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e- Historical sites. Georeferencing as availability of space-temporal data: Historical cartography towards advanced 3D view

Keywords: e-historical site; 3D-GIS; 3D view; panoramic view; old maps.

Summary
The first results of the research in course are presented here, concerning the specification guide on georeferencing cultural heritage which is part of the *Regione Lombardia* (Lombardy Region) Risk Map related to the advanced concept of georeference through the use of historical maps and historical 3Dviews in GIS approach applied to the specific case of historical sites. The georeferencing, as collection of space-time data related to differentiated levels, and the correlation between 2D / 3D historical and modern cartographies can contribute to improve the knowledge of site history, read on the state of art of the manufacts through the material traces of the transformations occured during the past centuries. It could contribute to guide the contemporary transformation, to support a sustainable development and to organized maintenance policy, in compliance to the policy for an active involvement of civil society in the protection of cultural heritage and for the transparent sharing of geoinformation within public institutions. A collection and organic management of the knowledge acquired represents a fundamental requirement for a proper policy towards an integrated conservation of the cultural heritage as subject of constant alteration; GIS, considered as an open and updated domain, can be used as a support in the processes of planning the protection and development of historical sites. One open question here is whether the GIS notion of "3D Point of View" can be combined with historic "3D View Map" in order to enable the reading and safeguarding the state of the art of complex heritage manufacts system. In other words how the "Topographic Dbases" should be improved in order to support 3D views simulating low to high human vision.

Methodologies of georeferencing cultural heritage and historical sites within risk-maps

For some years there is an increasing interest and research in Italy on the *georeferencing* methodologies for the localization and evaluation of cultural heritage. This research concerns famous Italian historical sites as well as the so called "minor sites", in the frame of the *Risk Map*[1] of Cultural Heritage. An important conservation policy is focused on the historical-documentary-environmental stratified values of a territorial scale aiming at the protection of the artistic heritage and the rediscovery of identity and common cultural roots. This policy is based on the conviction that the building heritage is not only an eco-

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[1] AA.VV., 1987. "La carta del rischio del patrimonio culturale", Ministero BB.CC.AA., Ufficio Centrale per i beni archeologici, artistici e storici – Istituto Centrale per il Restauro, ICR – Bonifica

nomic and social resource, but it could become an opportunity to improve the quality of 'urban living'.

The starting point of this research is the evolution of the "cataloguing concept"[2], which is directed towards the drafting project of Risk Map[3], in regional scale, handled by the Lombardy Region. The first step was the development of the technical specifications for georeferencing Cultural Heritage. This step has generated various considerations and is closely related to parallel research lines on complicated topics such as the maintenance of the cultural heritage and the organized conservation, the individualization of suitable methodologies for analysis and intervention politics, developed on architectonic scales (1:200, 1:50 and detail scales) strictly related to the context scale. Today "a new role for environmental context inside the Risk Map is taking shape, able not only to emphasize the risks, but also to point out the exploitation and development chances that cultural heritage offers, constitutive factor of various territorial identity[4]".

The principal purpose of georeferencing is the creation of geographic visualization of territorial distribution, finalized to build up a Map of Architectural Heritage. The georeferencing, as collection of space-time data developed thanks to the contribution of archeometric disciplines, and the relationship between current cartographies with 2D-3D historical one, can contribute to improve the knowledge of the history of small sites – only apparently anonymous and without connotation of ancient characters - read on the state of art through the material traces of the transformations during centuries, as in the study case here described. It could contribute to guide the contemporary transformation, to support a sustainable development and a programmed maintenance strategies, following the logic of an active participated protection by both, scientific and citizen community. Collecting and management of organic data represents an essential requirement for the policy of integrated conservation of the cultural heritage; GIS, considered as open and updated shape, can become a support to the processes of city planning of ' historical sites'.

A new interesting field of application is the generation of 3D view of the historical site inside GIS built on the Topographic DBase implementable with photogrammetric-laser scanner survey. For the model generation the most important issue is the quality of 3D data. If data are well structured, the developing of 3D visualizer allows the navigation and three-dimensional analysis of the site. Therefore, the research would like to focuse on the definition of the specific requirement of this 3D data.

Within the "guide of georeferencing cultural heritage for map of risk", the research has underlined some creases aspects related to the spread diffusion of data of historical sites to be georeferenced during the generation of flat Geodbase. The research has as aim to join the GIS and historical maps on CTC while, in the meantime, the rising up of a suitable and well defined Archeometric DataBase data collection continues.

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[2] www.iccd.beniculturali.it; www.regionibeniculturali.it/leggi/altro/dwd/cat_bbcc.doc

[3] P. Petraroia, Premessa, in R. Brumana, C. Monti, 2004. La Carta del Rischio del patrimonio culturale in Lombardia. Guida per la georeferenziazione dei beni storico-architettonici. Guerini e Associati, Milano.

[4] CulturAlp project, approved within community Interreg III B program (one of the leader project is Lombardy Region), is finalized to the valorization of historical alpine centers.

e-GIS of the historical sites of Cantù

The purpose of e-GIS of the HISTORICAL SITES of the Cantù area (Fig.1) – that has undergone an economic development from rural one to the famous Italian Furniture Industry Design - was articulated in various phases, under the contract with the municipality office that has begun three years ago: historical centres census data acquisition, DBASE cataloguing campaign, georeferentiation of Cantù historical cadastral maps, historical centres GIS generation with 2D-3D thematic maps.

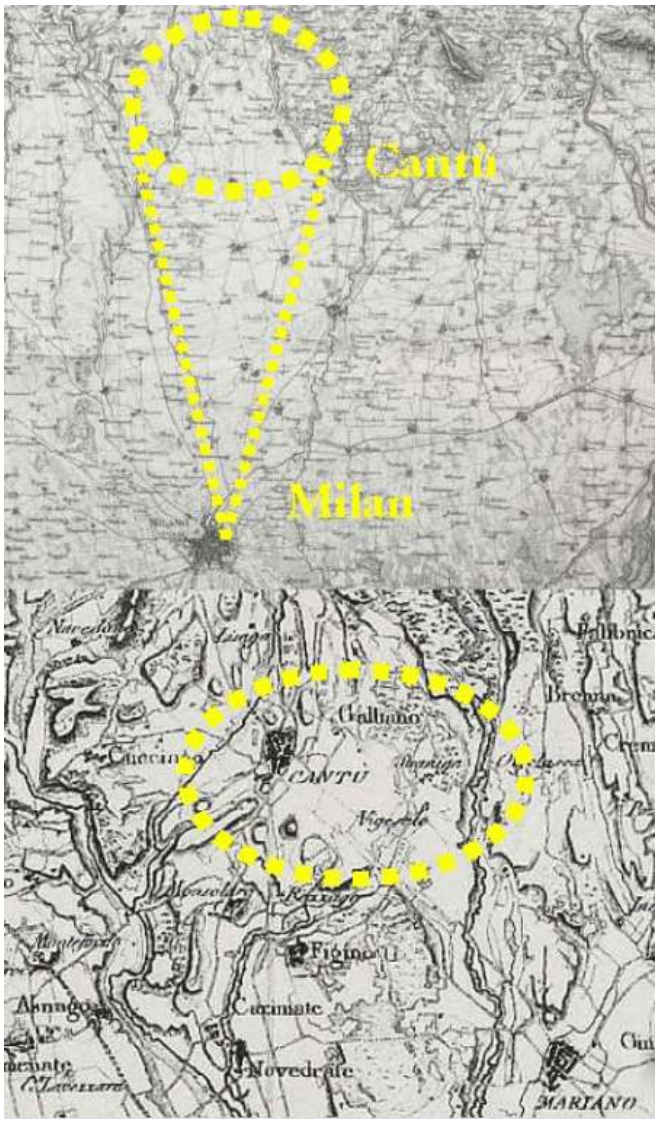

Figure 1. (*"Carta topografica del Milanese e del Mantovano basata sulle misure effettuate dagli astronomi di Brera fra il 1788 e il 1791").* A detail of the Topographic map of Milan and Mantova territory based on the measures made by the astronomer of Brera between 1788 and 1791. In the bottom figure is represented the area of the research, the historical site of Cantù, Galliano, the two decentred little site of Vighizzolo ('Vigesolo') and 'C.na Matta'.

The aim of the research was to set up and to experiment a semi-automatic representation of some façades (extracted from different levels of survey) as a support for the creation of thematic maps to be implemented in WEB-GIS interface developed for the On-Line pub-

lication of GeoDatabase of the historical centres, with various access levels, defined by different users categories: citizens, professionals, P.A.

