

## GEOMATIC CONTRIBUTIONS TO ARCHAEOLOGICAL INVESTIGATIONS. THE CASE OF TORRIONE OF POLLENZO (PIEDMONT – ITALY)

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### ABSTRACT:

The monument known as “Torrione” of Pollenzo (Piedmont – Italy), presently located in the garden of the “Agenzia” pertaining to the reign of Carlo Alberto, is placed in an extra-urban area of the ancient *Pollentia*, a roman city of Tanaro valley, founded in the last first century B.C..

Formerly, near this monument, some soundings uncovered a *domus* and a cobblestone paved road ruins, but due to the uncertain conditions of some portions of the Torrione masonry, which was heavily injured by deeply rooted weed, a urgent restoration was needed. The masonry, kept in sight, have been cleaned out, strengthened and kept in safety.

The geomatic side of deepening survey, applied both on the cleaned out masonry of Torrione and on the adjacent areas, has the role to provide a geometric contribution to catch up the settlement of the architectural structure.

Several issues had to be considered during the survey planning: the complex settlement of Torrione ruins, the need of recording its features in the most comprehensive way, the requirement of comparison between the Torrione and other archaeological evidences, etc. So the survey campaign has been organized mixing different methodologies of data acquisition, able to guarantee the capability to mutually compare all the emerged structures, spatially and because of typological features.

### 1. TIPS ABOUT A CONSERVATION PROJECT

The ancient Pollenzo, a small urban centre in the Tanaro Valley (South Piedemont) founded in the last first century B.C., focuses the interest of a multidisciplinary team of researchers. An important and articulate conservation project is still in progress.<sup>1</sup>

In the roman age, Pollentia stood at an important crossroads from where the main lines of communications leaved to reach the North Piedemont., the Alps passes, and, towards the South, the sea. After, transformations in landscape and in the urban centre are testified from V to VIII century; last, during the XIX century, under the reign of Carlo Alberto of Savoia an imposing architectural complex was built (1832-1849), made of many buildings among which there is the so called “Agenzia”.

There are many evidences of the history of Pollenzo: the make up of settlements in the surroundings, its position related to the main roads, the archaeological ruins (some documented in historical cartography and some others recently brought to light) and finally the uninterrupted reuse of important buildings. This last is the case of the amphitheatre: in spite of its transformation in houses it is still clearly understandable its original architectural frame.

Geomatics techniques have been applied to document the archaeological area actually located in the Agenzia gardens. Its main evidence is the “Torrione”, but all around archaeologists located other architectural structures; researchers are still working on hypothesis on their ancient use. Very many architectural marble fragments, belonging to the decorative covering of the monument, have been recovered from the superficial rearranged stratus and the absence of sepultures in

the surroundings has suggested that the Torrione has not a funerary nature.

One of the aim of geomatic contribution is to put in touch this ancient structures with other archaeological areas and landscape features. At the same time with restoration works applied to the Torrione, some archaeological investigations have revealed the presence of different building phases in roman age: we can see a stretch of a cobblestone paved road, a *domus* and a probable thermal building, edified during the first century A.D..

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Figure 1. The “Torrione” before and after restoration and excavation

<sup>1</sup> G.Carità (edited by), 2004.



Figure 2. The small city of Pollenzo. (Ikonos processed image superimposed on Regional Map 1:10000)

In particular, last survey is called to evaluate or not the accord between the present arrangement of Torrione and the formal feature derived from digging documentation and from other suggestions that archaeological ruins may reveal.

## 2. A CLOSE-RANGE SURVEY EVOLVING DURING RESTORATION AND DIGGINGS.

### 2.1 First step

The apprehension about the binder deterioration on the superficial portions of masonry, joint to the risk of falling down of stones during the complete removal of ivy roots wholly covering the Torrione, made urgent the first survey. All these unsure conditions defined the main purposes of survey that coincide with a preliminary accurate documentation of present state.

Due to the object shape we projected a survey with a 3D scanning system (HDS2500, Leica Geosystems): the original covering in stone of the Torrione is completely lost and the ancient building is actually made by lateritious foundations under a cobblestones wall, interrupted by a couple of rows of bricks and by sandstone blocks at about 2/3 of the height.

