

## 3D METRIC-MODELLING FOR KNOWLEDGE AND DOCUMENTATION OF ARCHITECTURAL STRUCTURES (ROYAL PALACE IN TURIN)

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### ABSTRACT

3D-models can aid to investigate and than to communicate how a structure is shaped and built up; this is the reason why architectural studies often use models to integrate 2D representations and drawings

In the last few years our group, directed by. prof. Bruno Astori, has carried out a large and complex survey of “Palazzo Reale” in Turin and its Gardens.

Several different nets of verteces, hierarchically connected each other, have been arranged gaining every room of the palace; the general goal of the topographic survey was to obtain a detailed geometric description of every part of the building located at different levels. The project result is the basic tool to organize the global preservation of the royal palace, to support restoration activities or historical analyses. Moreover 2D representations, at architectural scale, are one of the main devices to found the renewed arrangement of museum system of Savoia Residences.

In the Royal Palace of Turin, the intricate setting up of main rooms and stairs related to back ones, often required many differently oriented sections to describe single complex structures. These problems suggested to carry out 3D metric models made up according to previous spatial data acquisition methodologies. Moreover, since the Palace is a museum (most places but not all), particular kind of models can establish a virtual visit for rooms not included in guided visit.

This work is even a bargain to think about aims and capability of metric models to show Architecture. Architectural studies and other investigations examining historic buildings or part of them, certainly could need models, but it’s necessary to ask oneself what kind of details or information we expect that a model is able to reveal (different models can reveal different topics).

Some of these themes and observations about models suggest in what chances could be useful to perform laser scanner applications, in spite of others in wich these methods wouldn’t be so helpful.

### 1. INTRODUCTION

Items and problems that researchers are mastering about laser scanner technology and applications are a great number; merely discussing about close-range field, the main subjects could be pointed as following:<sup>1</sup>

- Evaluation (by applications) of real capacity of metric description.
- Automatic methods for multiple acquisitions registration
- Evaluation of spatial accuracy

Our group, according to the call to applications, rank to the first ones; we intend to study capacity of laser scanner in different sections of architectural or archaeological survey.<sup>2</sup>

Even though our field of study often brought us to use 3D modelling as an important part of architectural survey presentation and buildings documentation, laser-scanner applications persuaded us to fulfill a sistematic meditation upon role and purposes of 3D metric models.

The latest work on models about some structures and rooms of Royal Palace of Turin enable to spot and to show through examples some topics. (We achieved an accurate survey of this large palace, laying to the architectural nominal scale 1:100).



Figure 1 – Model of the lounge “Orba”, chosen for the experience

<sup>1</sup> Main part of references concerns these fields-work.

<sup>2</sup> We started to survey an ancient architectural object, the roman theater in Ventimiglia (B. Astori, et. al. 2002); now we are working in earlier architectures and we’ll soon present results.

## 2. OPENING DATA

Opening data for this experience about different metric models creation are extracted from the topographic survey of the whole Palace<sup>3</sup>.

This survey was managed carrying out a collection of different topographic nets framing the building, each level and, in the end, every room of the palace (figures 2, 3, 5).

The only one reference system enables to compare places and lounges locations and establish the assumption to make correct models according to a metric point of view.

Detailed topographic measures, integrated with traditional distance measures, allowed to form vectorial plans of different levels (figure 2 shows only six levels of the eleven ones); these plans, that overlap architectural drawings in a digital form, are obviously altimetrically referenced.

We can say that next models originate from a uniform spatial information about: state of walls, thickness of wooden or tissue inside coverings, technological elements as fireplaces, main heights of ceilings or vaulted roofs, stairs, windows ect.