In order to explain the origin of the historical area, we could begin with a map dated back to 1582 (Fig.2). The event it represents is the preparation of transferring Pieve (head-parish) from Galliano to the Cantù Village, as wished by San Carlo Borromeo: the map shows the village of Cantù, a densely populated centre, encircled by a medieval wall primeter of heptagonal shape, with four Gates oriented at the cardinal points. At the upper Gate there is the road to Galliano: the map is not oriented to the North, but to the East, in order to emphasize both: the existing relationship between two towns and the incongruence of the great developing Pieve di Cantù (Cantù parish) far away from an isolated Pieve di Galliano. The map is not a scaled orthogonal representation, it is a perspective one, but it uses different proportions to represent the village of Cantù (lower side) and the Church of Galliano (upper side), so as to highlight the significance of the mentioned monument.

In 1582 S. Carlo Borromeo has transferred Pieve and the so called 'Collegiata' from Galliano to the Church of S. Pauli in Cantù (ACAM, Sez. X. Cantù, vol XI q.3)[5].

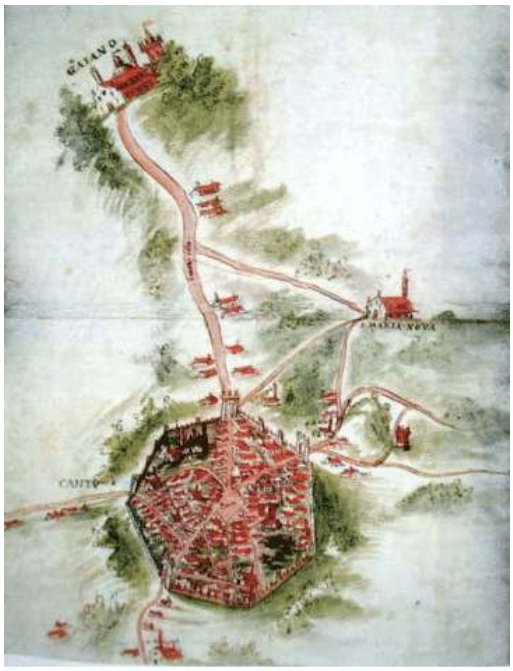

Figure 2. An ancient map representing the 'Design of the Pieve of Cantù (1579 – 1582), in the 'Collection of topographic map and design', inside Section X, Pastoral Visit, Pieve of Cantù. Pink colour (street), red (roof), brown (shaded fronts of the Churches, walls, tower, and some houses), green (gardens intra moenia, country). '*Disegno della Pieve di Cantù* (1579 - 1582) in ACAM, *Raccolta carte topografiche e disegni. Già in Sezione X, Visite Pastorali, Pieve di Cantù, vol.XXI. cm 55,5 x 48,8.*

[5] The reason of this important change is well described in this document inside the 'Pastoral Visit' of San Carlo Borromeo around all the territory outside Milan (the actual Lombardy Region). The Church of Galliano were sited "… *in loco campestri omni penitus hominum et aedificiorum frequentia destituto*", for this motive from some year *"praepositi et aliquorum ex canonicis residential per modum provisionis fit in ecclesia parochiali Sancti Pauli Burgi Canturii distanti per medium milliare vel circa et satis, et populi et aedificiorum frequentia insigni, et ubi etiam adsunt portiones parrocchiales ecclesiae seu portiones curatae, … monasteria duo scilicet monialium et plures scolarium confraternitates, pluraque oratoria et ubi residet magistratus episcopalism …" (ACAM, Sez.X, Cantù, vol.XI q.3).*

Galliano is an ancient village that is originaly dates back to the celtic age (the toponomastic name of '*Galliano*' is easily related to the 'Galliums', the tribe of 'Brecori' that came from the west region and founded their villages in this site establishing cult sites in honour of the celtic woman divinities of the '*Matronis Braecorum Gallianatium*'. Later on, Galliano becomes a parish (Pieve di Galliano) with the most number of Christian inscription from sec.V (466 A.D.) to the Longobard age. The Basilica of Galliano and the Battistero date back to the X cen. Il Colleggio dei canonici di Galliano (The College of canoncal priests) counted 20 members, between XI and XII cen.
Cantù, represented in the lower side of the ancient map, existed in the X cen., in 1124, during the battles between Milan and Comum Oppidum, it was mentioned with the qualified title of ' cittadella murata' (walled village). During the XIII century it becomes one of the greatest centres of the 'Contado della Martesana'. The town of Cantù is here reproduced (Fig.2) in a geometrical shape with a characteristic wall conformation with seven edges and it is not an imaginary view, as explained after observing the Cadastral Map of Maria Teresa of XVIII cen., called of Carlo VI. It is also possible to notice the radial distribution of the roads that meet in the centar of the town (Fig. 2,11-13). The North West sector it dominated by the 'collegiate church' of S. Pauli, the future head-parish church, close to the towered castle. Around the wall perimeter there are also some of the conventual churches together with the bell tower of S. Pauli, that even nowadays characterizes the profile skyline of the centre. Even tough the points of views are more than one, the representing technique could be defined as a perspective.

Relating the ancient map to the geo-dbase. Rectyfing and gereferencing the ancient cadastral maps

The first step has been represented by the digital acquisition of all the original sheets of Cadastral historic map of Cantù, by a semi-metric digital camera Rollei DB44 (40mm focal lens). There have been acquired some photogrammetric shots of the ancient cadastral maps conserved at the Historical Archive of Como (ASC). Since the digital acquisition by photographic camera introduces perspective transformation of the map, the re - transformation back to the original metric status (the orthogonal projection of these cadastral maps in a local system) requires the process of homographic transformation, or in other words the rectification of the digital image acquired. A dime has been used in order to obtain at least four points in each local map system, necessary to solve the parameter of the transformation, calibrated with an accuracy congruent to the local tolerance of each sheets represented at the scale 1:2000. A glass slab was recorded with four points at the four vertices of the rectangle circumscribing the dimension of the ancient maps. The position of the four points was determined interpolating all the linear direct measures acquired between each couple of point in the two vectorial direction obtaining the accuracy of the results by least squares method (in total 12 measures). On a digital image, the dime profile was acquired together with the maps. The results of the 2D coordinates position of each point at the corner of the sheets has been used to rectify each image to the orthogonal projection. Using a photogrammetric orthophoto projection sw (PCI Geomatic), introducing the Internal Orientation parameters and distortions of calibrated focal lens of the

camera, the orthogonal projection by rectifying images on a local plan (Fig.3) has been obtained.

Figure 3. Each map has been acquired by photogrammetric taken (Rollei Db44) to be rectified. In the upper left there is the map superimposed to the calibrated dime, a glass carved by lines, with four corners GCP, which coordinates and sqm are obtained by linear direct redundant measures of distances. In the right side a detail of the target. In the lower side is evidenced the rotation of each shot, once acquired, respect to the virtual horizontal map axe. Once rectified, the images are georeferenced to the technical map through 8-10 homologous point in the two systems (ancient and actual map) as explained. Cadastre of Carlo VI, Sheets n. 19, (1722).

Figure 4. A georeferenced historical map with rectifying pre-process (left and centred-detail) and without (right).

Even if surveyed without a geodetic network reference datum[6], as it is known, the Historic Cadastral Maps of 1722 are local metric projections. For this reason, once the original geometric status in the digital support is obtained, a global affine transformation was applied to each sheets so as to gain a local georeferentiation of each map.
All the maps were georeferenced to the Technical Digital Cartography of the Municipality of the City of Cantù (CTC 1:2000) by selecting about 10 homologous points in the CTC and in the Maps. The criteria of selection is guided under the hypothesis of identifying the points belonging to the plan-shape conservation of the manufacts during the last three centuries: for this reason is not enough to recognize the shape on the actual map and on

[6] Selvini A., Monti C., 1994. *Il catasto nella storia*, in S. Mattia, R. Bianchi a cura di, Forma e struttura di catasti antichi, Clup, Milano.

the ancient trace of it, but this geographic pre-existence was interrelated with the DBASE acquired[7] for each Building and georeferred to each polygonal parcel (as described in Figs. 6,8-10) with the reading of the material traces of ancient structures during the century: the Dbase created is obtained using cataloguing methodology for buildings analysis on urban scale that regards the principal constructive technologies, the materials, the state of the art, the instability and deterioration conditions. The aim was to set up a modality of data usage able to promote patrimony valorisation politics, following the logic of programmed maintenance and compatible uses.
It is necessary to read the state of the art of the manufacts, the state of conservation and transformation level of both, structures and finishing (Figs. 5,6 and 8,10, and the legend in Fig.9). In this way it is possible to discard the manufacts that maintained only the shape because totally destroyed and reconstructed in the centuries. At the and of the process managed by using ArcGIS, for every file there has been generated its own standard world file (tfw) in order to share the ancient maps on Web GIS of the historical site of Cantù.
This methodology has been applied to support the analysis of the centre of Cantù, and of the historical sites outside, Vighizzolo and C.na Matta.
In particular, there has been done a georeferentiation of these cadastral maps series:

- Catasto Teresiano (1722)[8];
- Updated maps (1856, 1874, 1898).

