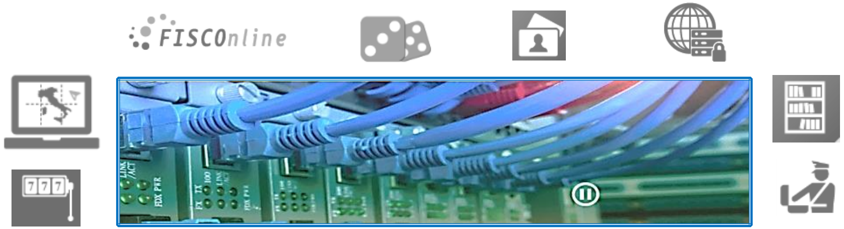
Using paper map-sheets to efficiently improve cartographic accuracy for Italian National Cadastral Management

Riccardo Del Frate, Manager Cartography Services, Sogei spa - rdelfrate@sogei.it

Overview

SOGEI S.p.A

(Società Generale d’Informatica)



and others …

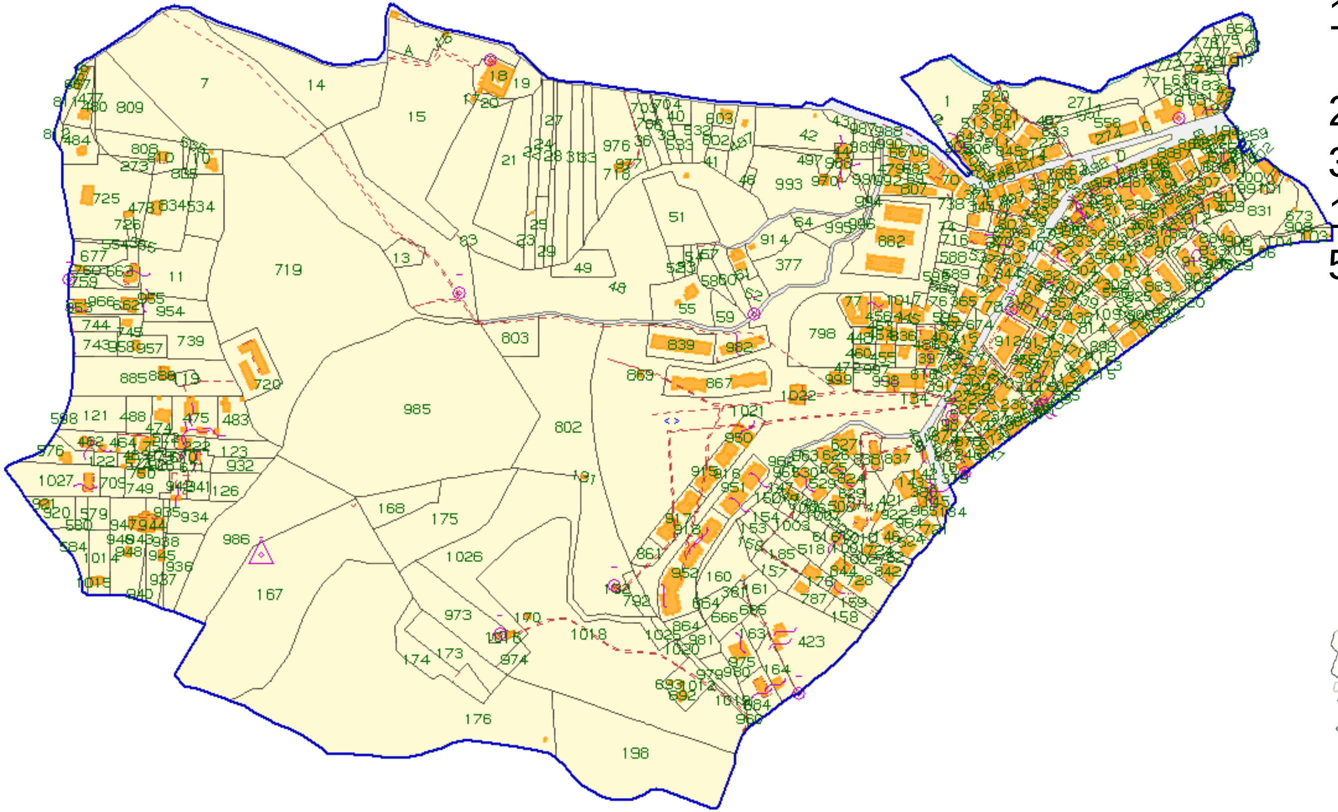
- Founded in 1976, company of **Italian Ministry of Economy and Finance**, provides services for Land and Tax Agency, Custom, Betting&Games, Health Care and other government agencies.

- +2000 employees, +5500 servers, +1300 LAN with
  +1000 connected servers, +11 petabytes
  4 Oracle SuperCluster (2 M family), 21 Exadata.
  Oracle Database EE + Option – Oracle EBS – IAM, Active data Gard

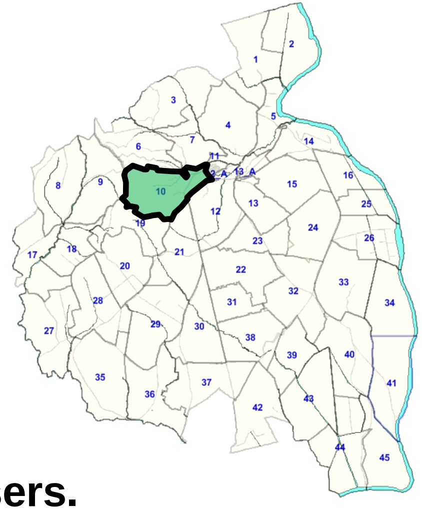
Challenge

- Improve accuracy for +120M polygons and +200M other features of the Italian Cadastral cartography.
- Save costs and time, exploiting metric precision from source cadastral maps and eliminating the on-field survey for millions of ground points.
- Realize an automatic process for cartography correction, completely integrated into Oracle Database.