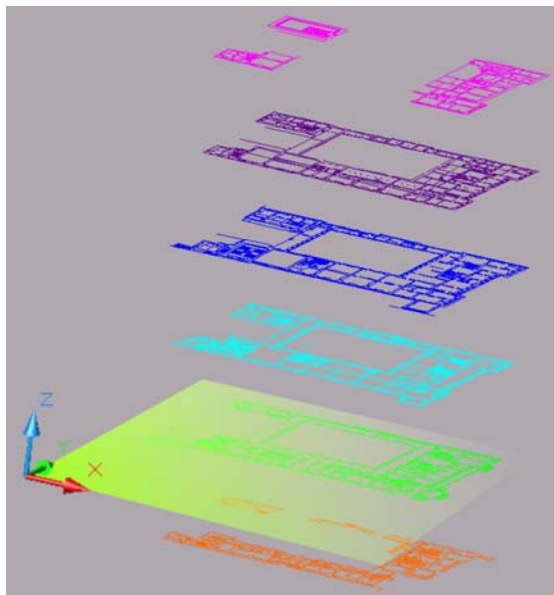
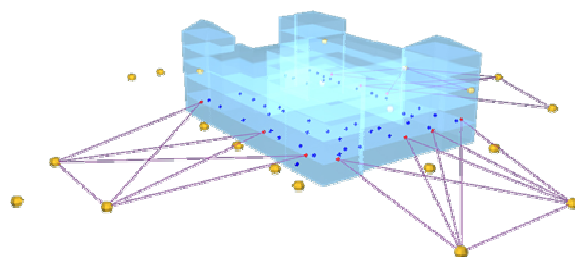


Figure 2 – Overlapped levels showing the unique reference system.

Figure 3 –Image that shows the connecting topographic net among the main one (outside) and each net laying at levels.



<sup>3</sup> The survey, sponsored by *Compagnia San Paolo* and having as addressee the *Sovrintendenza ai Beni Ambientali ed Architettonici*, rank to the outline of complex and integrate inquiries for documentation and safeguard of Savoy Residences; it belongs also to the extensive recovery and development project of museal circuit of Turin.

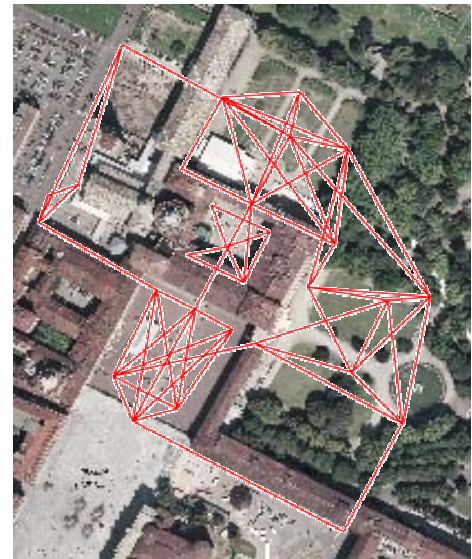
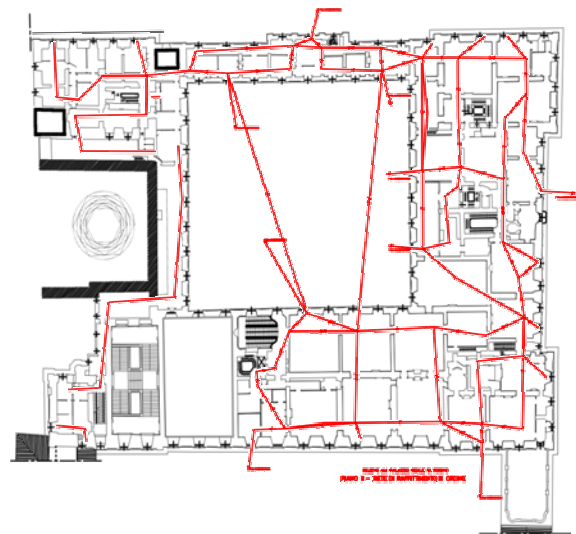


Figure 4 – Geometric scheme of the main topographic net, framing the palace and next areas. The net is overlapped to an extract of the orthophoto (scale 1:1000) carried out with the subsequent survey of Gardens. They are both geo-referenced to national cartography.