Cross reading the historical cadastral maps to support transformation analysis

Here starts the description of the example of a GIS built in order to support the safeguard and the valorisation policies of small 'anonymous' centres, widely distributed in the Italian territorial reality.
A thematic map of the transformation and evolution of the site is obtained through the cross checked reading of technical map 1:2000, of the georeferenced cadastral maps of different temporal series (1722 – 1856 – 1874 – 1898), strictly related by the GIS with the surveyed data collected 'on site' and structured in a rich Dbase. The map of the transformation is related to the degree of transformation of all the manufacts: original characters, transformation-conservation of the structures and of the finishings, serial details such as arcs of access, windows typologies during the centuries, degree of demolition and reconstruction of the manufacts.
The 2dPOLYonal GIS structure of the ancient block considered above is built on the Technical Map (Fig. 5, on the right). An ID code number of any architectural body manufacts is related to the corresponding records in the Dbase acquired about the state of conservation, the material reading made on the constructive technologies, on the stratified

[7] Brumana R., Achille C., Oreni D., *Studio e raccolta di dati finalizzati all'analisi dei Centri Storici di Vighizzolo, Cascina Amata e dei nuclei di interesse storico ambientale esterni all'abitato di Cantù (CO)*, in Rivista dell'Agenzia del Territorio, n. 3, Roma 2004.

[8] Cfr. T. Casartelli, *Cantù e il suo territorio dal 1721 al 1950: storia di un paesaggio rurale*, Cantù 1999. "…The Maria Teresa cadastre instituted by Carlo VI in 1718, became effective only the first January of 1760 , during the reign of Maria Teresa of Austria after the interruption of the succession wars in which the Lombardy Region was involved indirectly. The cadastral survey of the Cantù Pieve took place between October 1721 and February 1722, under direction of Geometra Federico Shulz…".

texture, on its elements and finishings. It has been evidenced a diffused court system, typical of the rural characteristic nature of those centres, at the border of Milan (Fig.6).

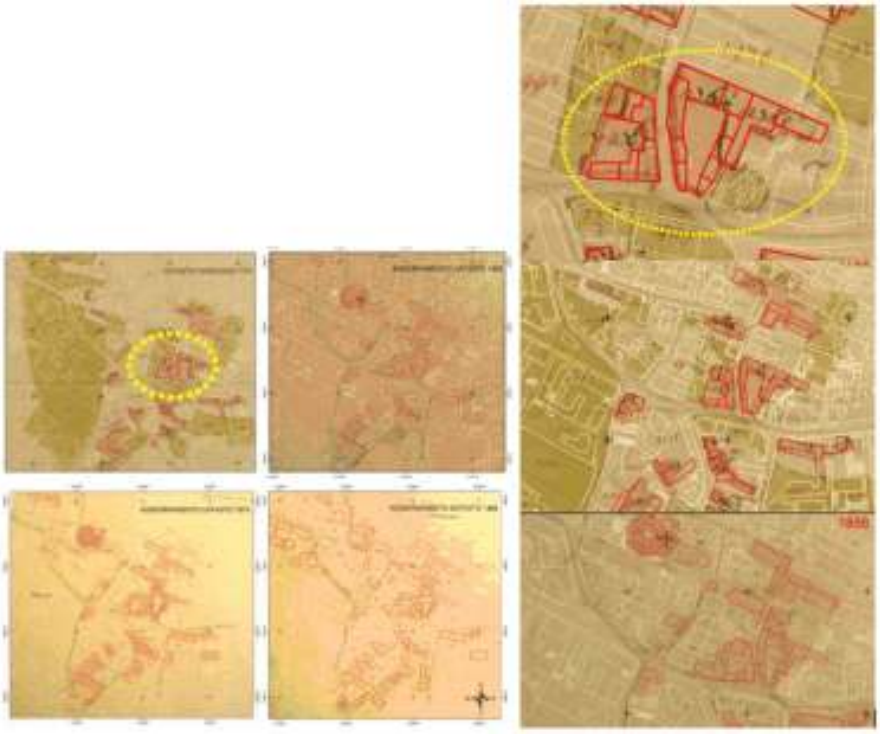

Figure 5. Left: The sequences of each sheet of the four historical cadastral map series, rectified and georeferenced (Vighizzolo site). Temporal series (1722, 1856, 1874, 1898). Right: The transversal transformation of an ancient block read on the Technical map, in white colour are the building not interested by pre-existences and transformations. In the upper window the current map is compared with the 1722Cadastre, at the bottom one, with that of the 1856 Cadastre. There can be read the transformation and enlargement of the bodies of each block.

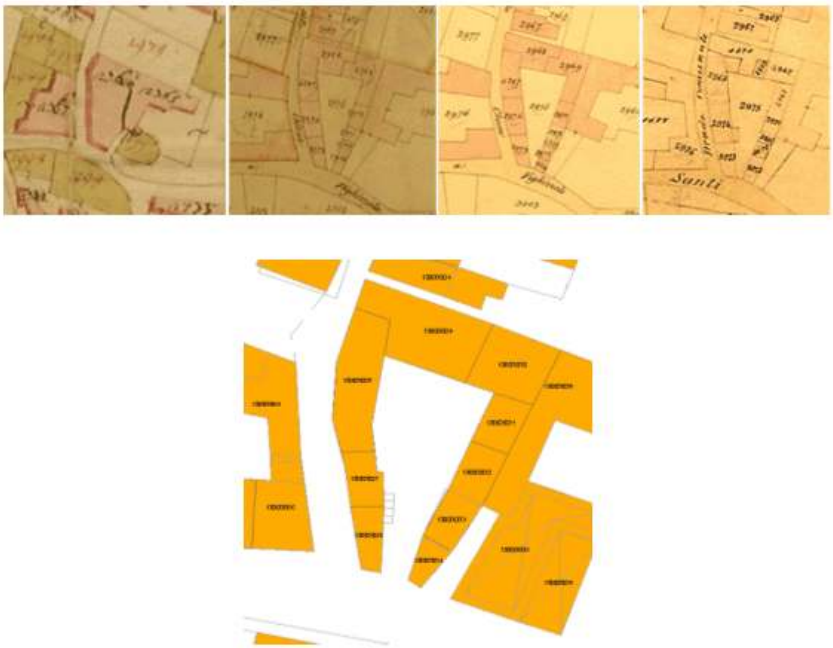

Figure 5. Up: The cadastral map transversal sequence in a block case: (1722, and the updating ones 1856, 1874, 1898) Down: The GIS structure on the current map.

Figure 6. The small site of 'Vigesolo'. In the left side, an example of the GIS built in order to support the safeguard and valorisation in case of anonymous little centres. The thematic map of the transformation and evolution is obtained through the cross checked reading of technical map 1:2000 with the georeferenced cadastral ancient map, related to the thematic DBASE, surveyed building by building. Right: The Court system. A sample of the synthesis GIS table layout (sw ArcGIS) extracted in the case of the ancient block considered above. The table represents the analysis and the comparison between the state of art and the historical evolution of one of the internal system of the 'court', evidenced all over the urban centres considered. The planimetric distribution is now recognizable on the different historical range period, but also recognizable on the elevation structures of the different main parts of the building developed during centuries around the court system, typical of the rural characteristic nature of those centres, at the border of Milan.

An improvement to GIS analysis: from georeferentiation of metric map to the advanced use of non metric historical map inside 3d gis system. The case of the centre of Cantù

The GIS of the Area of Cantù centre has been built, as explained above, on each historical building extracted from the cadastral pre-existence analysis and related to the Dbase acquired. Each construction is encoded in the GIS by an ID number so as to relate the polygon of its perimeter to the correspondent Dbase record with the information about the conservation, the state of art of the structure, the constructive technologies and stratigraphic reading made in the cataloguing campaign. The result obtained in a thematic map is well represented by a *shape of a bean*, with irregular shape perimeter. The problem is how to improve this knowledge, relating other non metric data such as non metric historical maps.

