned to each of the three types of points. To the perimeter points, a weight value twice than the others was chosen. This choice provides a balance between the goal of minimizing the differences between the correspondence points and the need for reducing the surface and shape deformation of the map sheets.

The kind of transformation allowed to the single sheet is fixed by the operator, prior to the adjustment:

- for sheets with uncertain or insufficiently constrained matches, the program apply a rotation and translation (3 parameters) or a similarity transformation (4 parameters);

- for inner sheets firmly framed to each other, or in the presence of evident distortions, the program suggests to apply a general affine transformation (6 parameters).

The least-squares estimation of the affine transformation parameters $\mathbf{p}_i = \begin{bmatrix} a & b & c & d & E_0 & N_0 \end{bmatrix}_i$ of the model $\mathbf{Ap} - \mathbf{l} = \mathbf{v}$ for the generic *i*-th single sheet, is performed by composing a design matrix **A** whose generic block element $\boldsymbol{a}_{k,i}$ is given by:

$$\begin{bmatrix} x & y & 0 & 0 & 1 & 0 \\ 0 & 0 & x & y & 0 & 1 \end{bmatrix}_{k,i} \begin{bmatrix} a & b & c & d & E_0 & N_0 \end{bmatrix}_i^T - \begin{bmatrix} E \\ N \end{bmatrix}_{k,i} = \begin{bmatrix} v_x \\ v_y \end{bmatrix}_{k,i} \qquad [3]$$

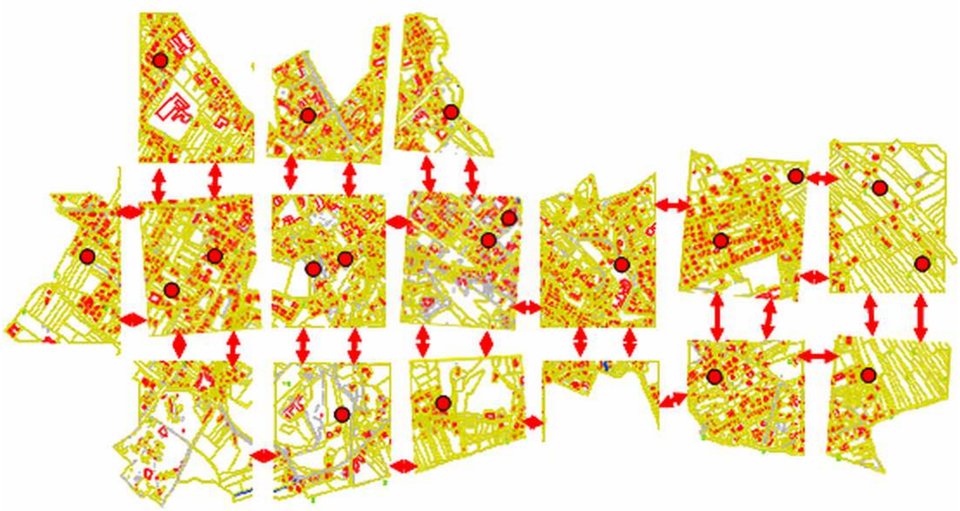

Figure 5 - Conceptual scheme of a block for the mosaicing of the cadastral map sheets: red dots represent constrains (consolidated or surveyed fiducial points), double arrows show point correspondences between sheets.

Where $\{x \;\; y\}_{k,i}$ are the coordinates, in the source reference frame, of the *k*-th correspondence point of the *i*-th sheet, $\{E \;\; N\}_{k,i}$ are the coordinates in the target reference frame of the same point, and $\{v_x \;\; v_y\}_{k,i}$ are the residuals. In case of tie points, in order to estimate the unknown coordinates of the point, appropriate components must be added to the generic element $\boldsymbol{a}_{l,i}$ of the linear system, and to the unknown vector $\mathbf{p}_i$.

From the generic element of the affine transformation it is possible to easily determine the corresponding elements of the rigid transformation, or of the similarity transformation, by posing $d = a$ and $c = - b$, but with a different meaning of the terms of the solution in the two cases. For the rigid rotation and translation the rotation angle is $\vartheta = \tan^{-1}(a/b)$ and the scale factor is $\lambda = 1$, while for the similarity transformation, we have $\vartheta = \tan^{-1}(a/b)$ again, but $\lambda = a/\cos\vartheta$. The weighting matrix $\mathbf{P}$ is diagonal.

Of course, more complex transformations could be introduced into the mathematical model. Those listed, as well as available in any GIS software, represent a compromise between the aim of obtaining an optimal adaptation, but preserving the conformity, and the need to introduce anisotropic deformations.

After the block adjustment, the transformation parameters are associated to the various map sheets. In this way, it is possible to automatically modify their coordinates, from the original cadastral reference system to that defined for the GIS, every time a new version of the map is available by the Agenzia del Territorio, that is the only institution in charge to provide the continuous updating.

The upgrading of the cadastral map has been completed for all the 219 municipalities of the region, for a total of 9640 map sheets, on the basis of 403408 correspondence points and 359033 tie points.