Figure 5 – The topographic net of the second level.



### 3. SELECTION OF PLACES AND TYPES OF MODEL

From the beginning, the selection of places to submit to model has been oriented to underline different descriptive needs of final 3D model; moreover places have been chosen in order to sharpen possible various matters and acquiring problems that a laser scanner survey could imply.

These preliminary assessments most refer to issues about acquisitions from several viewpoints, and even about spatial positions of viewpoints, settled to guarantee complete and homogeneous objects recording.

We singled out two types of places: the first one is composed of a sequence of places and rooms assigned to servants and including a stair, and the other one is a lounge at *piano nobile*.

Both of them are not involved in the museum visit so a subsequent purpose of this work is to show unknown portion of the palace by a sort of virtual visit.

Most time, historic buildings as the royal palace present a strict diversification between noble routes and servants ones; the portion of palace that we pointed to know deeper and to show, offer an unusual distribution set, because of the stair original and unexpected structure. This particular stair has the double function to distribute and connect each other aulic and poor

rooms, so, this occurrence make the stair undertake a curious shape.

Moreover, another important matter that makes a deep difference between two types of places, is about the survey. Topographic nets succeeded in evolving themselves along contiguous lounges and large rooms, but obviously they met some difficulties in close and winding routes (folding topographic methods inside the buildings isn't so easy, but sometimes is not helpful and cheap to force working).

We can close saying that these portions of palace are hardly visitable and surveyable, they need a great deal of drawing sections to show their structure, therefore, creating a model is warmly advisable.

Due to all these conditions and opening data, we decided to carry out two different 3D model types:

- A. geometric bases of architectural shape modelling, with least integration of measures and lean rendering aimed to emphasize geometry
- B. modelling enhanced with further metric data (acquired by topographic or photogrammetric methods) and mapping textures onto surfaces in order to achieve photo realistic appearance of objects.

#### 3.1 ACCOUNT OF MODELS PRODUCTION

##### A TYPE MODELLING STAIR AND SERVICE ROUTES CONNECTED WITH NOBLE ROOMS

Further metric data acquisition are focused on essential size identifying geometric structures. They are simply heights of significant points of cross vault, barrel vault etc. necessary and enough to trace geometric entities (Fig. 6 and 7).

After modelling every form, we can reference each other in the same coordinates system, to analyze and control relationships between architectural elements and structures (Fig. 8).