Figure 7. The case of the Historical Centre of Cantù. In the upper thematic map is evidenced the first result of the extraction of the historical building, by the relation between cadastral analysis of each building and the Dbase, on the Technical Map 1:2000. *(left side)* The shape of the historical site, obtained putting together each pre-existence buildings, is that of a *bean* as it can be recognized on the teresian cadastral map of 1722

The thematic map of historic evolution and transformation levels: a bean shape of the historical centre read on the historic cadastral pre-existence map

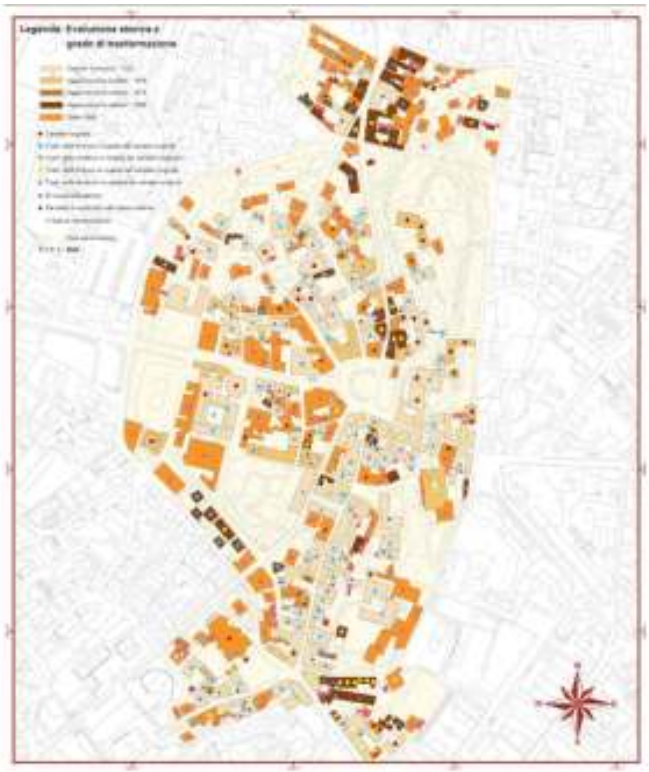

Figure 8. The GIS of the historical centre of Cantù: the historical evolution of the centre during centuries is analyzed beginning from the historic cadastral maps. The simultaneous reading of CTC scale 1:2000, of geo-referenced cadastral maps (1722-1856-1874-1898) and of Dbase surveyed on site was interrelated with transformation level of the buildings (see Figures 9-10).

Figure 9. The legend schedule of the GIS thematic table relative to the previous figure and to the detail in the following Fig.10. The **polygonal empty hatch colour** is referred to the period threshold value of the different pre-existence in each cadastral map series of each building. The **coloured punctual symbols** indicate the different level of conservation and transformation obtained from the punctual reading of the survey campaign in each building recorded inside the Dbase and co-related to the historical cadastral series (beginning from 1722 till to the other maps): demolition during the different centuries analyzed, with reconstruction on the same historical settlement on the ancient shape of the historical map (black triangle); new edification (magenta triangle); structures transformation without respect of the different original characters (blue triangle); finishing transformation without respect of the different original characters (yellow square); structures transformation with respect of the different original characters (green square); finishing transformation with respect of the different original characters (blue circle); original characters permanence (red circle).

Figure 10. The historical centre **evolution and transformation degree** of Cantù. The simultaneous reading of CTC scale 1:2000, of georeferenced cadastral maps (1722-1856-1874-1898), and of data taken on place, was interrelated with transformation level of the buildings as described in the legend at the upper Fig. 9. The **polygonal empty hatch colour** is referred to the period threshold value of the different pre-existence in each cadastral map series of each building. The **coloured punctual symbols** indicate the different level of conservation and transformation obtained from the punctual reading of the survey campaign in each building recorded inside the Dbase and co-related to the historical cadastral series (beginning from 1722 till to the other maps): demolition during the different centuries analyzed, with reconstruction on the same historical settlement on the ancient shape of the historical map (black triangle); new edification (magenta triangle); structures transformation without respect of the different original characters (blue triangle); finishing transformation without respect of the different original characters (yellow square); structures transformation with respect of the different original characters (green square); finishing transformation with respect of the different original characters (blue circle); original characters permanence (red circle).

Now, if we compare the upper thematic map with the following historical map, we can see an evident different shape contour line of the profile of the historical centre on the two maps. As shown on the upper Figure 8, the town has an irregular bean profile shape instead; the following map shows a regular polygonal heptagonal shape with seven edges and corners evidenced by the representation (Fig.11, a detail of the map in Fig.2).
This map is neither planimetric nor metric representation, but a perspective mixed to fantasy and to symbolic elements. This kind of representation is recognized to be difficult to use in a georeferenced system. But a careful reading of an apparent non realistic map can change the point of considering this map. The problem becomes: how to employ this kind of information inside GIS system? The importance of the approach to this problem finds its feedback on the map here considered and on all the maps conserved in the Diocesan Church Archive, representing the places visited by S. Carlo Borromeo during all his pastoral visits around the territory.

The heptagonal shape of the historical centre on the XVI map feedback to the XVIII one

Figure 11. A detail of the ancient map in Fig.2, representing the 'Design of the Pieve of Cantù' (1579 – 1582), painted during the occasion of the pastoral visit of the Bishop S. Carlo Borromeo. The ancient distribution of the road system and of the external connection through the Gates related by the heptagonal wall is clearly evident.

Figure 12. Historical Centre of Cantù: georeferentiation of *Disegno della Pieve di Cantù* (1579 - 1582) on CTC scale 1:2000. It was utilized Georeferencing module of ArcMap by using at least 15 common homologous points applying an affine global transformation, in order to not modify the internal local geometric shape of each particular but only to best fit the ancient map to the actual map. The result of the global correlation-georeferentiation of the ancient perspective map is represented on the right side. In yellow line the vectorial technical map is obviously less readable since the two different typologies of representation, represented separately in the bottom images (Fig.13)

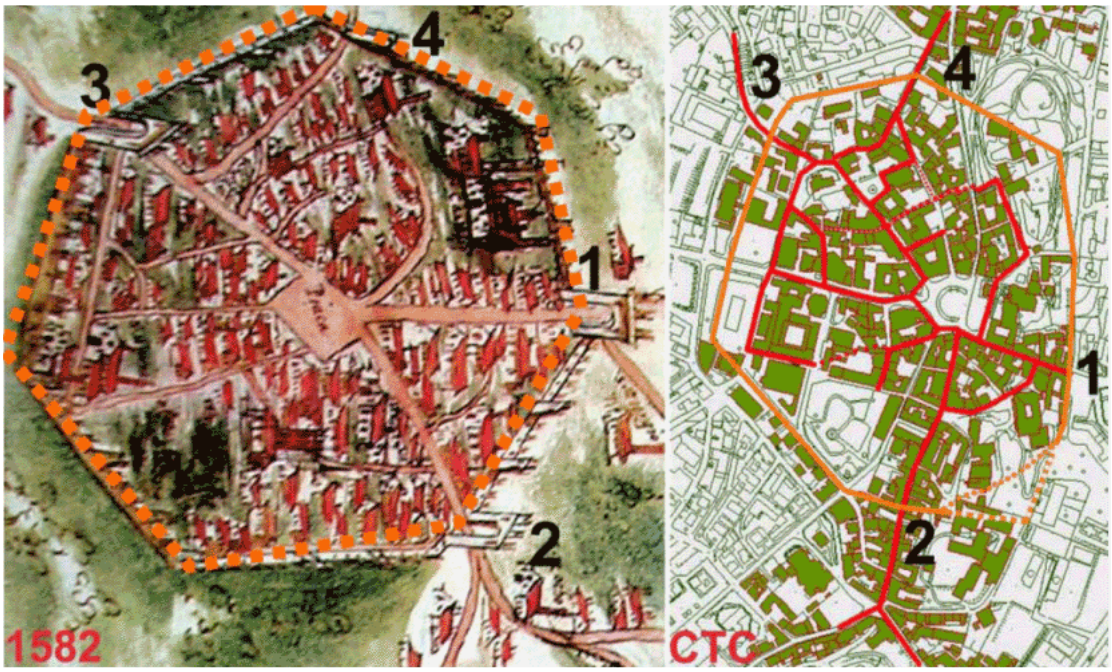

Figure 13. The result of the global correlation-georeferentiation of the ancient perspective map on the left. On the right side, in the CTC Geographic shape of the roads, are highlighted the ancient courses now recognizable with red colour, and the route of destroyed boundary wall with orange colour. The four corner characterized by the presence of the Gates of connection to the outside territory are coded with progressive number, relating them in the both maps georeferenced one to the other, here represented separately

Figure 14. Historical centre of Cantù: *the ancient courses and staircases systems*.

The ancient paths and staircases systems already existing in *'Disegno della Pieve di Cantù'* (1579-1582) were found out in the actual map and georeferenced through the cadastral map of 1722 and the actual images acquired inside the Dbase. It is possible to recognize an extraordinary correlation and similarity between most of the ancient shape of the paths and staircases around the central place of S. Pauli Church in the two ancient maps, as it is the case of particular A block, B block, and the others, evidenced by dotted yellow lines.