Cadastral Digital Cartography

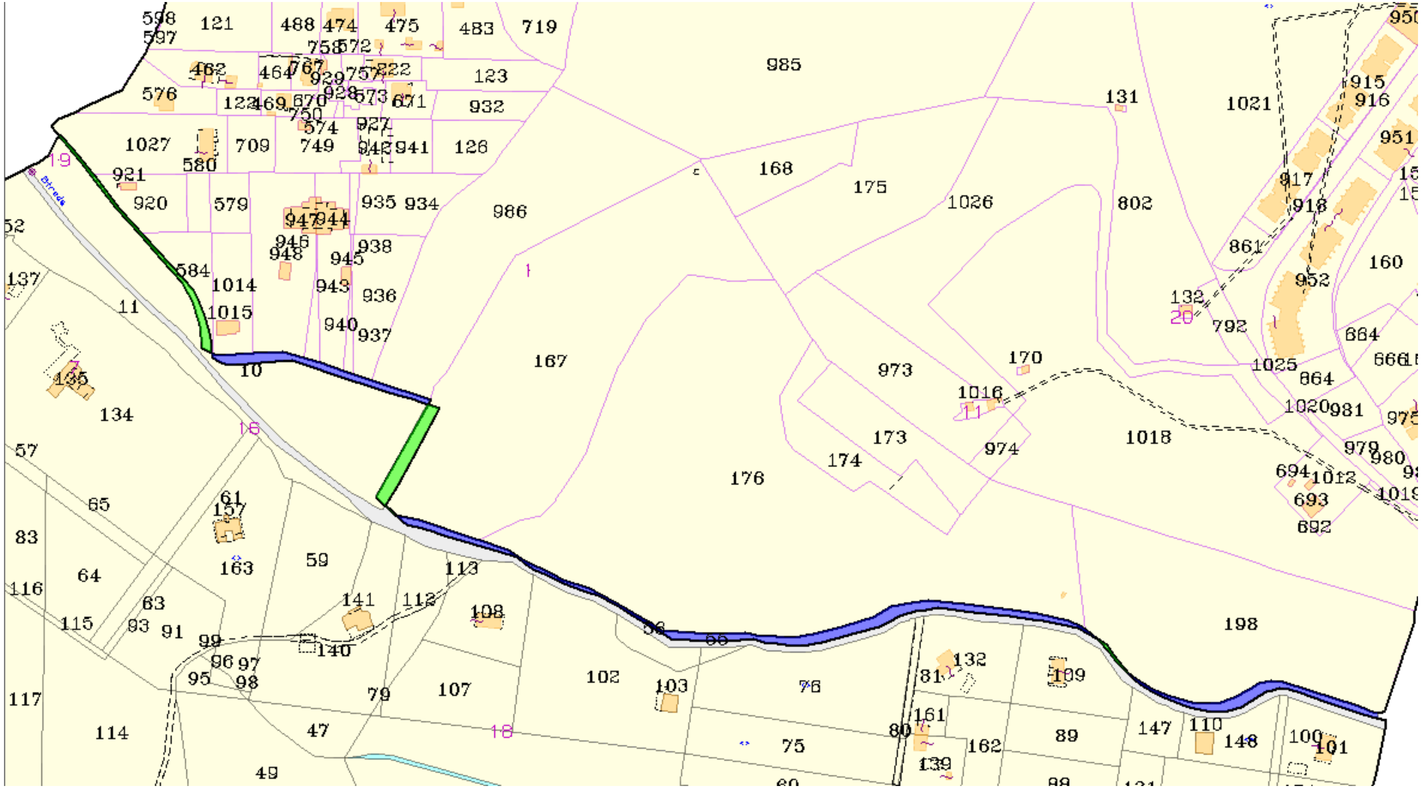


- 101 provincial land agency dept served
- 200K registered users
- 300K digital maps
- 11M yearly downloaded maps
- 500K yearly cartographic cadastral updates



constantly updated and easily queried by 200000 registered users.

Problems of Cadastral Digital Cartography



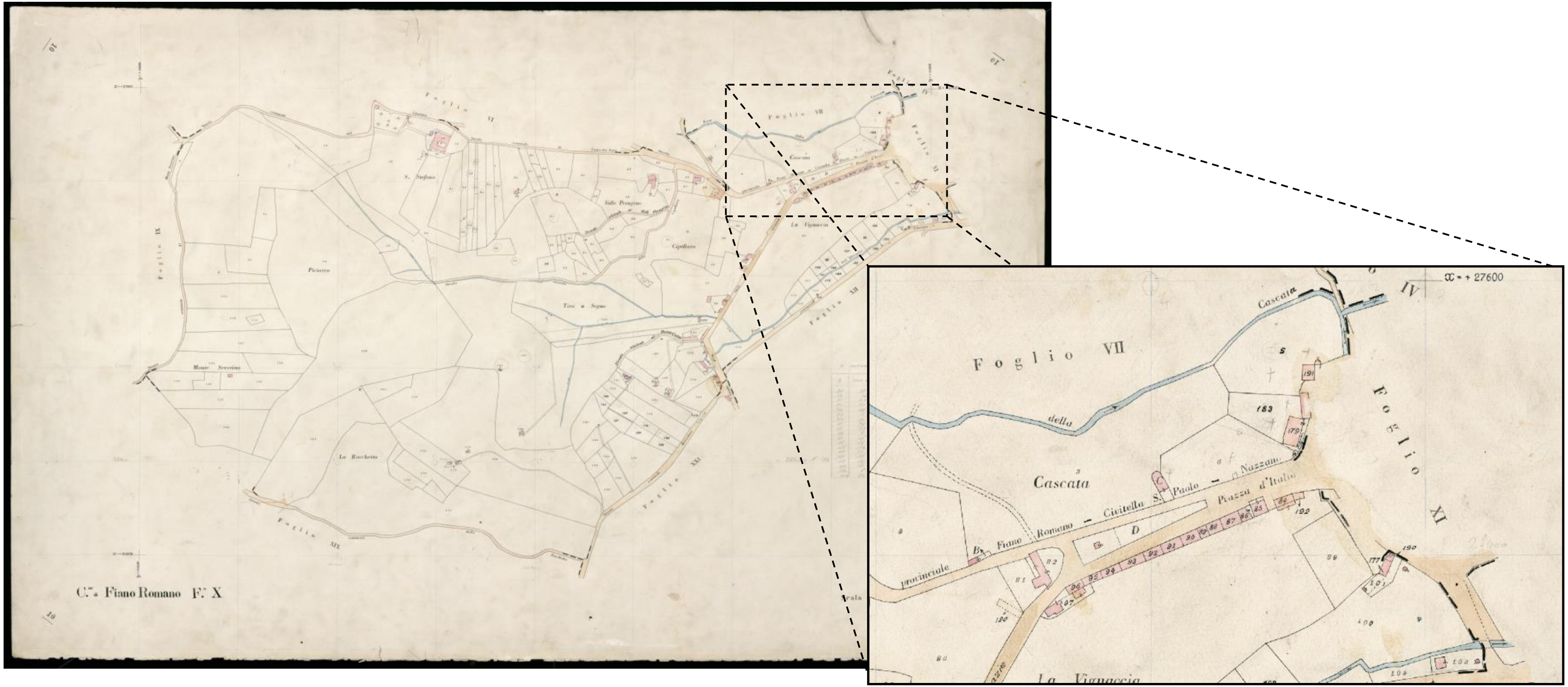
overlapping zones

disjunction zones

The original geo-reference of digital maps has been lost !