5. FURTHER DEVELOPMENTS

The structured set of actions described so far allows the FVG Region to have updated cadastral data, and a unique geo-referenced map. The misalignments of the map sheets, that before the interventions reached even several tens of meters, are generally reduced to below 1-2 meters. Further improvements are still planned, with less resources, by acting along two directions:

- improving the process of geo-referencing of the individual sheets, replacing the existing way of finding correspondences between the cadastral and the technical map;

- removing the inconsistencies along the edges of the sheets, by a procedure able to distribute the error over the full sheet, particularly for the majority of parcels near the sheet perimeter.

For both issues, there are projects ongoing, and the results of preliminary experiments are already available. In the first case, a new service map is built from scratch, on a frame formed by the upgraded fiducial network, geometrically precise and reliable. This frame is then progressively filled with the Pregeo surveys made by the professionals, whose geometries are automatically inserted in the map by conformal transformation (Figure 6b). The full task is straightforward since each survey is linked to a minimum of three fiducial points, and each fiducial point has a unique identifier over the whole country.

Theoretically, this procedure can generate over time a complete new map, all based on field surveys; at the present however, the Pregeo reliefs form only a limited part of the map. But, although partial, the new cadastral map can provide entities having exact semantic correspondence with the present cadastral map (Figure 6a). This identify in a direct and proper way the correspondence points for the coordinate transformation, that can be performed again by block adjustment (Sossai, 2006) or in other way (Figure 6c).

The second action is subordinated to the first one. After the geo referencing of the map sheets, it is necessary to eliminate the inconsistencies along the perimeter of adjacent sheets, consisting of empty areas or overlapping edges. Very often, this operation is considered "cosmetic" and carried out manually: it is evident that this solution is not reproducible nor rigorous. It is therefore necessary to develop objective criteria and a procedure that can automatically perform the task. Along with other proposals (Garnero and Ferrante, 2009), a prototype is under development that works on geo-referenced maps. Inside a perimeter buffer of some tens of meters, the procedure compensate the geometry of the parcels, by equally distributing the corrections between the adjacent sheets, and propagating the deformations inside the sheet to an extent inversely proportional to the square of the distance from the edge.

The removal of the residual discontinuities represents the last phase of the cadastral map restoration and aims to obtain the continuum mapping required for the full operation of the GIS.

a

b

c

Figure 6 – Map sheets in their actual misaligned reference frame (a); Pregeo surveys framed into the adjusted fiducial network (red dots and dashed lines) (b); Original map sheets realigned by way of the corresponding Pregeo surveys (in black) (c)

REFERENCES

Basso, M., Battaino, S., Beinat, A., Bertos, S., Crosilla, F., Furlan, M., Ghidini, M., Picech, G., Piuzzo, R., Sossai, E., Tommasoni, L., 2009a. Il rilievo con strumentazione GPS e la ricomposizione della rete dei Punti Fiduciali della Regione Friuli Venezia Giulia, *Proc. XIII Conferenza Nazionale ASITA*, Bari, 1 - 4 dicembre 2009.

Basso, M., Battaino, S., Beinat, A., Bertos, S., Crosilla, F., Furlan, M., Ghidini, M., Picech, G., Piuzzo, R., Sossai, E., Tommasoni, L., 2009b. La georeferenziazione delle mappe catastali della Regione Friuli Venezia Giulia nel sistema cartografico regionale, *Proc. XIII Conferenza Nazionale ASITA*, Bari, 1 - 4 dicembre 2009.

Beinat, A., Crosilla, F., 2002. Una procedura per la ricomposizione conforme della cartografia catastale digitale, *Bollettino SIFET*, 1, pp 17-34.

Beinat, A., Crosilla, F., Clerici, A., 2002. Prime sperimentazioni di una proposta innovativa per la ricomposizione cartografica del catasto", *Proc. VI Conferenza Nazionale ASITA*, Perugia 5-8 novembre, pp. 355-360.

Beinat, A., Crosilla, F., 2003. Generalised Procrustes Algorithms for the Conformal Updating of a Cadastral Map, *ZfV-Zeitschrift für Geodäsie, Geoinformation und Landmanagement*, 5, pp. 341-349.

Beinat, A., Crosilla, F., Sossai, E., 2004a. Analisi della copertura e prime sperimentazioni di concatenamento a scala regionale dei poligoni fiduciali in Friuli Venezia Giulia, *Proc. VIII Conferenza Nazionale ASITA*, Roma 14-17 Dicembre, pp. 339-344

Beinat, A., Crosilla, F., Furlan, M., Sossai, E., 2004b. Ricomposizione procustiana della rete fiduciale catastale mediante dati dell'archivio PREGEO, *Proc. VIII Conferenza Nazionale ASITA*, Roma 14-17 Dicembre, pp. 333-338.

Beinat, A., Crosilla, F., Sossai, E., 2004c An Automatic Analitical Procedure for Searching Corresponding Feature Points in a Cadastral Map, TS 28, *FIG Conference Proceedings* ISBN 87-90907-30-2, FIG Working Week 2004, Athens, Greece, May 22-27.