'Flat 3D model' towards advanced 3D model developed from 3D historical view map

The starting point was a 3D model built opon a transformed thematic map described in the previous paragraphs (Figs. 15-16). The attribute 'flat' is not a paradox if we think about the real potential of information which could be implemented comparing to the plan representation. This 3D basic-model can contribute to some essential analysis, but it is not enough respect to the opportunities that exit. It offers very few possibilities considering the potential it could develop if better directed to support policies of safeguarding, sustainable transformation and re-use of historical sites: one of the future bets in order to support well such complex policies, is to pass beyond the '*flat 3D model*" *towards 'advanced 3D model'* developed from the example of 3D historical view map that would become directly involved in the knowledge process and in the conservation process itself.

Figure 15. The 3D city model built on each building with different level of pre-existence in the case of Cantù centre: the thematic map with the different level of maintenance and transformation of buildings becomes a '*flat 3d GIS*'

Different researche lines are in course, at international and national level, regarding the government of the environment in a more extensive meaning (disaster prevention, risk analysis, VIA, urban policies, simulation, ecosystem analysis of complex problem). They are also getting more and more involved in the generation of advanced standard 3D GEOdatabase, as a sign of the recognized role assigned to the three-dimensional GEO information.

Within information system, the development of modern technologies, based on GML3-SVG standards for 3D geographic database and web publication, is directed to guarantee interoperability between data, subjects and exchangeable systems, free access and remote sharing between different platforms and geodatabase distributed *on line*. Particularly interesting are the different actions promoted beginning from the international and national legislative reference points, such as: the ISO TC/211 normative for the standardization criteria, the documents about the use of XML/GML and the Open GIS Consortium (OGC), at international level; among those, in Italy, there are detailed lists of such contents of the Technical Committee of "Intesa Stato-Regioni"[9] for the contents of the Geo-Database (Topographic Database Technical and Content specifications, 2004).

[9] "Intesa GIS" is an Agreement State-Region-Local Site for the realization of Geographical Information System, approved by State Region conferences. Topographic Database Technical and Content (DGR 18964 08 October 2004 and modifications with *errata corrige* 3 April 2006).

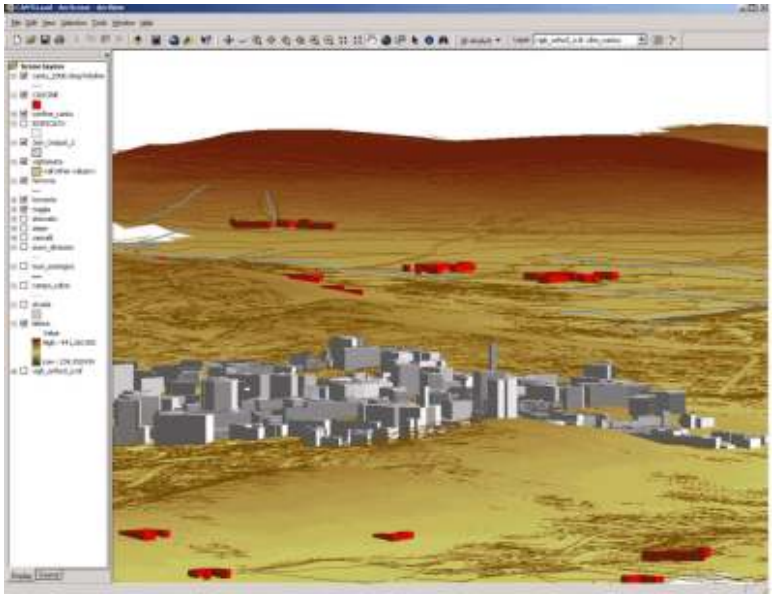

Figure 16. The 3D model built on the technical cartography 1:2000.

At the end, action Policies inside the Regional Law to support the Government of Environment (Lombardy Region case, L.r. n. 12/2005) are finalized in order to create the Topographic Database for the Integrated Information System of Lombardy Region held up even through financial measures to support it. Inside this outline, one of the research goal is focused on the 3D structuring cartography in GML3 to support an interoperable generation, distribution and sharing on network of GeoDataBase for GIS and WEB10. The work was articulated, in a first phase of methodological analysis, in order to characterize the existing standard that can be used to improve the quality of the requirement of 3D cartographic structure.

Homogenous cartographic data have therefore been predisposed and their quality about the previous standard has been verified; the follow aspects were mainly analyzed:

- definition of geometric-semantic congruence-coherence
- definition of the 3D advanced information data.

Subsequently, from this technical specifics, the translation in formal contents will be investigated using an interchange software (ESRI, open source and other), to support some guide lines implementations in order to generate a GIS3D structured in GML3. The research is focused on conceptual models such as spatial and logic relationship, typologies of geometric object, ties and relations between the objects which allow defining a geometric structure based on topological proprieties.

Advanced e-3DGIS structures for 3D models-distributed via web

Two orders of problems will be approached. On one hand side, optimizing of e-3D cartography that will enable us to overcome a complex structure in order to generate 3D

[10] Co-financed research developed inside Prin04 "Advanced structures of the numeric cartography for GIS and WEB" (coordinator R. Galetto), Unity B-Polytechnic of Milan "Web GIS: WEB GIS: GeoDBase sharing and System Interoperability to support service distribution at the urban scale" (R. Brumana)

models with GIS technology to support environmental-DTM for involved analyses and the complex urban structure-building. On the other, development of 3D WEB applications not well investigated until now, such as the 3D generation *e-requests* of panoramic views. A 3D representation of reality, inserting some parameters by request (i.e. positioning the perspective) will become an objective of the research. It will be necessary to proceed to identify a supporting architecture for publishing the 3D cartography (raster-vector), the related archives (height of building, height of the land, soft/hard breakline,..) and management of the plan-volumetric urban context Results will be an important support for the VIA, towards inserting rehabilitation-restructuring projects into the surroundings, for the simulation and contextualisation of new priority action.
In general, the ability to share and distribute a series of data in the form of 3D-databases moves in the direction of offering a better chance of programming and orientation of the advanced level choices to *e-users-not expert in GIS*.
The research unit will also study the possibilities of on-line 3D viewing and identification of operating methods, to allow the downloading of preferential views, pre-selected panoramic cones of urban, landscape and environmental contexts (Fig.17). It is essential that these views are managed with entire series of correlated data inserted in the on-line GIS (i.e. PRG for volumetric zone analyses, archeometric Dbase, ...) and the facilitate integration of those information with other geographic layers handled locally by the *e-users.*

From flat 3D model zoomed inside in, to advanced 3D views

The query is how to develop and support an easy and sustainable process to build advanced views, such us:
- Panoramic 3D View
- Front View 2D extraction
- Perspective landscape cones.

These model allows to relate ancient and current maps using 3D model, beginning from the reconstruction of the ancient point of view (Figs. 17,18,19) with obvious opportunities.
A 3D model with lot of critical points is obtained automatically starting from traditional altimetric information of the technical cartography (Fig. 19).
We have called it ‘flat’ to make an evidence on various lacks that it has (Figs. 20-27) considering the purpose it was generated for - the support of different project level: analysis, contextualization, safeguarding policies, maintenance, simulation process, Environmental Valuation Impact, and so on.