SCM, Source Cadastral Map

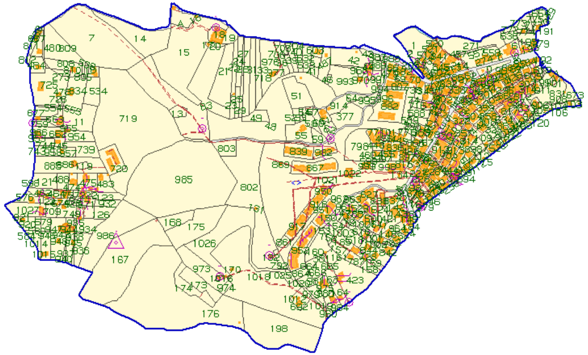
0.6 meters precision provided by the source cadastral map.



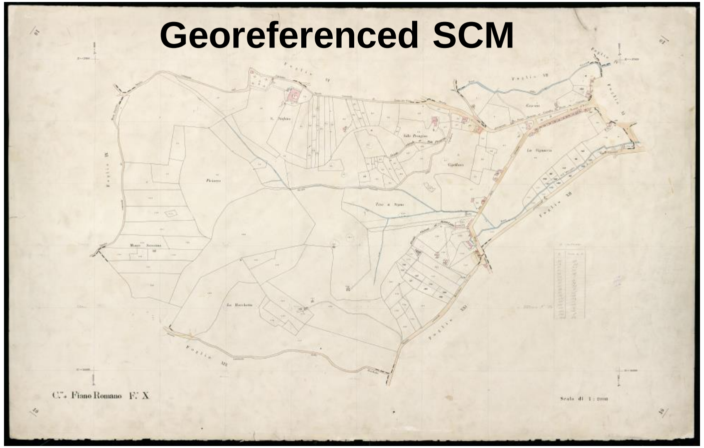
Manual updating and digitization processes from copy (of copy …) of the SCM caused a loss of precision of the current cartography.

Example of the precision to be recovered

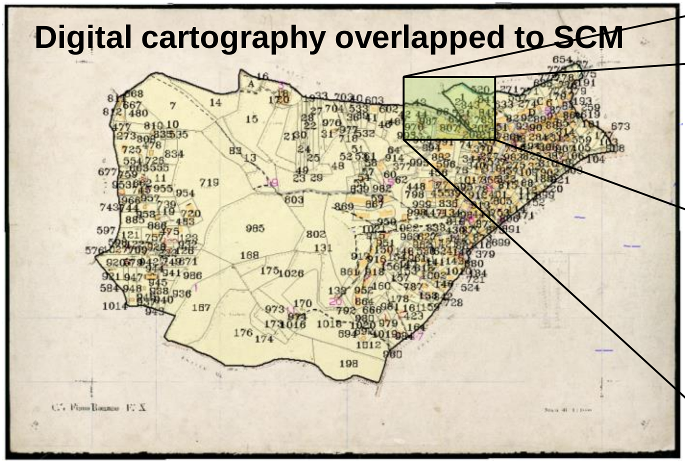
Current cartography

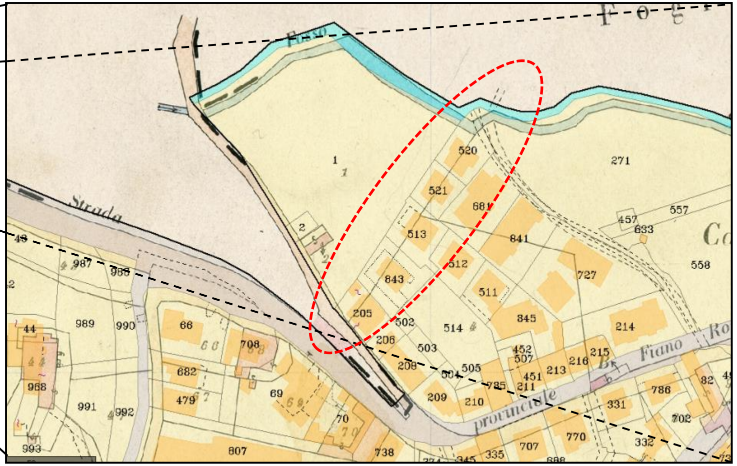


Georeferenced SCM



Digital cartography overlapped to SCM



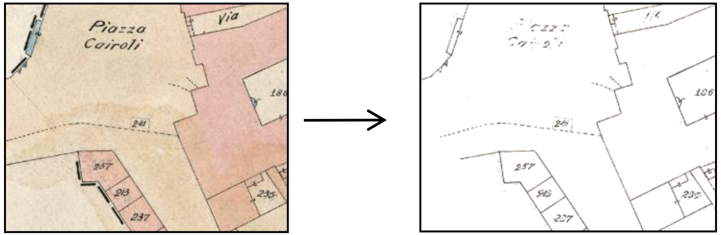


Technological Solution

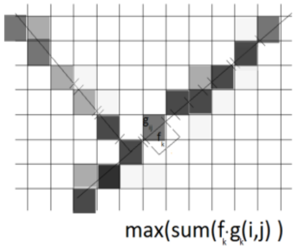
- Client/Server: completely developed in PL/SQL
- Oracle Database 11g2 on Exadata
- Spatial and Graph
  - GeoRaster native support for georeferenced raster imagery
  - TIN functionalities
- Partitioning