The shapeless geometry makes quite impossible to represent it in a synthetic way focusing on breaklines.

3D scanning systems allow high detailed survey, with fast data acquisitions and good accuracy. The incoming spread of these techniques shade more and more measure into representation; there's no doubt about the more suggestive capabilities of points clouds (viewed in real time and interactively explorable), instead of a long list of coordinates and attributes. The high density acquisition seems to guarantee a complete object description even without the necessary interpolation aimed to obtain continuous data.

Several issues had to be considered during the survey planning: the complex settlement of Torrione ruins, the need of recording its features in the most comprehensive way, the requirement of comparison between the Torrione and other archaeological evidences, etc. So the survey campaign has been organized combining 3D scans with different methodologies of data acquisition, in order to guarantee the capability to mutually

compare all the emerged structures, spatially and because of typological features.

During a first survey campaign we used the following techniques:

- (whole archaeological area) GPS system, to setting up a topographic net made by 4 vertices; some others vertices have been measured by topographical resection.
- (Torrione and roman road) terrestrial laser scanner, allowing the detailed documentation of the building; and digital photogrammetry: photograms have been acquired by semi-metric Rollei 6006 camera and then digitalized, while control points have been topographically measured by proper target. Then a bundle block adjustment has been performed for each elevation plan. Digital Surface Model from laser data supports orthoprojection process.

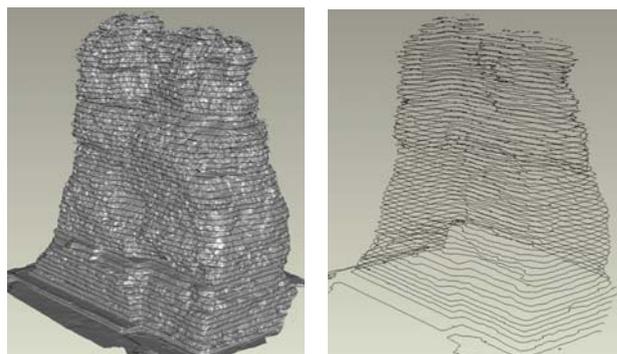


Figure 3. Surface model with horizontal sections and contours

### 2.2 Data elaboration and graphical representations

The arranged graphical representations combine:

- vectorial data, related to the geometry, coming from range maps;
- digital orthophotos, made by projection of digitalized photograms onto a laser scanner DEM.

Plans and elevations are drawn by scan data: we moved cutting planes (horizontal and vertical ones) through the point model in

order to obtain sections and contours. This kind of representation allow to describe complex shapes in a synthetic way.<sup>2</sup> Usually a generalization of detailed surveys are geo-referenced on cartographic bases and managed in a GIS while data processed at the architectural or archaeological scale are elaborated in dedicated software. Working on this project, after close range data elaboration, we preferred to exploit GIS system both to manage and to show all heterogeneous data (stored in different format files) at their multi-scale representations.

Moreover, GIS functionalities have been useful to manage all the local reference systems indispensable (as always in an architectural survey) to made a congruent representation of plans and elevations. Their choose is obviously defined in an arbitrary way even if one try to find the best corresponding medium plane on the object (moreover they are quite hard to identify on the Torrione, due to its complex shape). Projection planes define which elements will be show in real scale and which others will be foreshortened.

GIS allow as well to underline spatial relationship between original 3D data and their elaborations, both 2.5D (DEM, where 3th dimension is managed as an attribute) and 2D (orthophoto).

