FIG Working Week 2012

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

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Summary

- The cadastral mapping: an 'hub' for spatial data connections
- Problems related to the integration of the cadastral map in a large scale GIS
  - Reference system fragmentation
  - Map distortions
  - Approximated updating
- Solutions developed for the spatial data infrastructure of the FVG Region
  - Fiducial Point network survey and adjustment
  - Cadastral map recomposition
- Further developments

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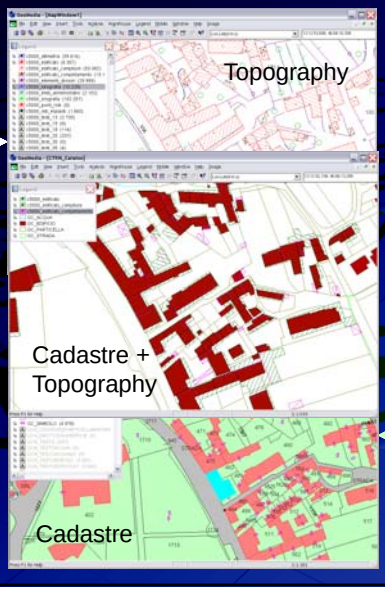
Spatial Data Connection: the Key Role of the Cadastral Map

Hydrology
Elevation
Infrastructure
Networks
Transportation
+ other …



Real estate
Land Register
Urban plans
Zoning
+ other …

GIS screenshots courtesy of Comune di Tavagnacco (UD)

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Obstacles to the cadastral map integration in a l.s. GIS

Map metric defects ⇨ incongruences

– Coordinate reference system fragmented (⇨ historical reasons*), distorted or unknown (⇨ digitization – vectorization of original paper maps);

– Approximated or partial map updates;

– Map distortions and discontinuities (⇨ technical reasons; ⇨ age and deterioration of the original maps etc.);

** The Italian cadastral map is mostly based on Cassini-Soldner (818 local and 32 wide CRS), partly on Gauss-Boaga (few local CRS)*

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Background

The cadastral mapping is owned and exclusively managed by the Agenzia del Territorio, the Italian Cadastre National Agency.

Currently, the cadastral mapping fits the (internal) needs of the National Cadastre: a deep improvement – therefore - is not urgent nor foreseen.

But for many other e-government activities, particularly large scale GIS implementations at local level, the cadastral mapping is often inadequate due to its intrinsic characteristics and historical origins.

These problems have to be solved at regional and local level, i.e. “outside” the cadastre.

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FVG Region initiatives

To integrate the cadastral map, GIS managers need to apply “patches” to their dBs. These solutions are often singular: not rigorous, not reproducible, difficult to maintain and to exchange (⇨ **different dBs are not interoperable**).

To achieve higher accuracy and interoperability for the Spatial Data Infrastructure of the public administration, the FVG Region signed in 2005 a three years agreement with the national “Agenzia del Territorio” to perform a general **upgrade of the cadastral mapping**:

1. Complete vectorisation and full updating of the cadastral raster maps;
2. Topographic re-adjustment of the whole regional fiducial network;
3. Cadastral map re-projection in Gauss-Boaga/Roma40 and UTM/ETRS89 CRS;

Insiel Spa was charged of the cartographic activities with the scientific support of the University of Udine.

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Topographic re-adjustment of the regional fiducial network

Fixing the fiducial network: goals

The national network of the fiducial points (FP) was established in 1987, to guarantee a stable and reproducible point location in the cadastral reference frame.

Most fiducial points coords. were estimated on the map and have poor accuracy.

The cadastral norms (⇨ "Pregeo" procedure), prescribe to locally constrain every updating topographic survey to the fiducial network, and to determine the mutual distances (no coords!) inside the fiducial polygon vertexes.

A large amount of measures has been collected by AdT, that can be used to readjust and fix the FP coordinates.

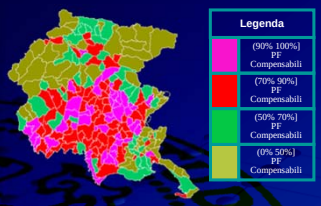
By fixing the FP network and inserting the Pregeo surveys – in theory - a new and directly surveyed cadastral map could be obtained.

Although incomplete in reality, this map can furnish correspondences and constraints to improve the geometrical precision of the current cartography (i.e. a frame on which to stretch the current cadastral mapping).

Fixing the fiducial network: field surveys

An analysis (2004) proved > 90% FVG regional FP network was linked by Pregeo surveys.