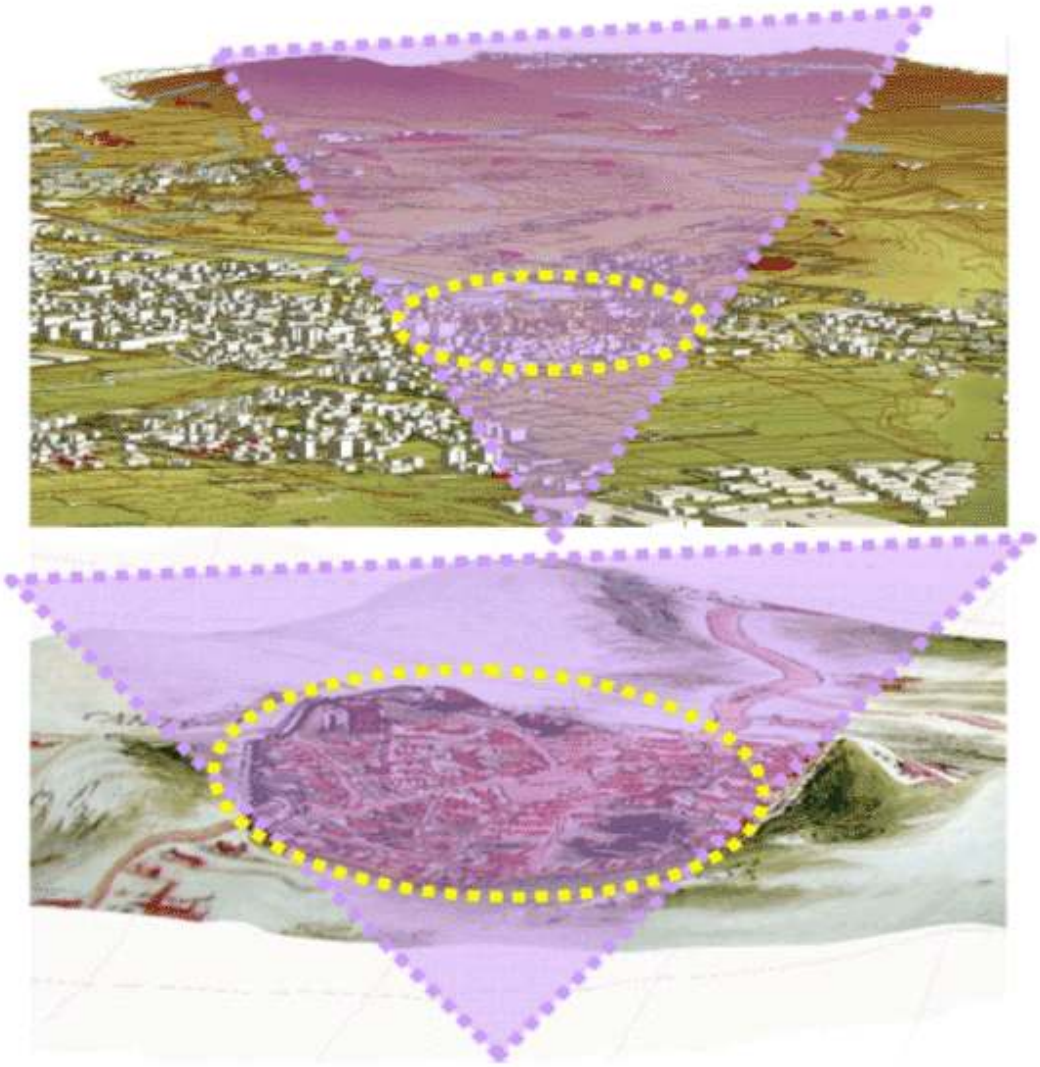

Figure 17. The skyline reconstructed inside the 3D GIS MAP (upper side) beginning from the ancient point of view (bottom side) of the perspective map represented on the 3D terrain model to emphasize the ancient point of view.

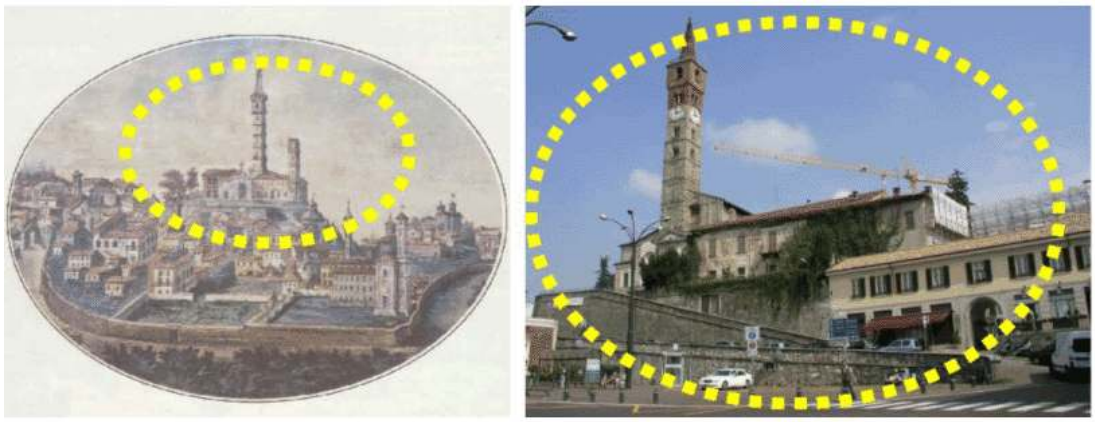

Figure 18. An ancient 3D view of the historical walled site of Cantù pictured from west (about XVIII). View of the Basilica of S. Pauli, built at the end of XI cen., which became in 1584 the 'Head church of the Cantù Pieve'.

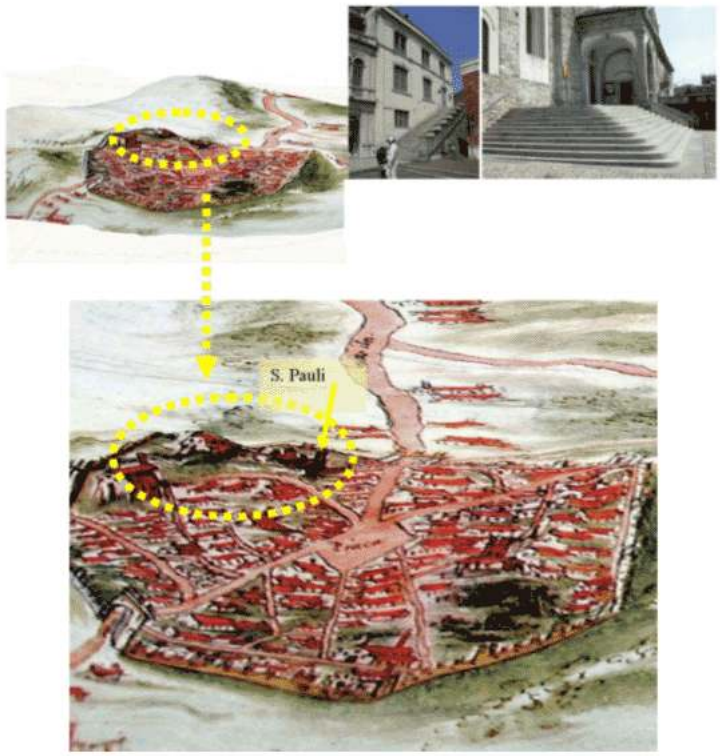

Figure 19. Relating and comparing the ancient view in Fig.18 with the actual one (upper right side and details) acquired from the ancient point of view of the Borromeo XVI map (left side and detail at the bottom page), it is well recognizable the permanence of the same preferential panoramic point of view from west to east

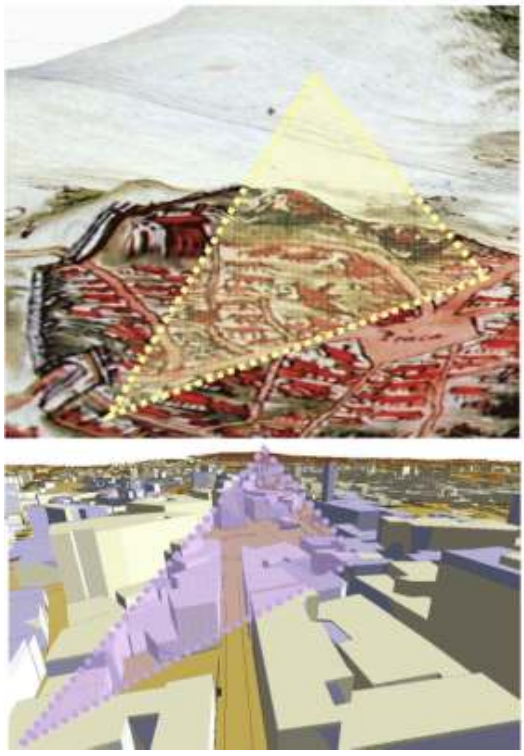

Figure 19. The skyline reconstructed inside the 3D GIS MAP from the ancient point of view of the ancient perspective (upper side) of the Design of the Pieve di Cantù. The model return back '*fla*t' for less information, if zoomed inside the city model from a low point of observation

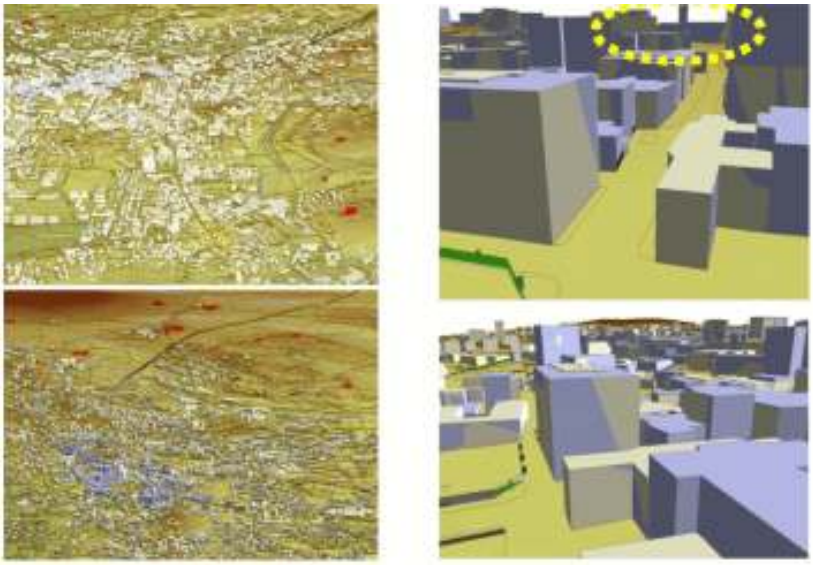

Figure 20. Different points of view reconstructed beginning from the ancient map point of view in order to support the safeguarding of panorama cones, landscape views of ancient cultural heritage aggregation manufacts in the historical sites: they need to improve information respect to this base level

Conclusions: Towards 3D-structured cartographic system as a support 3D view analysis relating paste to the future

Comparing an ancient view (i.e. the one in Fig.19) with the actual one (Fig.20 detail on the upper right side) extracted as a 3D model from the similar point of view, it is possible to filter some of the most recurrent problems of information lack which caused 3d simplified model.