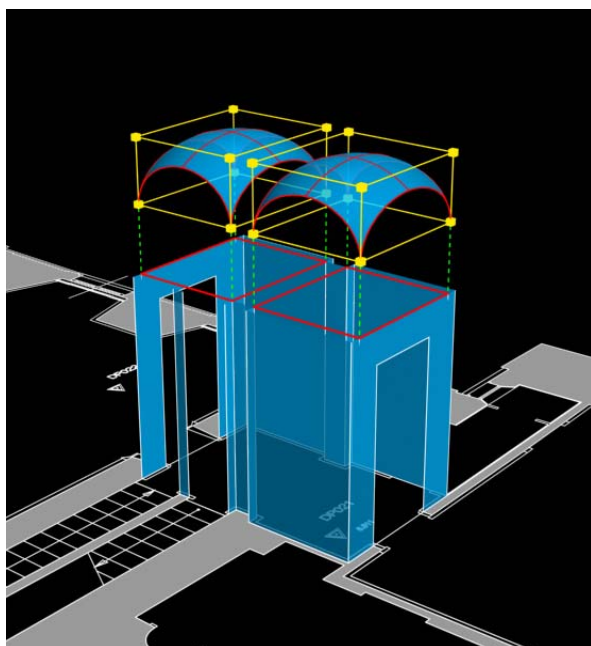


Figure 7 – Tracing geometric primitives

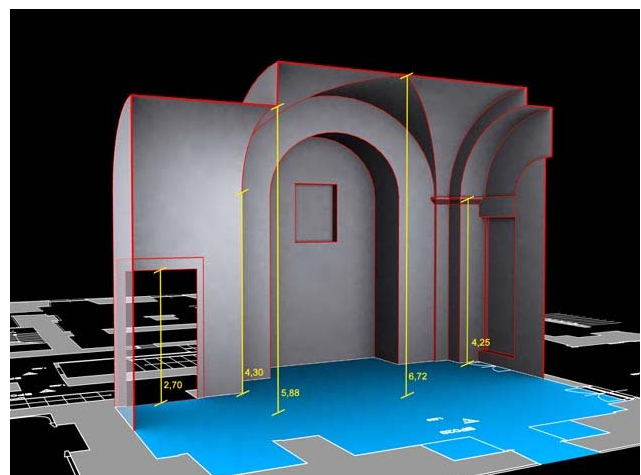
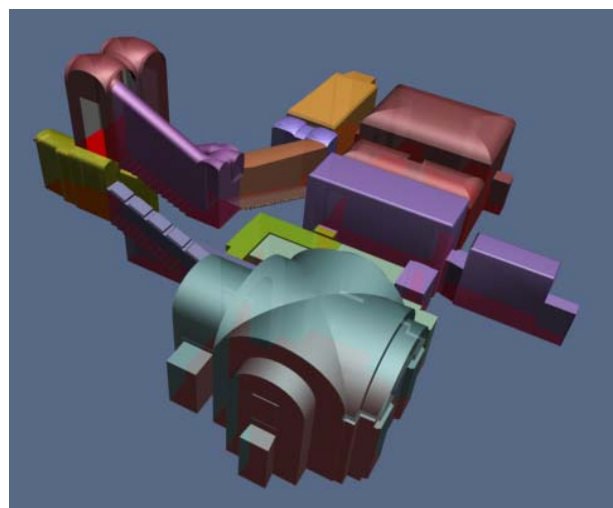
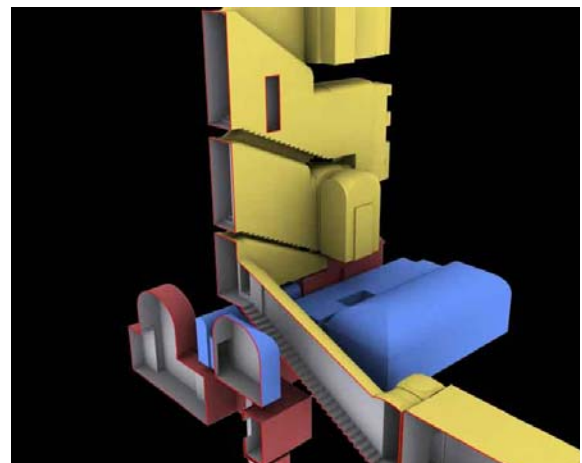
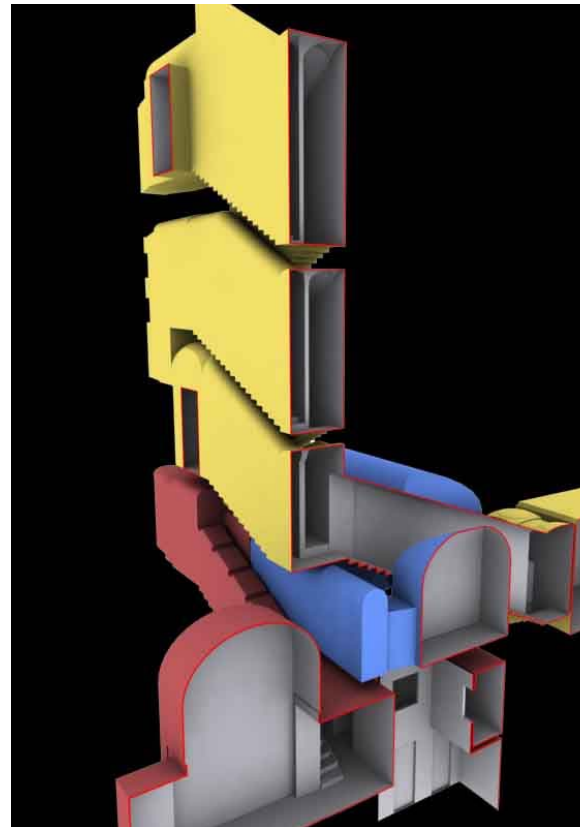
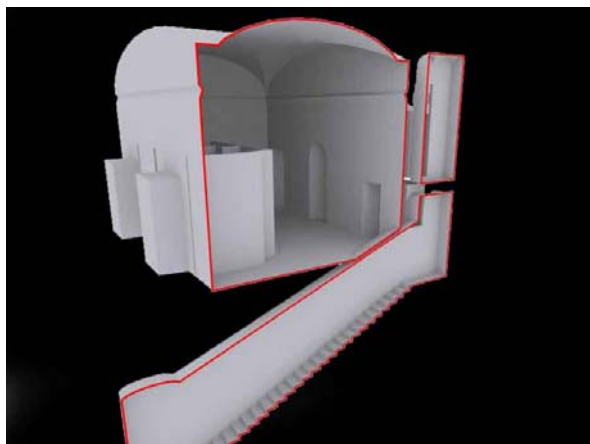
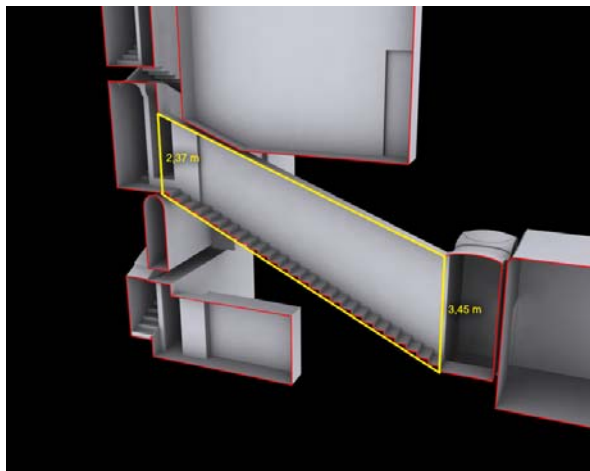