Preparing steps

Load cleansed and georeferenced SCM into GeoRaster

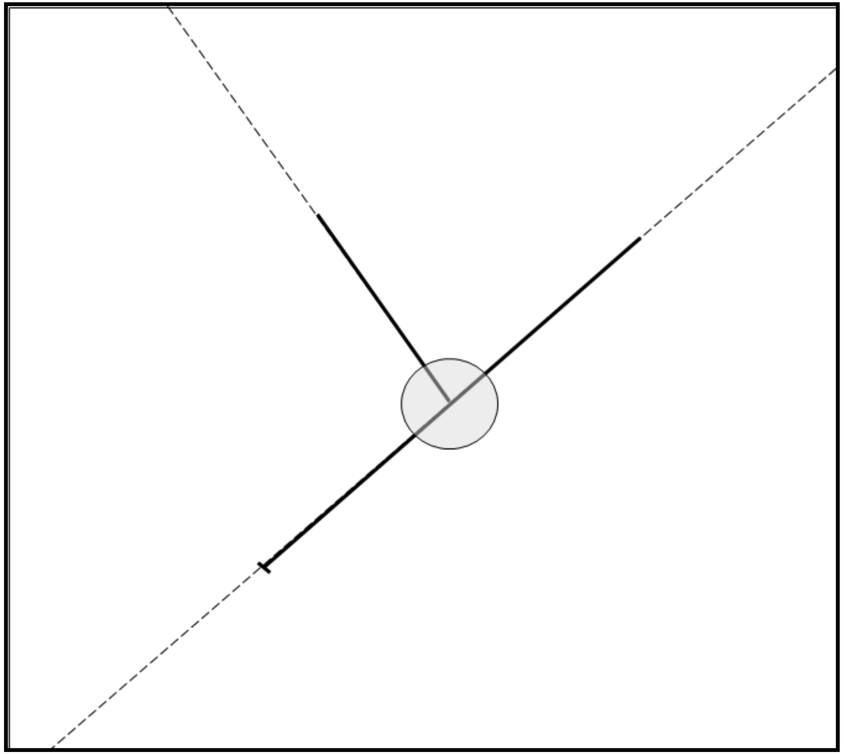


Recognize Homologous Points between vectorial and raster data



Vector-Raster pattern recognition (1)

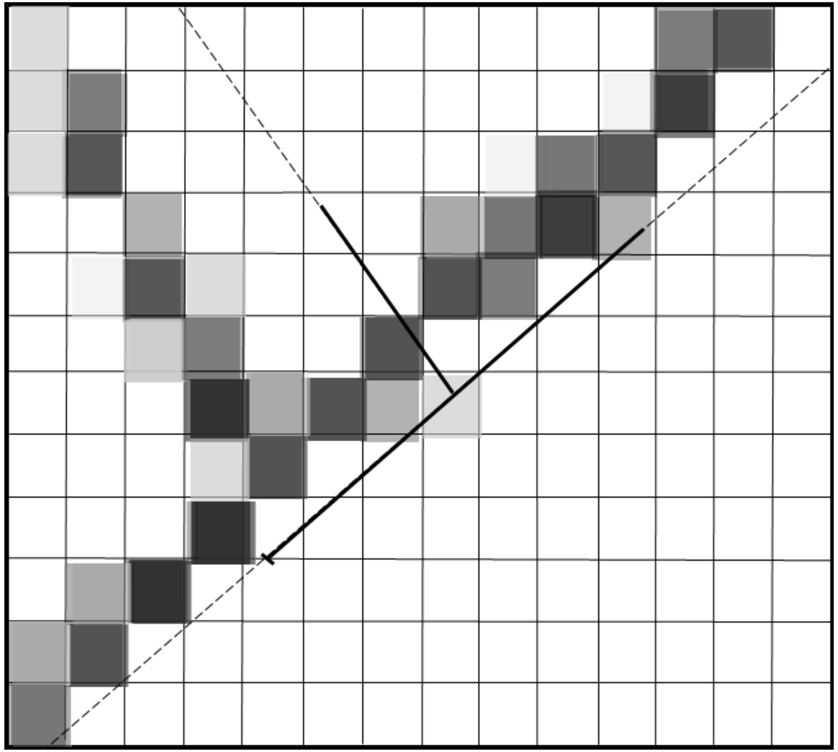
Given a ‘vectorial’ vertex
(here an example having degree 3)



Vector-Raster pattern recognition (2)

Given a ‘vectorial’ vertex
(here an example having degree 3)

Get Raster Subset of the SCM on the MBR of the outgoing segmets.



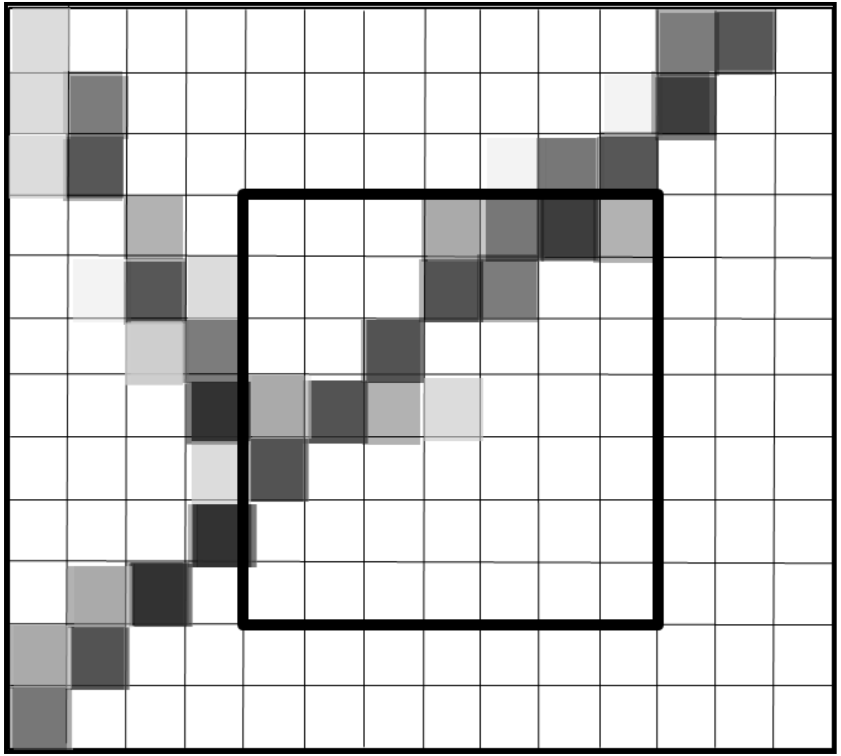
As we start cadastral migration to 12.2, the capability of getRasterSubset to return cell values directly will improve ricognition performance.

Vector-Raster pattern recognition (3)

Given a ‘vectorial’ vertex
(here an example having degree 3)

Get Raster Subset of the SCM on the MBR of the outgoing segmets.

Define a ‘SearchingBOX’ where recognize the homologous point. The inizial size of the searchingBox is assumed to be 40 meters.



Vector-Raster pattern recognition (4)

Given a ‘vectorial’ vertex
(here an example having degree 3)

Get Raster Subset of the SCM on the MBR of the outgoing segmets.