The international research of the advanced structures of 3d cartography specification aims to cover those geographic deficiencies as most automatically as possible, at different scales and fields of applications, with the minimum effort of survey and economic costs requirement, through the *integrated aid* of:

- Minimal Integration of data survey
- Singling out Semantic Feature Classes
- Identifying correspondent Geographic Entities
- Logical-topological relations
- Improving 3D automatic-semiautomatic procedures of building 3d objects.

Here are some simplified problems of 3D geographic information deficiency, in this case inside the Technical Cartography 1:2000[11], in order to support an advanced model extracted from the selected historical perspective view, positioned from bottom up, instead of the classical '*bird flight view'*. The problems are also related to different symbols to be represented on the different images and maps (Fig.24).

[11] The Technical Numeric Cartography of the Municipality of Cantù has been built about 1995: it is a 2D cartography with few 3D information, Polygon auto-consistency, and 3D entities. But in the complex ancient urban structures such as the historical site, the problem of lacking altimetric points in order to generate 3DView from lower point and Front view find out again the analogue problem of 3D entity description

Geographic information lack to support 3DGIS data management

Semantic Feature Classes → Geographic Entities through topological relation

(triangle) – Lack of Ground Altimetric Point

Perhaps at the intersection of different sloping plan directions, like in this case the complex system of the path staircases branched off from the central place. The *ground points* are totally absent in order to define the 3D elements necessary to built a 3D view with lot of unevenness, as it is the case of the different level of the S. Paul Churchm the Place and the other ancient pre-existence block (Fig. 22). In this case points have been surveyed by Geodetic GPS Leica 1200 in order to build the flight steps beginning with the altimetric position of starting and ending point of each one, on which 3D model is to be developed later.

(Figs.23-24).

(arrow dot line) - - > *wall containment*

The yellow arrow dot line indicates the *wall containment (such as the scarp wall or the escarpment*), in this case wall *of staircases* erroneously represented (Fig.21 upper side, 24) due to the previous lack of altimetric data and of geographic entities. Once obtained the altimetric different levels, they have to be managed inside 3dGIS development in order to be represened it in a shaped elevation model (triangular, trapeze…) in a semi-automatic way. An easy automatic lisp procedure has been created to generate a *3D Poly* from which a *3D Polygon* can be obtained beginning with the two upper points of the wall-head (starting and ending points) and with the ground points (horizontal projection in case of single point, sloping intersection in case of double points or of DTM enable).

(Figure 21, the two images at the bottom side)

(square dot line) - - > *sloping road surface*

(the case of ancient staircases)

3D GIS road management from the border upper line of the staircases, or previous slope road, through 3dpoly, and than transforming them in 3DPolyg with discontinuity lines *(Figures 25-27).*

(circle dot line) - - > *front view building*

(the case of mapping 3D urban view)

3D GIS management of orthophoto, rectified images, or simple digital image acquired and mapped of the 3dmodel has been implemented inside ArcGIS (orthoimages generated by Laser Scanner clouds using photogrammetric sw can also be used) *(Figures 24, 27-28)*

(trapezoid) - - > *sloping surface - - > 3D pitch*

GIS modelling building of historical site pitch

The 3D GIS management of semi-automatic 3D pitch is obtained beginning from the border line of the roof sloping and from the heaves line *(Figures 27-28).*

Here are presented some results of fronts, roofs and wall containments integration obtained in different study cases. The next step will be the 3D-congruence validation of topological adjacency in a 3Dspace of the staircases along the fronts and wall containments.

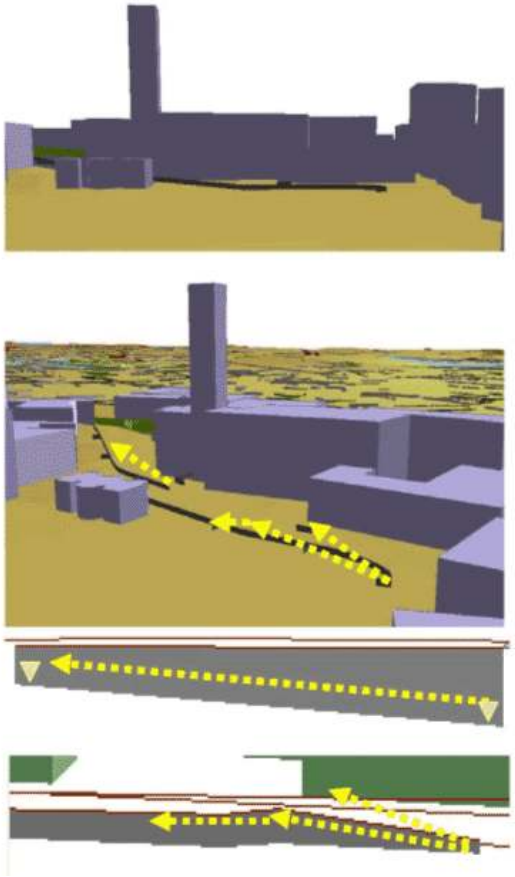

Figure 21. Wo*rks ahead...* → - - > > First result of the automatic *lisp procedure* to generate inside GIS sw ArcGIS 3D Polygon of containment wall of staircases: totally absent from the first two upper models, it has been built beginning from the altimetric data acquired by GPS and from the obtained head and ground line of projection. Respect to the reality, it is absent on the map one of the two existent perrons, the second parallel to the great one drawn on the plan along the church, and for both 3D information is missing (see Figs. 22,24).

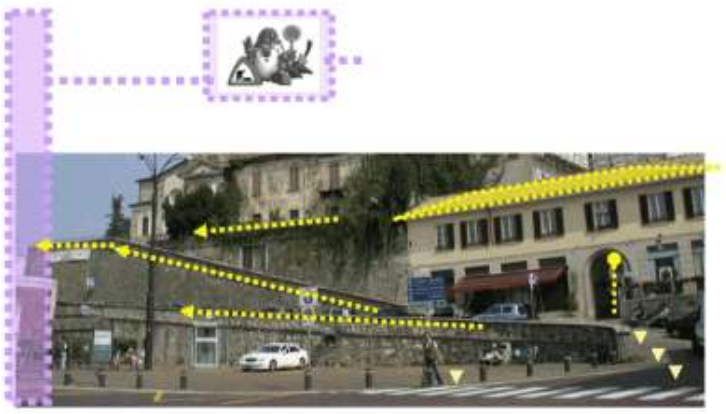

Figure 22. The Staircases Ancient System.

Figure 23. The GPS surveying.