Figure 6 – Measures identifying geometric structures

Figure 8 –geometric structures assembly by known coordinates of planimetric projections







These images shows mastering analyses of this portion of palace:

Figure 9 – A ramp perpendicularly oriented to the stairs, inserts itself to the main body of vertical route. Different keystone heights of starting and final barrel vault of the ramp emphasizes prospective and perception of long ramp.

Figura 10 – Even though the height of vaulted roof of ramp is reduced, it intersect the floor of the room, which is obviously a service one.

Figure 11, 12 – (right side) These pictures are planned to underline the intricate setting up of rooms. The first red ramp start to climb and soon it stops. The yellow ramp, coming from king's apartments, gets over an other corridor (blue colour) and climb over the red stair.

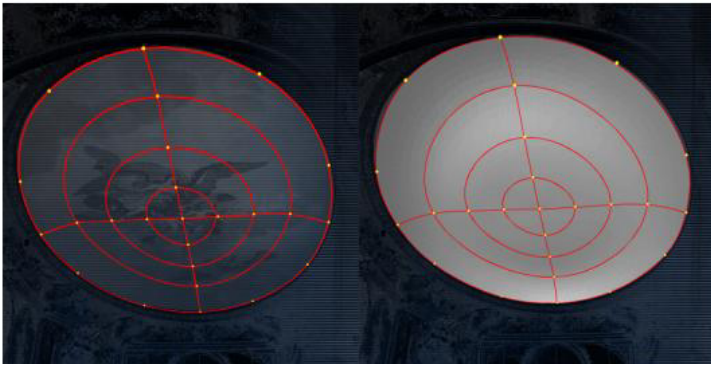
**B TYPE MODELLING**  
(LOUNGE)

We applied this second type of model to a single lounge, with a vaulted roof and rich decorations all over walls. To model the room we acquire some further data:

- Using a reflectorless total station, we measured many adjacent points along two main arch of the vault (even though it is a rather flat vault, it is a double curvature surface)
- Still with a topographic methods, we measured a suitable number of points lying onto the wooden covered walls, in order to apply and achieve the analytical rectification of images.