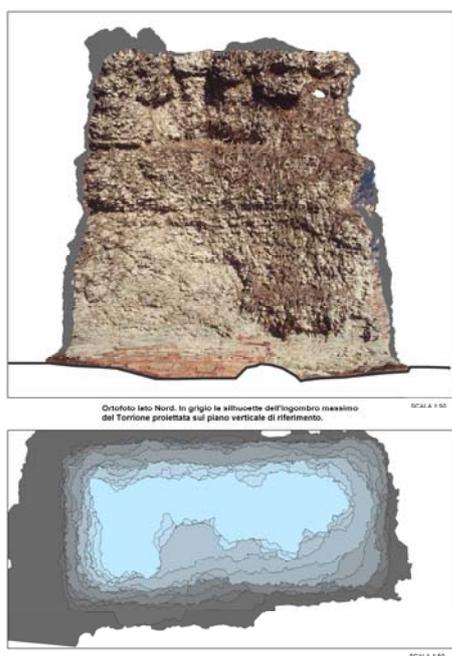


Figure 4. A final double projection representation: plan and West front represented with orthophoto

### 2.3 New survey campaign

During archaeological studies it is quite uncommon that a complete documentation could be collected in a only one survey campaign: more often metric survey have to follow in a flexible way other researches carried out during the excavation campaign occurring.

Archaeological investigations made after our first survey brought out the lowest level of the Torrione (about 1.5m deeper than the previous terrain level) base on fronts North, Est and South. So we performed a new survey to document it, combining previous data with new ones.

Survey techniques adopted have been the same of the first survey campaign: an integration of 3D laser scanning,

photogrammetric acquisitions and topographical survey of control points were needed. Obviously data have been acquired only on the lowest part of the Torrione. (cfr. Figure 7)

In order to reference data coming from subsequent survey campaign it is indispensable to firmly materialize some references: by remeasuring them in every survey campaign it is possible to define transformation parameters to rototraslate transitory reference systems in the general one.

In some situations it is possible to stick or to glue some target leaving them how much time is necessary

From time to time it is important to evaluate how to made the target and how to fix them, paying attention on avoiding invasive works that could damage the building. In fact, in the survey of the Torrione, it was impossible to firmly fix target onto the building: its surface has been cleaned and restored after our first survey.

On the other hand, this is a quite common problem working in archaeological field: the progress of archaeological investigations and diggings imply that terrain layer are subsequently removed. So, reference points have to be put at a suitable distance from the object; moreover, they should be overabundant. In Pollenzo, the topographical net project has been effective: even if one of its vertices was removed (due to digging works) it was possible to use the others to measure the control points useful for both photogrammetric orientations and for range data alignment.

Analogous data elaborations have been performed on the roman paved road.

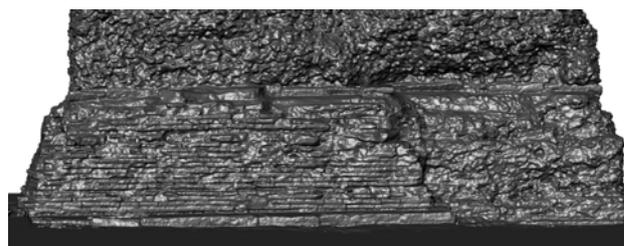


Figure 5. New surface model from scan data of basement.

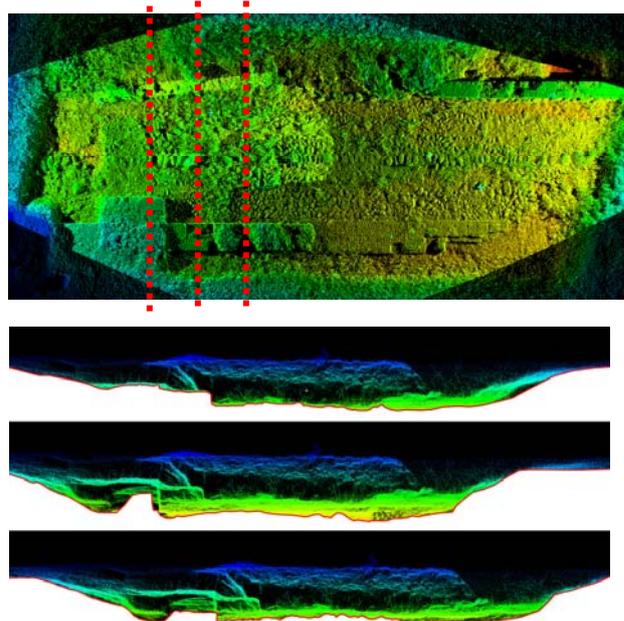


Figure 6. Plan view of paved road points cloud, after alignment. Below: cross section of points cloud with vector profiles

<sup>2</sup> More details about data elaborations (laser data and digital photogrammetry processings) are in Bonora V. et al., 2006.