To successfully constrain and drive the fiducial point network adjustment, 10% of the regional FP were surveyed in the field (Of 34000 FP ⇨ 3538 FP).



The FPs survey has been carried out by GPS + TS.
GPS: Postprocessed rapid static relative positioning,
t session > 20 min, double base.

⇨ 6409 GPS vertices surveyed

- 722 FP in centre (20%)
- 2816 FP off centre (80%)

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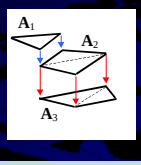
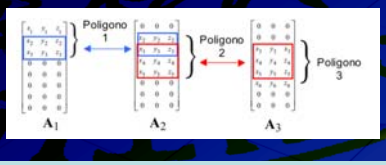
Fixing the fiducial network: adjustment

The fiducial network adjustment was conceptually inspired to the photogrammetric block adjustment by independent models.

A global iterative least squares similarity transformation to the various Pregeo fiducial polygons was applied. At each iteration the various fiducial polygons (A_i) are translated (t_i), rotated (T_i) and eventually scaled (c_i) to optimally fit all the other polygons (and the constraints) without anisotropic deformation.

The procedure, derived from the Generalized Procrustes analysis, allows a robust estimate and the capability to model possible systematic effects by an isotropic scale factor.





$$S = \sum_{i<k}^{m} \mathrm{tr}\left(c_i \mathbf{A}_i \mathbf{T}_i + \mathbf{jt}_i - c_k \mathbf{A}_k \mathbf{T}_k - \mathbf{jt}_k\right)^{\mathrm{T}} \mathbf{D}_i \mathbf{D}_k \left(\sum_{j=1}^{m} \mathbf{D}_j\right)^{-1} \left(c_i \mathbf{A}_i \mathbf{T}_i + \mathbf{jt}_i - c_k \mathbf{A}_k \mathbf{T}_k - \mathbf{jt}_k\right) = \min$$

⇨ 28355 FP adjusted and fixed (87%)

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Cadastral map re-projection in Gauss-Boaga/Roma40 and UTM/ETRS89 CRS

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Cadastral map recomposition: goals and strategies

Cadastral map recomposition aims to unify the cadastral reference system, to recover the original accuracy, and to restore the geometric continuity without gaps or overlaps between contiguous sheets.

Among others researchers, UniUd developed two analytical solutions:

- recomposition by sheets, for 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 (piecewise mosaicing);

- recomposition by parcels, where the map sheet is first exploded in its elements (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 (tesserae mosaicing).

For the upgrading of the cadastral map of the FVG Region, the adopted method was "by sheets", because of the reduced timing and favourable cost-benefit analysis. The target was to achieve 1 – 2 meters agreement between the (1:2000) cadastral map and the (1:2000 equiv.) digital technical map of the FVG Region.

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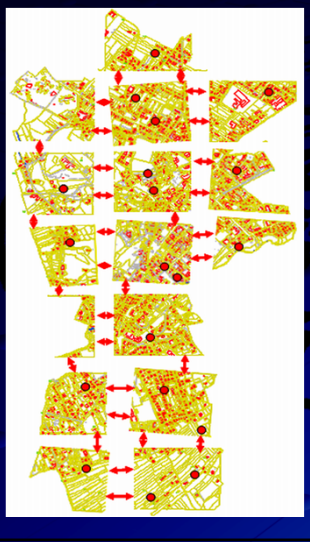
Cadastral map recomposition: piecewise approach

The map recomposition refers again to the photogrammetric 2-d block adjustment by independent models, with some extensions.



- The 2-d models are the map sheets. The block includes the sheets of a whole municipality.

- Tie-points are corresponding points at the perimeter of two adjacent sheets;

- Control points are map points matched to real world points (e.g. surveyed FP) or to other cartography

The LS adjustment estimates the rigid, the similarity or the affine transformation parameters that simultaneously fit the various map sheets to each other and to the control network.

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

Cadastral map recomposition: piecewise application

The piecewise mosaicing method has been applied to align the cadastral map to the digital technical map of the FVG Region.

The technical map provided the set of control points (correspondence points) for the LS piecewise adjustment.

The technical map has a metrical quality higher than the cadastral map, but has different cartographic properties and contents. Hence, correspondence points between topography and cadastre have to be selected interactively, using GIS tools, while tie-points are extracted automatically.