Figure 13 – A multimedial tool has been used to refer topographic measures. First form shows the vaulted ceiling.



Figures 14, 15 – Next form of multimedial tool explain topographic sections of vault and the surface construction. The vault section prove that the big crystal chandelier hanged to the wooden ceiling had deformed it. (yellow curves).

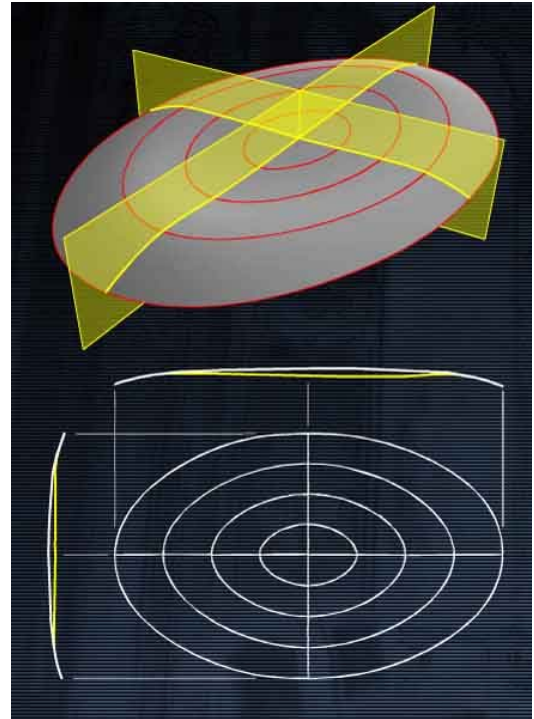
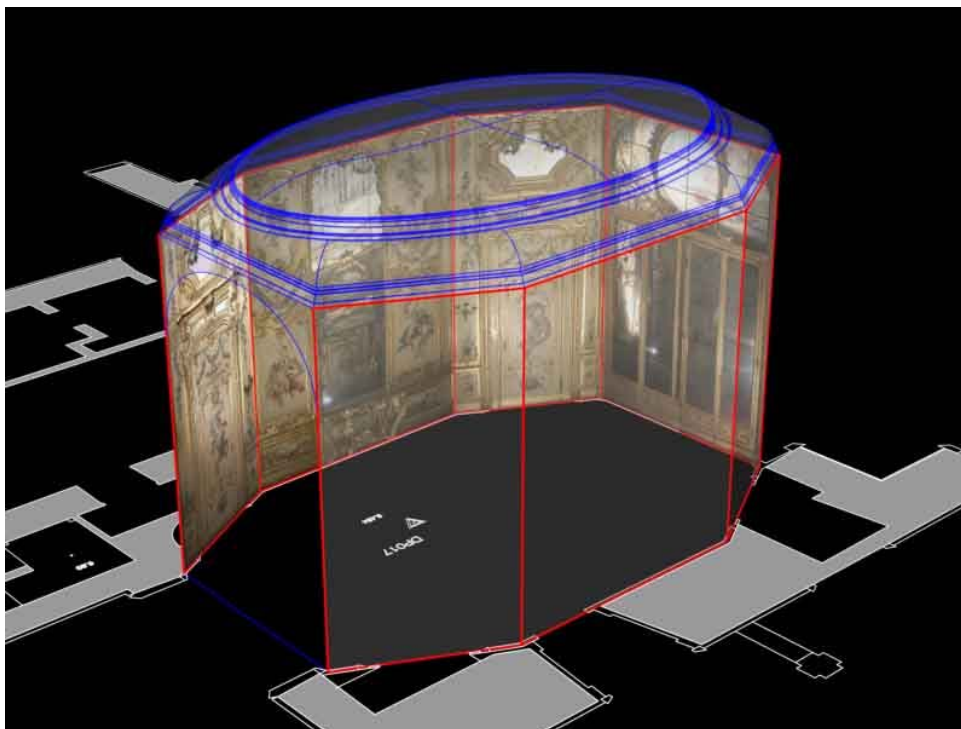