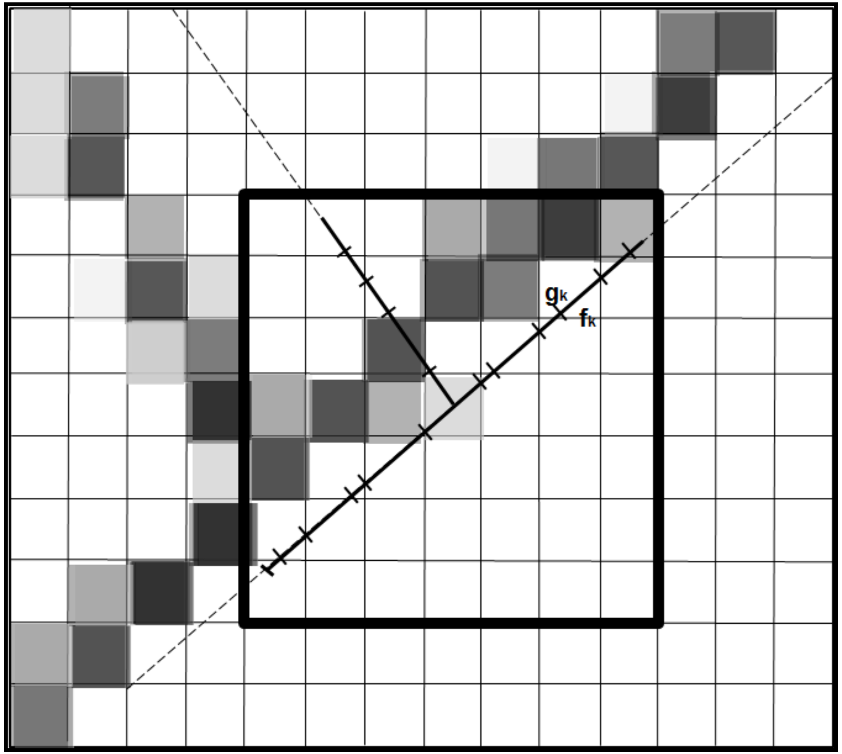
Define a ‘SearchingBOX’ where recognize the homologous point. The inizial size of the searchingBox is assumed to be 40 meters.

For each cell of the RasterSubset:

1. Define $\mathbf{f_k}$ as the length of the intersection of every segment and the BRs of the pixel(i,j).
2. Define $\mathbf{g_k}$ as the value (grey tone) of the intersected pixel(i,j).
3. Compute the SUM: $\sum \mathbf{f_k * g_k}$

Move the vertex on a new position of the ‘SearchingBOX’ and repeat the calculus

Recognize the homologous point as the position having the maximum SUM



$$\mathrm{sum}(f_k \cdot g_k(i,j)) = 5$$

Vector-Raster pattern recognition (5)

Given a 'vectorial' vertex
(here an example having degree 3)

Get Raster Subset of the SCM on the MBR of the outgoing segmets.

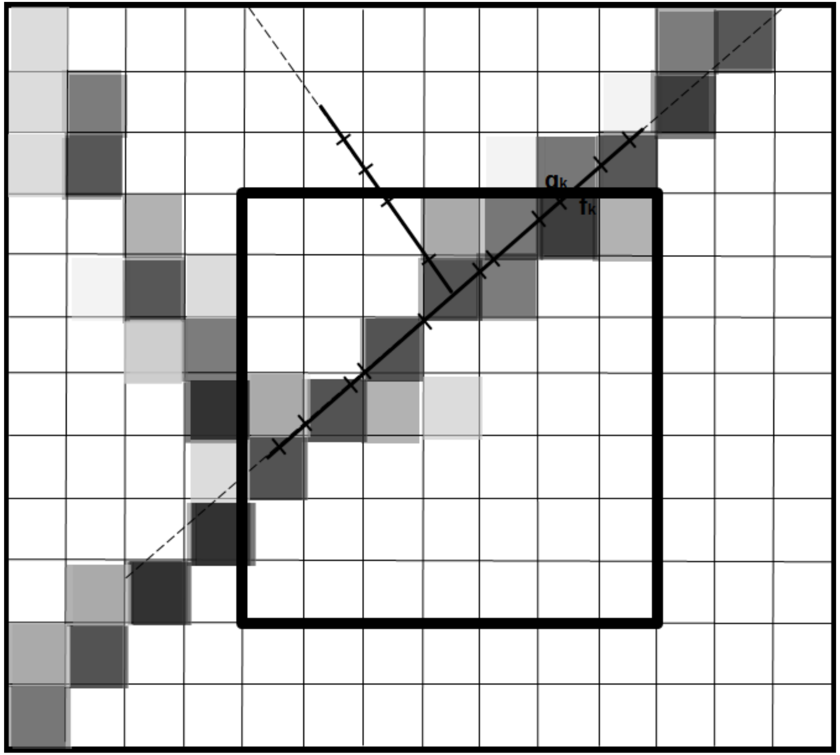
Define a 'SearchingBOX' where recognize the homologous point. The inizial size of the searchingBox is assumed to be 40 meters.

For each cell of the RasterSubset:

1. Define $\mathbf{f}_k$ as the length of the intersection of every segment and the BRs of the pixel(i,j).
2. Define $\mathbf{g}_k$ as the value (grey tone) of the intersected pixel(i,j).
3. Compute the SUM: $\sum \mathbf{f}_k * \mathbf{g}_k$

Move the vertex on a new position of the 'SearchingBOX' and repeat the calculus

Recognize the homologous point as the position having the maximum SUM



$\text{sum}(f_k \cdot g_k(i,j)) = 63$

Vector-Raster pattern recognition (6)

Given a 'vectorial' vertex
(here an example having degree 3)

Get Raster Subset of the SCM on the MBR of the outgoing segmets.