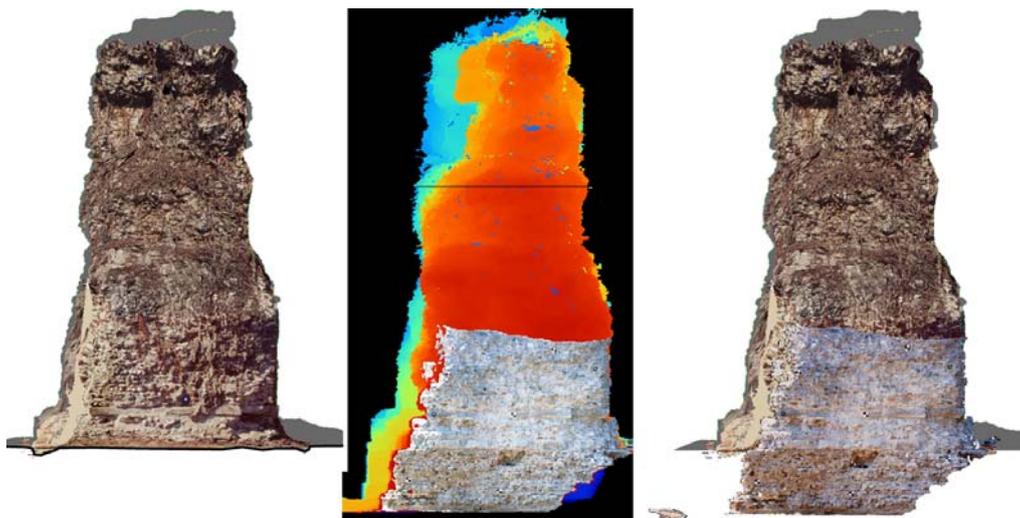


Figure 7. Comparison between first and updated orthomaps of South front (after excavations). Centre: overlapping of DEM and updating orthomapping

#### 2.4 Relationship with land

In documentation project of Cultural Heritage, focusing both on architecture, landscape or archaeological field (or on all this feature at the same time, as in the presented multi-disciplinary project) guide lines suggest the best way to approach territorial analysis in order to highlight the relationship between the object and the surrounding landscape. Results should be referred to the available multi-scale cartography.

A basic and well shared criteria for a GIS project is in fact the multi-scale principle, based on the suitable integration of spatial bases and cartographical products, allowing the interpretation of different level of detail and accuracy relationship.

Another interesting possibility offered by GIS systems is to perform territorial analysis in their diachronical development and not related at only one specific time. Temporal contextualization is in fact a more and more requested feature, both referred to a time interval and at a specific time.

In the presented case study, topographical net geo-referencing has been performed in UTM and Gauss-Boaga systems: in this way it has been possible to geo-reference the whole survey and to superimpose layer with spatial information, getting out new thematic maps at small (1:100.000) and regional (1:10.000) scale.

The map in Figure 8 shows the road linking main settlements in roman age in South Piedmont; it was produced starting by geographical data in 1:100.000 scale. Altimetrical data and administrative boundary markers was helpful for orographic representation of the landscape. The ancient settlement plan come from layer with the main hydrographical ways, roads, urban centres.

Cartographic map at 1:10000 was produced from a photogrammetric survey in 1991, followed by an update in 1997, while 1: 10.000 orthophoto was made by photo taken in 1998/1999. In order to update the available regional maps we performed a orthorectification of an Ikonos satellite image (July 2005).

The further referencing of cadastral map, still integrating the ancient urbanization<sup>3</sup>, allow an updated comparison with modern buildings and roads net. Geo-referencing the large scale

survey of the Torrione and of the paved road suggest to compare the *Cardo* and *Decumano* directions (as in the

archaeologist hypothesis) with the road direction and to rectify the wrong referencing of the Torrione made on the cadastral map.