Beinat, A., Crosilla, F., Sossai, E., 2004d. Automatic Point Matching of Gis Geometric Figures, XXth ISPRS Congress Conference Proceedings ISSN 1682-1777, 12-23 July 2004 Istanbul, Turkey, Ed. M. Orhan Altan, *The International Archives of Photogrammetry and Remote Sensing*, Vol. XXXV, Part B4, 92-97.

Beinat, A., Crosilla, F., Sossai, E., 2005a. Un metodo particellare per l'aggiornamento progressivo della cartografia catastale. *Proc. IX Conferenza Nazionale ASITA*, Catania, 15-18/11, pp. 279-284

Beinat, A., Crosilla, F., Sossai, E., 2005b. Ricomposizione particellare conforme della cartografia catastale numerica, *Proc. Convegno Nazionale SIFET*, Mondello (Palermo), 29/06/2005-01/07/2005.

Bendea, H., Cina, A., De Agostino, M., Manzino, A., Piras, M., Porporato, C., 2009. La ricomposizione dei piccoli sistemi d'asse catastali nel sistema WGS84. *Proc. XIII Conferenza Nazionale ASITA*, Bari, 1 - 4 dicembre 2009.

Brovelli, M. A., Zamboni, G., 2003. Integrazione di basi cartografiche su grandi aree, *Bollettino SIFET*, 4, pp. 11-32.

Brovelli, M. A., Zamboni, G., 2004. Adaptive Transformation of Cartographic Bases by Means of Multi-Resolution Spline Interpolation, *XXth ISPRS Congress*, Istanbul, Turkey,

12-23/07/04
Brovelli, M. A., Guzzetti, F., Ruggeri, R., Zamboni, G., 2007. Punti fiduciali e recupero della mappa catastale: il caso di Cremona, *Bollettino di Geodesia e Scienze Affini,* 2, pp. 91-109.
Cina, A., 2008. La carta catastale in un sistema globale, *Rivista dell'Agenzia del Territorio,* I, pp. 13-26.
Conia, G., Del Frate, R., Mencancini, N., Tufillaro, D., 1992. Procedura automatica per il controllo della congruenza dei tipi di aggiornamento sulla base di un quadro d'unione della rete dei punti fiduciali e della misura G.P.S. di alcuni lati significativi, *Bollettino SIFET*, 4, pp. 87-97.
Crespi, M., Reina, T. 2004 Applicazioni non catastali dei punti fiduciali: proposta di una metodologia per l'inquadramento della maglia dei punti fiduciali nel sistema cartografico UTM-WGS84-ETRF89, *Bollettino SIFET*, 3, pp. 13-22.
Di Filippo, S., 1995. Sulla trasformazione delle coordinate plano-cartografiche dalla rappresentazione di Cassini-Soldner alla rappresentazione di Gauss-Boaga e viceversa (parte prima), *Rivista del Dipartimento del Territorio,* 3/1995, pp. 151-186.
Di Filippo, S., 1996. Sulla trasformazione delle coordinate plano-cartografiche dalla rappresentazione di Cassini-Soldner alla rappresentazione di Gauss-Boaga e viceversa (parte seconda), *Rivista del Dipartimento del Territorio*, 1/1996, pp. 105-187.
Di Filippo, S., 2003. Sul passaggio delle coordinate plano-cartografiche catastali al sistema WGS84 e viceversa. *Rivista dell'Agenzia del Territorio*, 59-89.
Di Filippo, S., Ferrante, F., Garnero, G., Gnesivo, P. R., Rao, S., 2005. Unificazione dei sistemi di coordinate catastali di piccola estensione, *Proc. VIII Conferenza Nazionale ASITA*, Catania, Catania, 15-18 novembre.
D'Urso, M. G., Mazzoni, A., Rotondi, A., 2009. Una sperimentazione sull'inquadramento della cartografia catastale nel sistema di riferimento WGS84/ETRF89. *Proc. XIII Conferenza Nazionale ASITA*, Bari, 1 - 4 dicembre 2009.
Ferrante, F., Di Filippo, S., Gnesivo, P. R., Tufillaro, D., 2005. Consolidamento delle coordinate dei punti fiduciali su aree di vasta estensione, *Proc.VIII Conferenza Nazionale ASITA*, Catania, Catania, 15-18 novembre, II, pp. 1071-1078.
Garnero, G., Ferrante, F. C., 2009. La valorizzazione delle mappe originali d'impianto del catasto per la ricostruzione delle congruenze topologiche tra fogli adiacenti. *Proc. XIII Conferenza Nazionale ASITA*, Bari, 1 - 4 dicembre 2009.
Sossai, E. 2005 La ricomposizione di una rete fiduciale catastale di ampie dimensioni: l'esempio di Tarcento (UD), *Proc. IX Conferenza nazionale ASITA*, Catania 15-18 novembre 2005.
Sossai, E. 2006 Ricomposizione cartografica mediante integrazione di rilievi PREGEO e di cartografia numerica esistente, *Proc. X Conferenza nazionale ASITA*, Bolzano 14-17 novembre 2006.

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