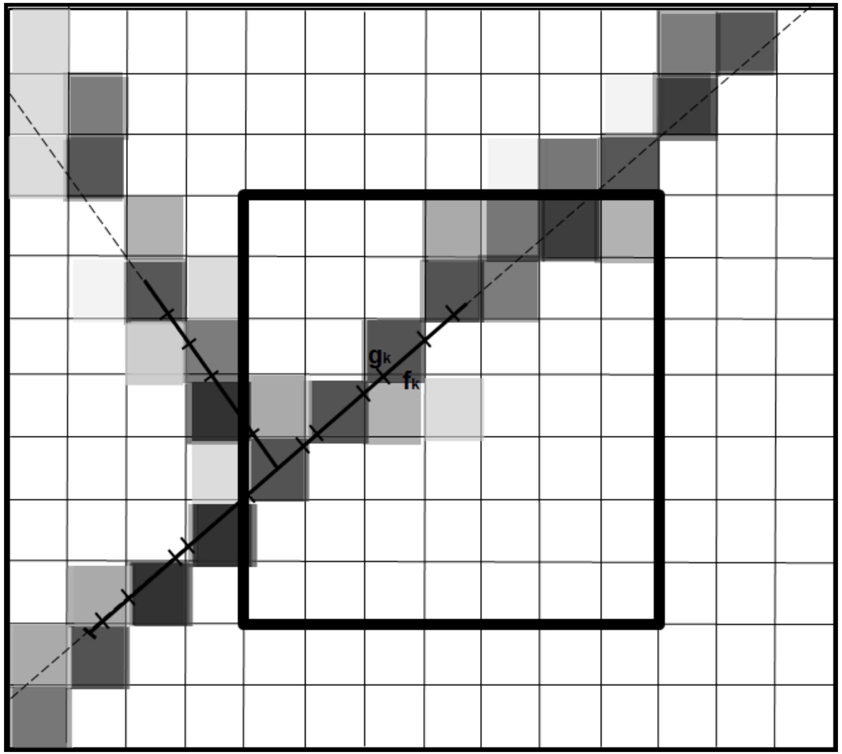
Define a 'SearchingBOX' where recognize the homologous point. The inizial size of the searchingBox is assumed to be 40 meters.

For each cell of the RasterSubset:

1. Define $\mathbf{f}_k$ as the length of the intersection of every segment and the BRs of the pixel$_{(i,j)}$.
2. Define $\mathbf{g}_k$ as the value (grey tone) of the intersected pixel(i,j).
3. Compute the SUM: $\sum \mathbf{f}_k * \mathbf{g}_k$

Move the vertex on a new position of the 'SearchingBOX' and repeat the calculus

Recognize the homologous point as the position having the maximum SUM



$$\mathrm{sum}(f_k \cdot g_k(i,j)) = 89$$

$$\max(\mathrm{sum}(f_k \cdot g_k(i,j)))$$

MOSAICA Recognition criteria

To collect a big number of reliable couples of homologous points,

instead of using only pattern recognition techniques we have developed

a specific technique that we name MOSAICA.

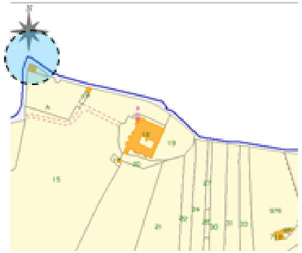
MOSAICA 'recognizes' homologous points emulating the behavior

of a human operator:

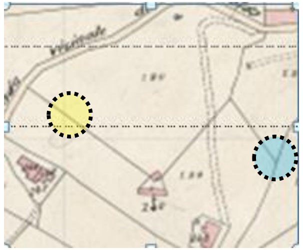
- First, take due account that data describe cartographic cadastral themes
- Second, take advantage from the 'transformation' derived from already detected points to increase capability of recognizing new points.

Taking account of the cadastral nature of data

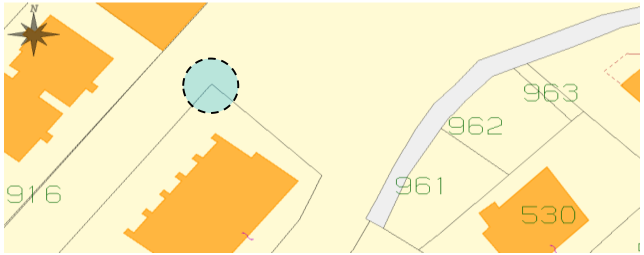
1) Vertices on the map border



2) Vertices having degree > 2



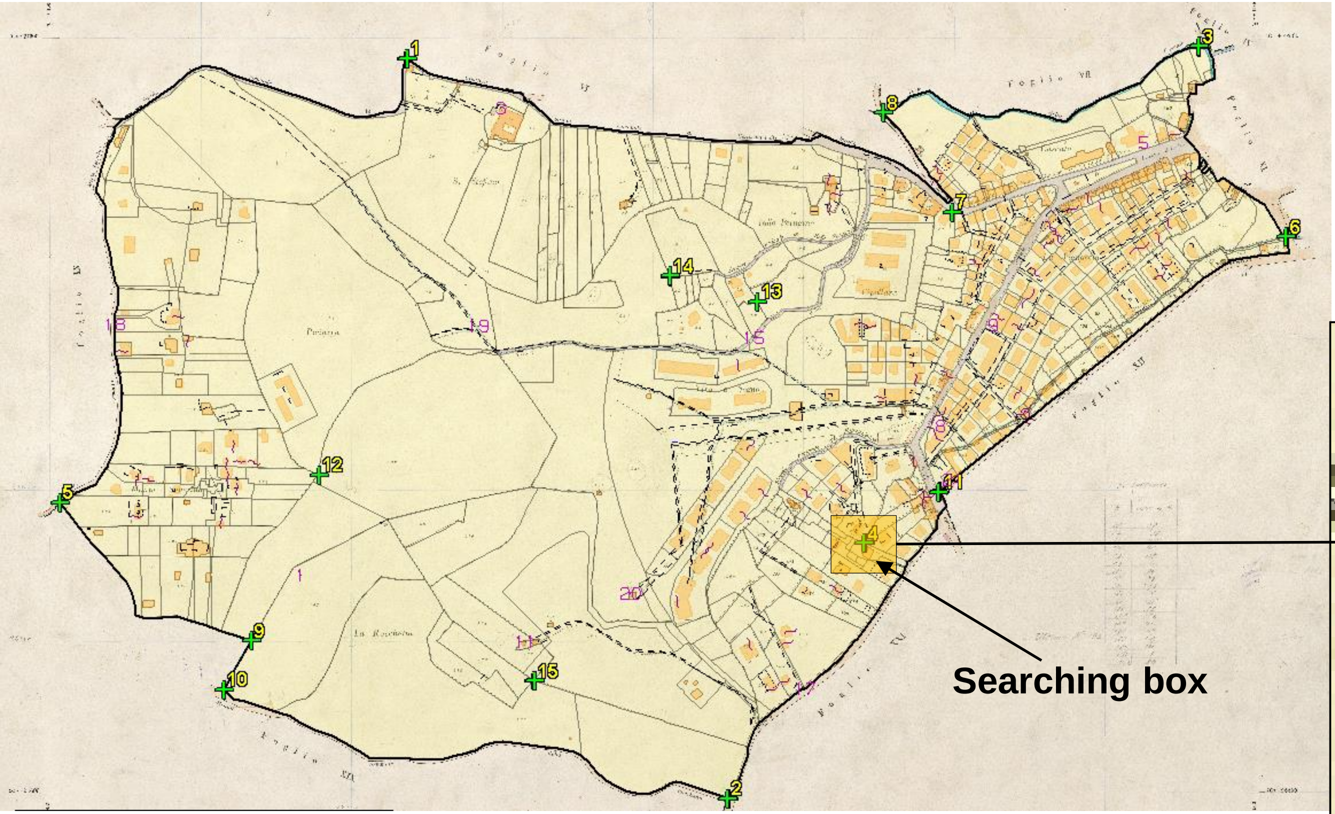
3) Privilege more acuity angle for vertices with degree 2