Figure 16 – Straightened digital photos of each wall are assembled to wireframe model (analytical rectification method has provide an accuracy of  $RMS=\pm 1.5$  cm).



### CONCLUSION – EVALUATION OF EXPERIENCE

Best expectations about laser scanner survey for architectural heritage recording, can be summarized in next statements:

- Metric global recording to gain every detailed section needed.
- 3D visualization of whole object model, possible, or desirable, orthoprojection of textures to obtain best and deeper knowledge of objects.

In the light of these thoughts, we try to list some possible aims of experienced modelling, and an evaluation about laser scanner survey if applied in the same cases:



**A** type modelling:

1. Knowledge of constructive characters of historic buildings. (Such model is able to support historical researches)
2. Since this kind of buildings often accomodate museums, an **A** type model can aid ordinary and special maintenance of buildings.
3. From comunication point of view, even without virtual reality, visitors can learn about rooms not involved in the visit.
4. A laser scanner application would see same difficulties than photogrammetric methods.
5. These architectural structures and rooms sharpen how in laser scanner close-range survey the chance to select acquiring information is warmly needed.

**B** type modelling:

1. B type models enable first and second previous capability, and surely allow further analyses: history of art investigations upon paintings, decorations etc.
2. In addition to maintenance, this kind of model enable anlyses of structural instability, material deterioration or simply deformations of objects.
3. Communicative power is bigger than previous; we can consider a virtual visit for visitors who can't get inside. This kind of model constitute even the basic assumption to achieve virtual Restoration.
4. Laser scanner applications are surely more suitable than previous case, maybe that a similar survey would allow further news about the architectural object.



**REFERENCES**

Böhler, W.; Heinz, G.;Marbs, A.,The potential of non-contact close range laser scanners for cultural heritage recording - CIPA International Symposium, Proceedings - Potsdam, Germany - 2001

Lemmens, M., Heuvel, F. A., 3D clode range laser mapping system, Gim International, 1/2001

Colombo, L., Marana, B., La visualizzazione tridimensionale del costruito, Rivista dell' Agenzia del Territorio, 3/2001

Fangi, G., Fiori, F., Gagliardini, G., Malinverni, E. S., Fast and accurate close range 3D modelling by laser scanning system - CIPA International Symposium, Proceedings - Potsdam 2001

Monti, C., Fregonese, L., Achille, C., Laser scanner application on complex shapes of architecture. Profiles extraction processing and 3D modelling - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV-5/W10

Cantoni, R., Vassena, G., Lanzi, C., Laser scanning and traditional survey integration to buid a complete 3D digital model of "Sacrestia dell' Archivio di Stato a Mantova" - CIPA International Symposium, Proceedings - Corfù, Grece - 2002

Rinaudo, F., Bornaz, L., Lingua, A. , 2002. *Il trattamento dei dati laser scanner nelle applicazioni terrestri* - Proceedings of National conference ASITA, Perugia 2002.

Migliari, R., Frontiere del rilievo. Dalla matita alle scansioni 3D, Gangemi Editore, Roma 2001

Astori, B., Bonora, V., Garnero, G., 2002. *Il rilievo laser scanner del teatro romano di Ventimiglia: esperienze e prospettive* -Proceedings of National conference ASITA, Perugia 2002.

Astori, B. (a cura di), Il rilievo metrico di Palazzo Reale di Torino, pp.