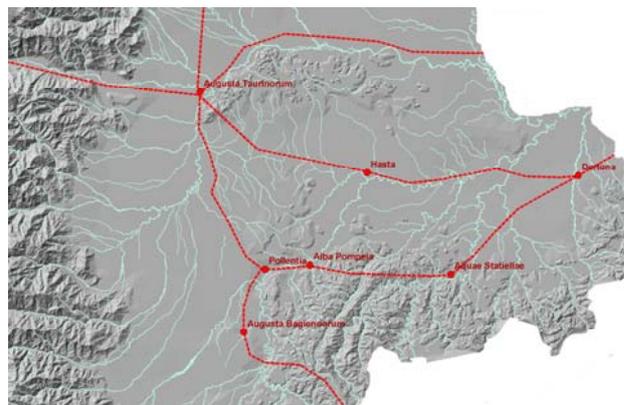


Figure 8. Road linking main settlements in roman age in South Piedmont.



Figure 9. Last result of restoration and valorization activities on Gardens of Agenzia are shown in the satellite ortho-image

<sup>3</sup> Preacco M.C., 2004.

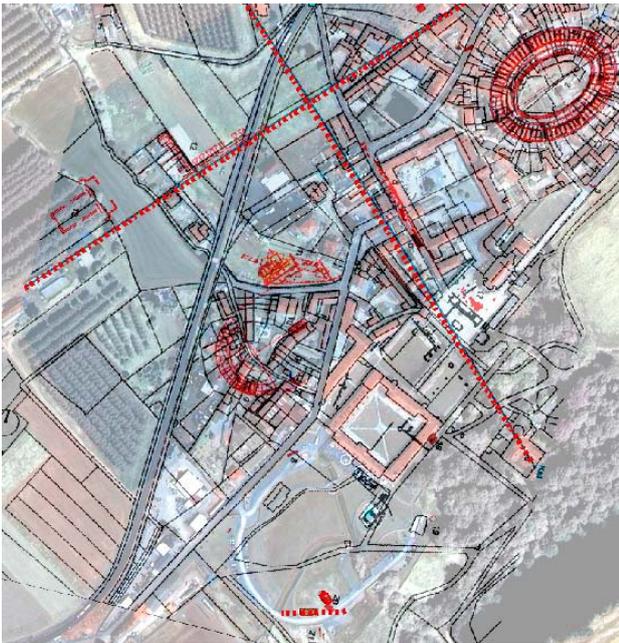


Figure 10. Cadastral 1:2000 map overlapping satellite ortho-image. A comparison between directions of hypothesized Cardo and Decumano and paved surveyed road.

### 3. DATA MANAGEMENT

Survey data and final metric drawings have been elaborated by several software: topographic data computation, range maps alignment, photogrammetric and 3D modelling tools. GIS technology has been chosen to publish final 2D representations; GIS tools have been helpful in order to integrate and manage all those spatial data and, particularly, in order to represent raster and vectorial data in an integrated way.

This last choice, without doubt, has implied an heaviness on necessary elaborations aimed to obtain geometric and topological features of entities performing in a geodatabase. These spatial DB objects, in fact, had to provide specific representative requirements to obtain final metric products at architectural scale (section profiles extracted from points cloud, after vectorialization and editing have been imported in geodatabase as polygons)

The chosen symbolizing (figure xxx) shows through range colour the distance from specific reference plans (elevation has the meaning of altimetric attribute if the reference plan is the cartographic one, but it has the role of a distance if the reference plane is vertical and parallel to the architectural structure fronts).

This organizing data option, which representation comes out easy to perceive, offer benefits about classifications editing, the chance to make cluster of objects, adding to the opportunity of fast updating through the export of symbolization in different dataframes (dataframe often include different final projections of the surveyed object)

As much thin to now we have used tools mostly aimed to data presentation, making this kind of entities enables to perform spatial analyses, peculiar in Gis of this data format.