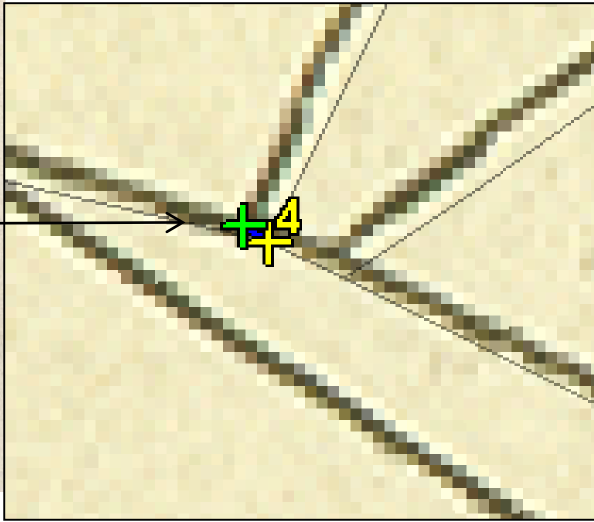
...

Iterative process (1)

First 2 steps by means of a **Linear Least Squares Transformation** based on a restricted set of homologous points



Situation after the linear least squares processing



Iterative process (2)

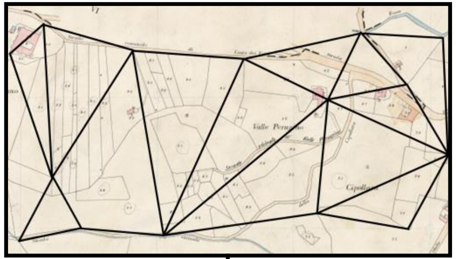
Last 3 steps by means of a **Zero Differences Transformation**

Recognize new Homologous Points

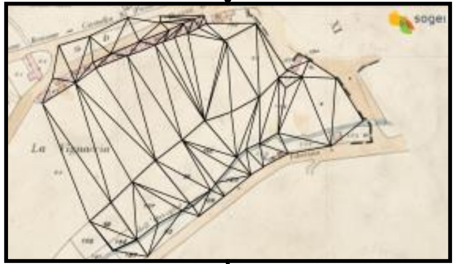
Compute TIN (**SDO_Triangulate**)

For each triangle Compute 0-errors affine coefficients

For each triangle transform the contained vertices

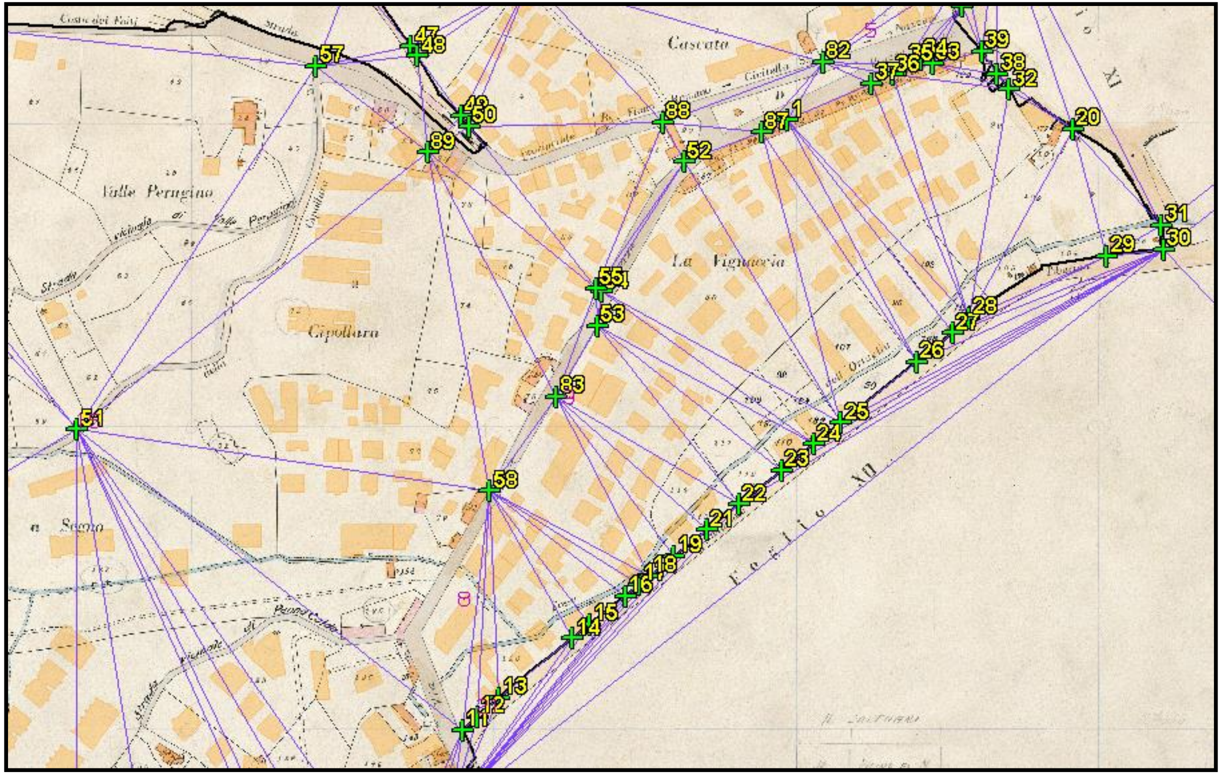


Enrich TIN



ITERATE

Terrain TIN tessellation



sdo_triangulate for all the ‘vectorial’ vertices

of couples of homologous points

Homologous Points Data Quality

Remove **CHP**s (couples of homologous points) with excessive distance

A CHP distance is considered excessive if :

- It differs more than 2 meters from the average distances of the first 6 nearest CHPs

OR

- It exceeds 3*(global standard deviation)