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

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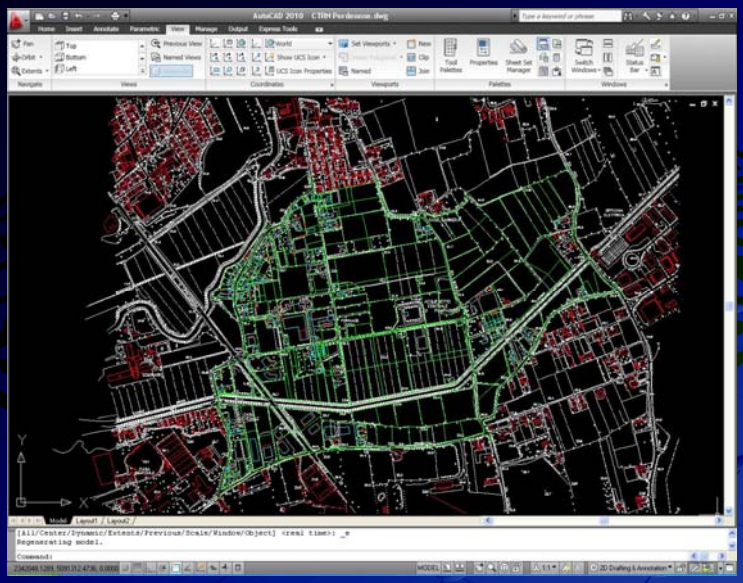
Cadastral map recomposition: tools

Control Points Selection



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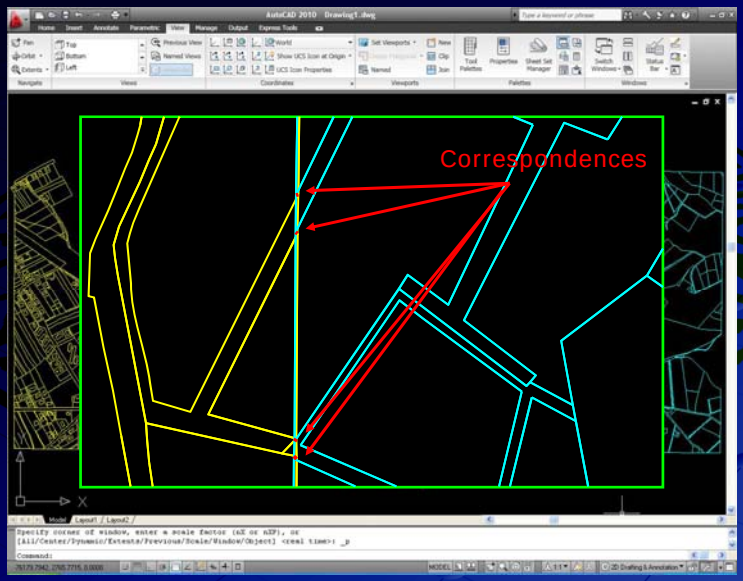
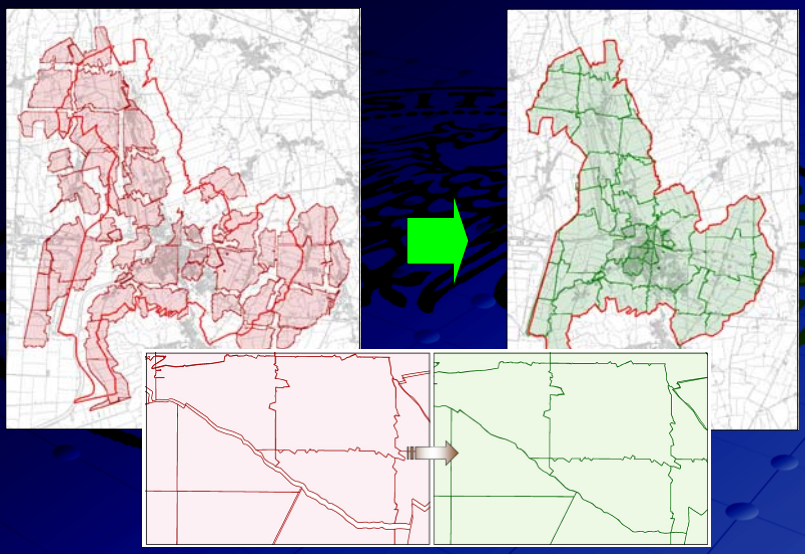
Cadastral map recomposition: tools