As well known, GIS presents significant limits in managing a third dimension if not related to z axis (that is on the contrary a well developed skill in 3D modelling software). On the other hand, GIS software allows referencing data in different spatial coordinate systems, and recording raster images (DEM, orthophoto) separately from geo-referencing image information.

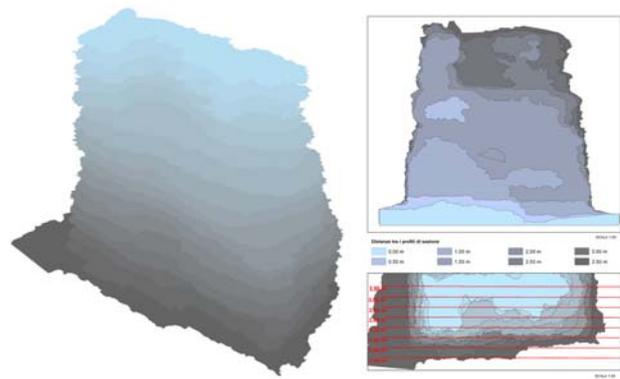


Figure 11. An example of representation obtained by symbolized polygons derived from section profiles.

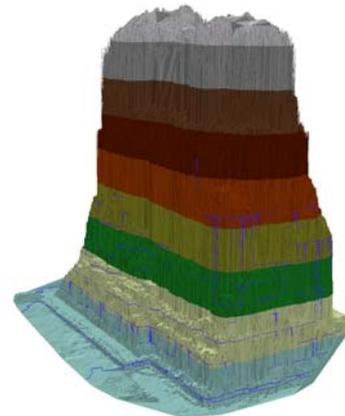


Figure 12. Decay of morphological information in vector 3D GIS format (TIN).

### 4. REPRESENTING TYPES

Graphical representations made on the occasion of this studies, both bi- and three-dimensional, could be classified as following, based on their prevalent purposes:

- Graphical representations aimed to document the building: they refer both to the traditional 2D drawing and to 3D models. Plans and elevation view have been made by exploiting the complementary skills of raster data (orthophoto) and vectorial ones (level contours); GIS allowed data management. At the end, an interesting tool has been chosen to visualize and explore the 3D model, to measure distances on it and to define cutting planes.

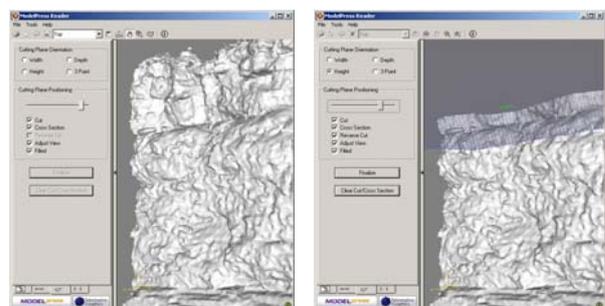


Figure 13. A tool for the on-line exploration of a simplified model: it is possible to interactively explore it, to measure distances and to define cutting planes.

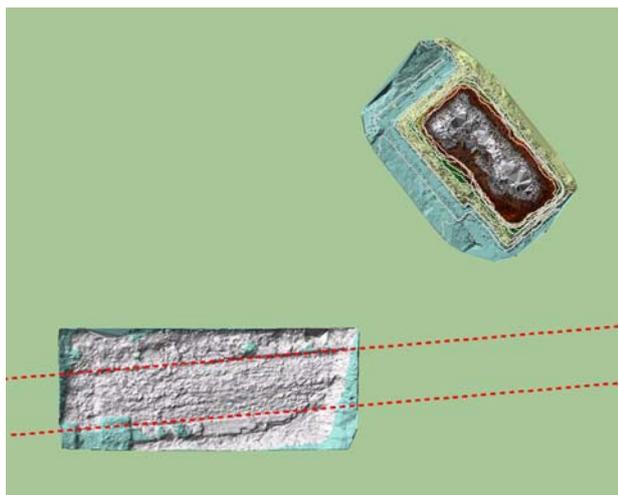


Figure 14. TIN georeferenced models of both archaeological structures, to compare dimension, location, orientation.