Reliability of the recognizing process

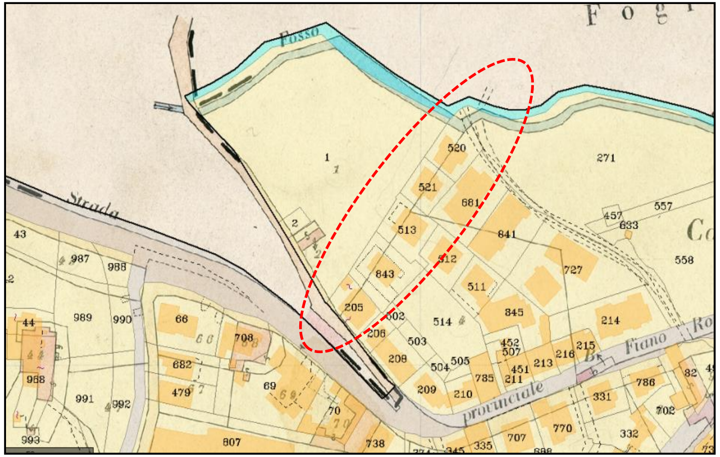
Map name	Vertices (nodes)	CHPs	STD (m.)	Maximum diff. m.
D561_000100	1279	273	0,7	1,9
D561_000200	792	174	0,7	1,5
D561_000300	1499	418	0,7	2,6
D561_000400	3992	766	0,6	1,9
D561_000500	2157	648	0,7	2,1
D561_000600	3490	1060	0,6	2,0
D561_000700	2429	846	0,6	2,5
D561_000800	1662	786	0,7	1,8
D561_000900	2435	606	0,7	2,6
D561_001000	7143	1020	0,7	2,1
D561_001100	1582	850	0,6	1,6
D561_001200	7682	1148	0,6	1,6

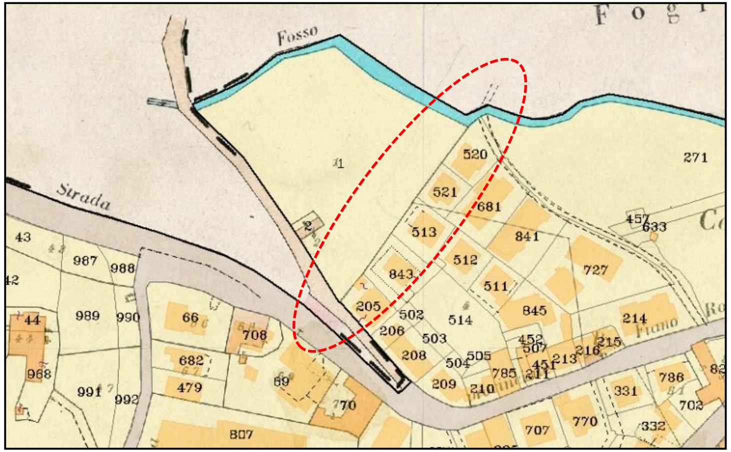
The Standard Deviation relative to the Linear Least Square Transformation applied to all the detected CHPs has the same dimension of the native theorical error of SCMs

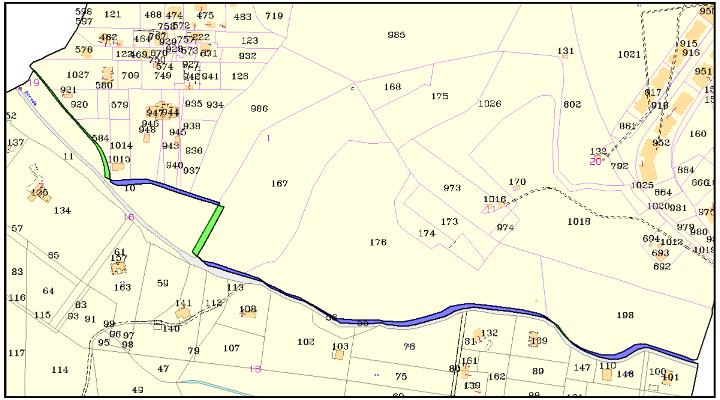
Effectiveness - Global view of identified homologous points

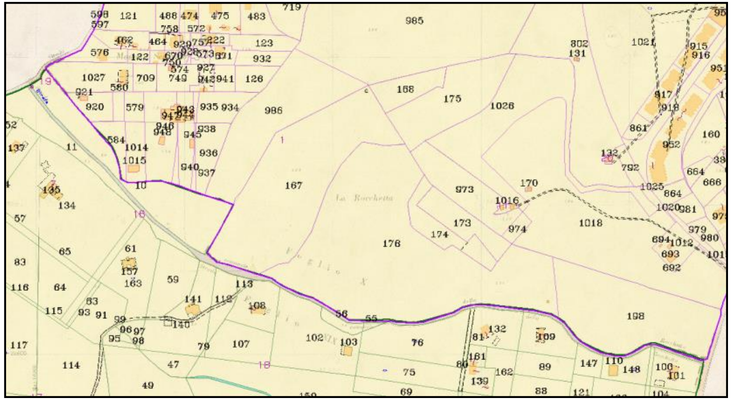
Efficiency - Total processing time of 30 minutes for each map

Before and After

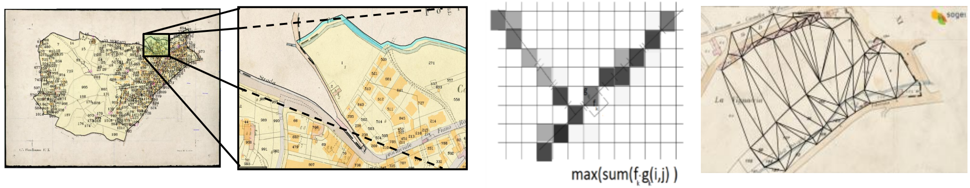








MOSAICA Results



MOSAICA has proved to correctly improve the accuracy of cadastral features and reduce discontinuities between maps.

- Medium error is reduced **from 5 meters to 0.5 m**. by saving:
  - **99.5**% the total cost of a traditional survey
  - **95**% the total cost of a manual process.
- Without induced human error
- Creating the fundamental prerequisite for a topologically consistent cartography

Next steps

The improved accuracy paves the way for other future improvements of cadastral cartography:

- Creation of a continuous territorial representation.
- Conversion to the persistent topology data model.
- Availability as a basic layer of geographic information for other public agencies

Riccardo Del Frate, Manager Cartography Services, Sogei spa
Paolo Giardiello, Manager Cadastral Services, Sogei spa
Giovanni Corcione, Master Principal Sales Consultant, Oracle Italia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