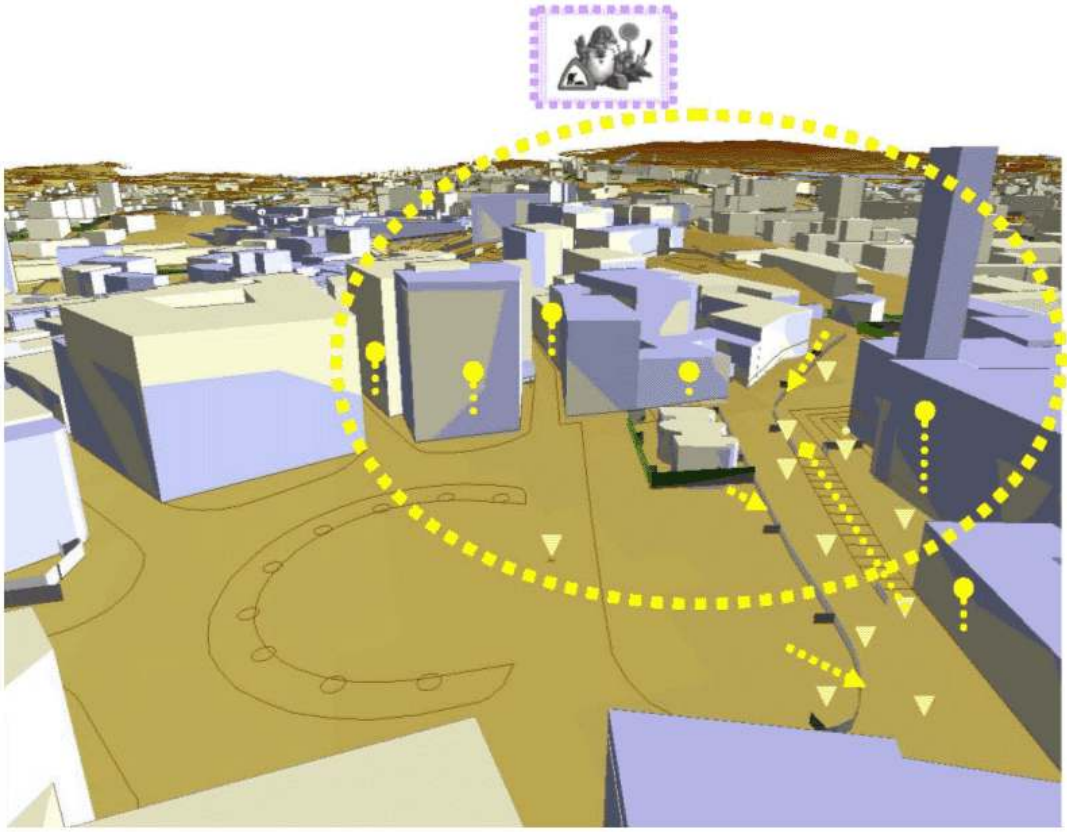

Figure 24. A sample of 3D Geo-information lack. Here are simplified samples of problems of 3D geographic information lack inside the Technical Map 1:2000, in order to support an advanced model of a selected historical view, positioned from the low, instead of the classical 'bird flight view'. a. Totally absent are the *ground points* that define the 3D elements of a 3D view with lot of *unevenness*, as it is the case of the different level of the S. Paul Church, the Place and the other ancient pre-existence block. Here are some of the points to be surveyed by GPS to build the flight steps (triangle) beginning with the altimetric position of starting and ending point of each one, on which develop the 3D model. b. The yellow arrow dot line indicates the *wall escarpment* erroneously represented due to the previous lack. Once obtained the altimetric different level, it need after to be managed inside 3dGIS development in order to represent it in the shaped elevation model (triangular, trapeze,…) in a semi-automatic way. c. Respect to the reality, it is absent one of the two existent perrons, the second one parallel to the great one drawn along the church.

Figure 25. Cantù: (left) Teresian cadastral map (right) Located paths and flights of steps already existing in 1722.

Figure 26. The system of ancient paths with pre-existence drawn on the XVI Borromeo's map, georeferenced according to the cadastral map of 1722: integration of altimetric data with GPS measures (works ahead)

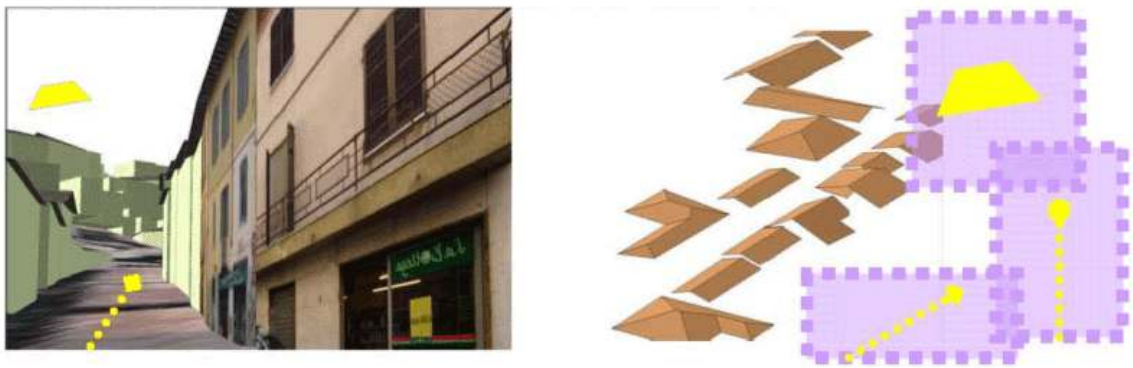

Figure 27. First results of a front, street and roof implementation inside 3d view model. It has been obtained in the case of historical site in Monferrato and applied in this case, to improve of the 3D panoramic view

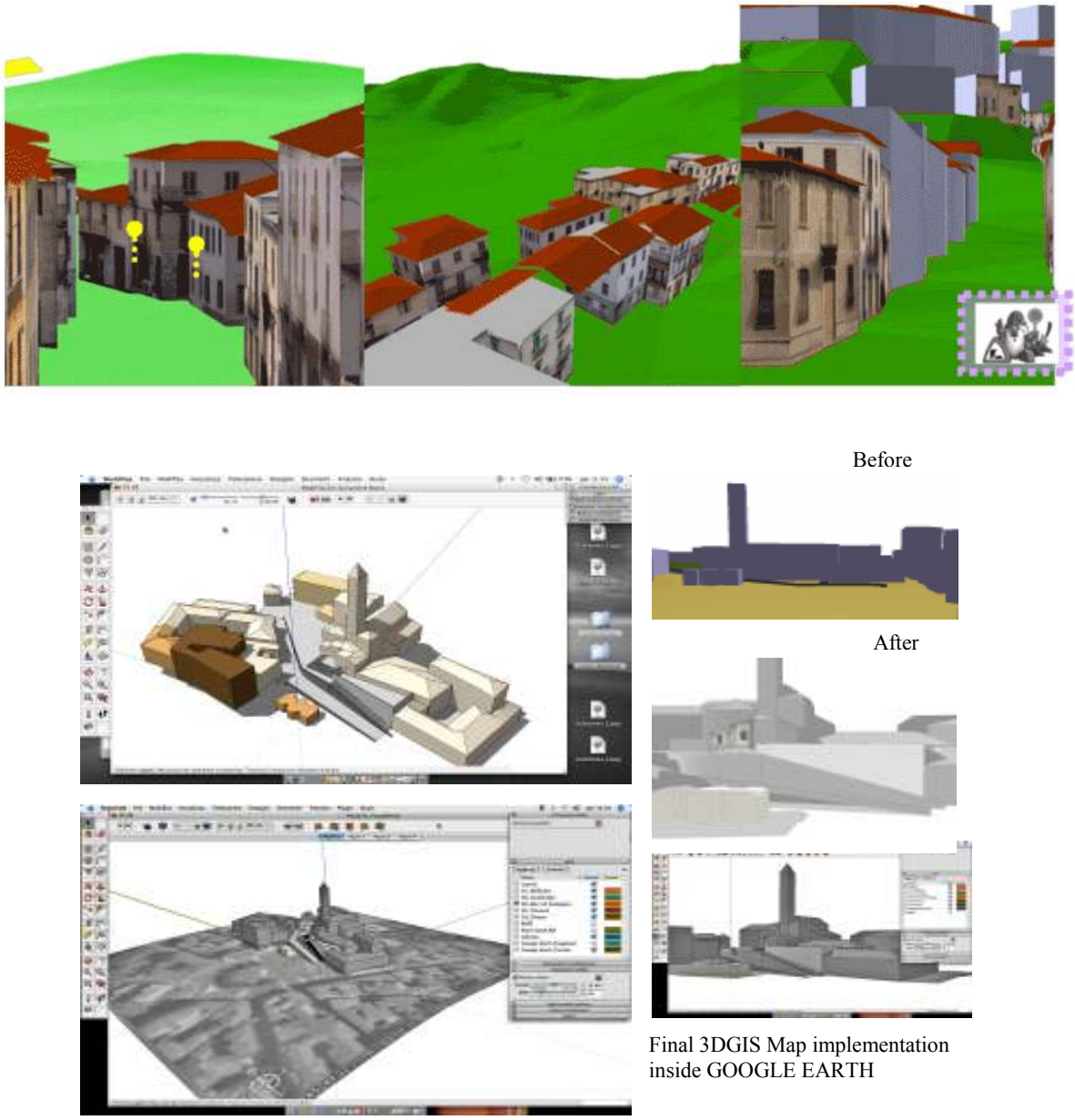

Figure 28. The first results.
Up: Roof modelling and 3D-fronts integration by rectified fronts (orthoimages generated by Laser Scanner clouds using photogrammetric sw can be used). Down: Results obtained improving panoramic view through 3D-congruence validation of topological adjacency of the staircases along the fronts and wall containments.

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