Tie Point Automatic Identification



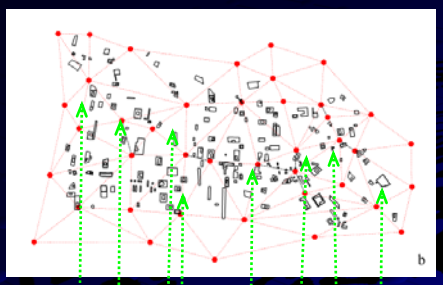
Cadastral map recomposition: results



Present activities

Cadastral map recomposition: piecewise general model

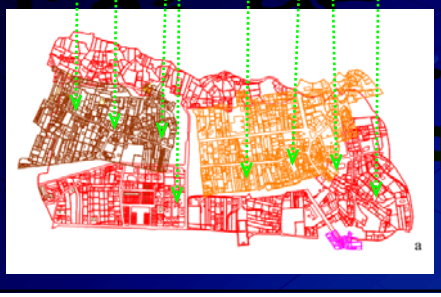
A more general and rigorous method is under implementation.

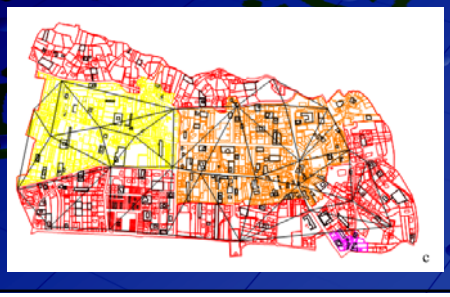


1 step: The FP network is adjusted and the Pregeo surveys are automatically inserted into the fiducial frame;

2 step: Correspondences are directly set between the fiducial frame and the current sheets; control points are included;

3 step: LS block adj. is performed.





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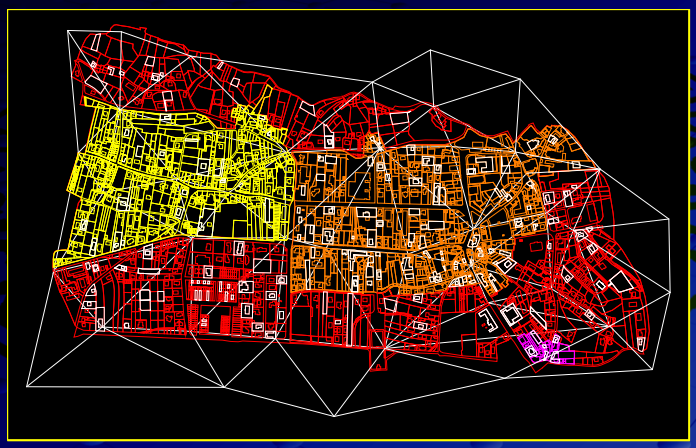
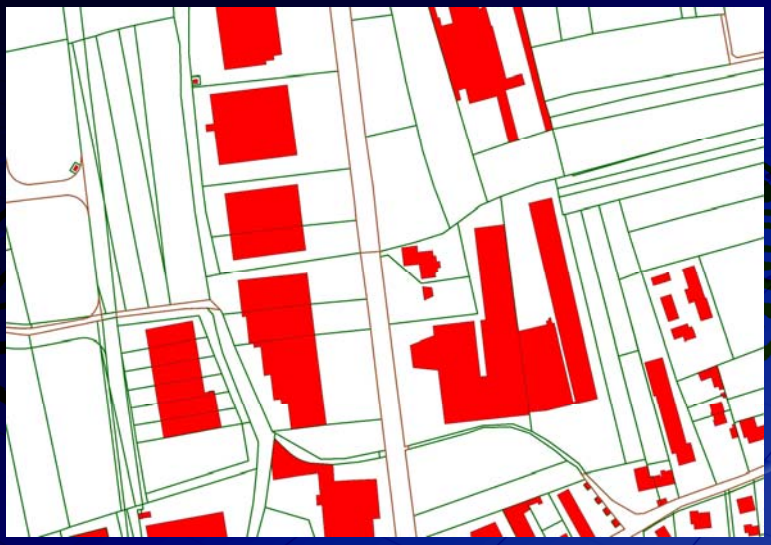
Cadastral map recomposition: piecewise approach

Global adjustment



Further developments: cartographic continuum



Concluding ...

The described interventions let the Region FVG to realign the cadastral map at 1-2 metre accuracy, sufficient for the interoperability and the needs of its large scale GIS.

The solution is univocal and reproducible.

It operates at local level, independently of the central db of AdT, and therefore it does not affect its content.

Further accuracy can eventually be obtained by locally deforming the cadastral map (→ law constraints, GIS limitations) or by a full remake of the cadastral map (→ money, time).

Thank-you

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