- Popularization and communication projects: they could clearly be produced in an independent way, with metric data really limited or even without any of them. Important features are geometrical ratio and visualization effectiveness. Texture play a major part, because it improves informative contents of a 3d model with a simplified geometry.

Otherwise, in the Torrione survey, this kind of graphical representation come from the large amount of 3D data with a known metric value and high resolution: this is a surplus value supplied by the integrated survey techniques applied in the project.

- Graphics supporting reconstructive analysis and hypothesis: the representation of diachronic phases of a building life unavoidably requires the introduction of elements with different accuracy (i.e. because coming from documentary sources or from analogies). The actual state of the building, or its ruins, is the only reference of which geometrical and dimensional validity is known and verifiable – this is true if the documentation project followed correct procedures and convenient instruments.

Moreover, when the aim of the survey is a reconstructive hypothesis it is often interesting to postpone the subjective interpretation to the measure, or to allow different researchers to deal with every specific problem. 3D scanning systems and digital photogrammetry are survey techniques that allow to store complementary and objective data: geometric data, the former, and chromatic ones the latter.

## 5. CONCLUSIONS

This experience highlights the profitableness of an interdisciplinary approach in this kind of studies. The increasing spread of the computer science in the Archaeological field make archaeological researchers more and more sensitive to innovative solutions coming from Geomatic, valuables for them accuracy value and for them digital and three-dimensional nature.

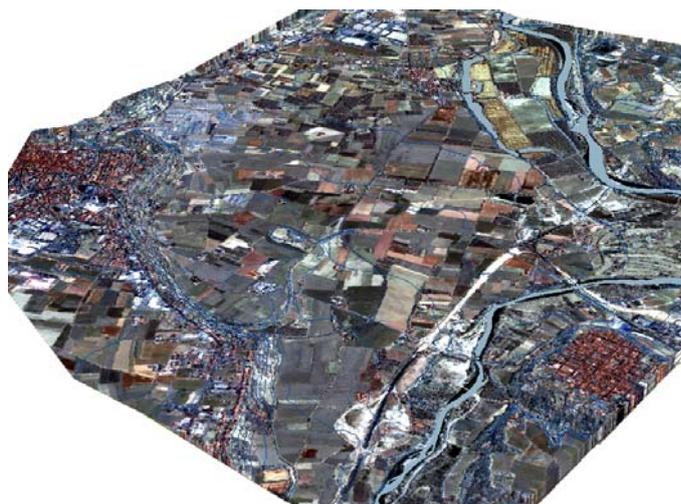


Figure 15. Satellite georeferenced image data drapping a DEM derived from 1:10000 regional Map.

## 6. REFERENCES

- Bonora V., Spanò A., Tucci G., 2006, Rappresentazioni per l'archeologia, in: Bollettino SIFET, n. 4/2006
- Bonora, V., Tucci, G., Vaccaro, V., 2005, 3D data fusion and multi-resolution approach for a new survey aimed to a complete model of Rucellai Chapel by Leon Battista Alberti in Florence, Proceedings of CIPA International Symposium, Torino.
- Spanò A., Bonfanti C., (2005), Large scale spatial database supporting archaeological research, In: *International Archives of the Photogrammetry, Remote sensing and Spatial Information Sciences*, vol. XXXVI-5/C34 ISSN: 1682-1750
- Preacco, M.C., 2004, Pollentia. Una città romana della Regio IX, in Carità G. (edited by), 2004.
- G.Carità (edited by), 2004, *Pollenzo, una città romana per una "real villeggiatura" romantica*, l' Artistica Editrice, Savigliano.
- Dequal, S., Lingua, A., Biasion, A., A new procedure for the automatic production of true orthophotos, Proceedings of the XXth ISPRS Congress "Geo-Imagery Bridging Continents", Istanbul 2004.
- Monti, C., Brumana, R., Fassi, F., Fregonese, L., Coalizzi, L., De Pascalis, F., Fotogrammetria e scansioni laser: creazione di ortofoto 3D di precisione, Atti della 8a Conferenza Nazionale ASITA "Geomatica, standardizzazione, interoperabilità e nuove tecnologie", Roma 2004.

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