LASER SCANNING SUPPORTS ARCHITECTURAL MAPPINGS AND HISTORICAL URBAN VIEW ANALYSIS

Daniela ORENI*, Francesco FASSI**, Raffaella BRUMANA**, Federico PRANDI**, Hande TUNCER**

* DIAP - Politecnico di Milano Via Bonardi, 3 – 20133 Milano
** DIIAR – Politecnico di Milano P.za Leonardo da Vinci, 32 – 20133 Milano
daniela.oreni@polimi.it

Commission VI, WG VI/4

KEY WORDS: cultural heritage, laser scanning, surveying, mapping, urban analysis

ABSTRACT:

Spilamberto is a little country near Modena (Italy), that expanded all around the original medieval Castle. Rocca Rangoni was a part of this Castle, was built at the beginning of XIII century and was modified till to have actual look. When in 2005 the Rocca was bought from the Common of Spilamberto, the Administration decided to open the building and its Park to the citizens.
The complicated shape of the buildings and of their round places (Park, square and Castle), the absence of any previous survey and the need to reconstruct the geometry of the places in not too much time, obliged, step by step, to use and couple different techniques. This choice proceeded not only from the scale of representation, but also from environmental and morphological conditions of the places. In particular, the main purpose of our written communication is to show, through a concrete example, how to use a large quantity of laser scanner data to integrate and check a survey executed with traditional techniques (geometric, topographic, photogrammetric and GPS survey), both to architectonic and urban scale.

1. INTRODUCTION

The use of laser scanner to measure the shape and the geometry of historical buildings it's now very diffused, also because the instrument allows to obtain in a short time a large quantities of data. What is not as much foreseen and simple is the utilization of this information, according to the purposes of every survey, both at architectonical and at urban scale.
The aim of our written is to synthetically show how we used laser scanner data to integrate and to check the measurements registered by manual and topographic instruments.

2. FROM MODEL AT ARCHITECTONICAL SCALE TO URBAN CONTEXT: DATA INTEGRATION FOR PLANNING

2.1 Extraction of horizontal and vertical cross-sections from points cloud: integration to manual and topographic survey

The aim of the first part of measurements[*] was the drawing of plants, cross-sections and fronts of Rocca Rangoni, at nominal scale 1:50.
The construction of geometries required the creation of a principal plano-altimetric network, in order to deduce the coordinates of a sufficient number of points, which to connect the secondary networks, support for manual survey (through alignment and trilateration method).

Figure 1. Top view of Rocca Rangoni in Spilamberto

By using optical and digital levels there were materialized four horizontal cross-section levels (basement, ground floor, mezzanine and noble floor); there were acquired about 2500 topographic points for plants drawing and about 2000 for the seven plans of vertical cross-section.
Parallel we realized a laser scanner survey of outside building, georeferenced in the same global reference system, in order to have an immediately compatibility between different data.
The points clouds obtained with Leica HDS 3000 were associated with low resolution information[***]. The phase of georeferencing of numerous scans, by using targets (average error of alignment 7 mm), was in fact followed by topographic position survey of targets.

---

[*] Our survey work is a part of a big project of diagnostic knowledge of the buildings, contracted to Politecnico di Milano (Diap, Sezione Restauro, scientific responsible prof. Carolina Di Biase): Campagna di indagine architettonica e di prima diagnostica mirata all'approfondimento conoscitivo della Rocca Rangoni di Spilamberto e delle relative pertinenze. Topographic and laser scanner survey organized by Diiar (scientific responsible: Prof. Carlo Monti, Prof. Raffaella Brumana).

[***] System performance between 0 and 50 m scan range: Accuracy in the distance measurement = 4mm; Accuracy in the position measurement = 6mm; Angle (both vertical and horizontal) 60microradians; target acquisition accuracy 1,5mm; modeled surface precision = 2mm (Information taken from official Leica website http://www.leica-geosystems.com/corporate/en/ndef/lgs_62189.htm).
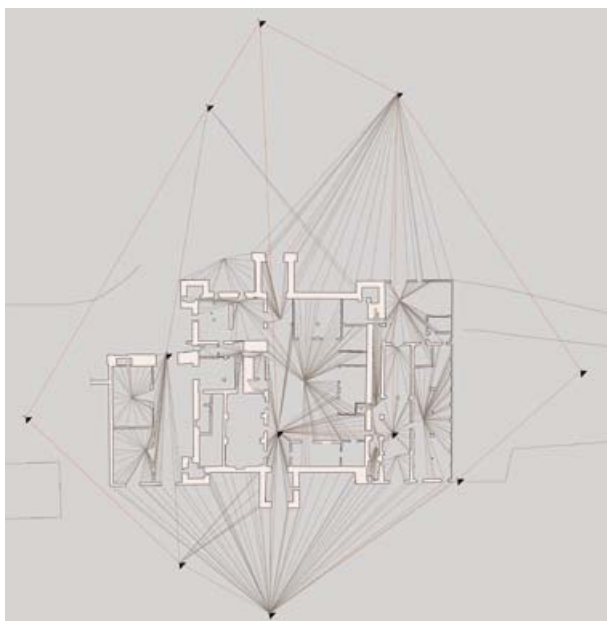
Figure 2. Principal and secondary topographic networks: indication of realized measurements

In particular, the need to obtain a large quantity of information about external architectonic elements, often difficulty reachable (for example, in the case of roof gutter or roof hipper), in quick time and at detail scale superior to 1:50 (for the parts of the building characterized by presence of decorations or geometric irregularity, scale 1:20 – 1:10), required a lot of scans, with a general resolution of 15 mm and of 5 mm for the vertical cross-sections.

	Rocca Rangoni	Square - street
n. scans	44	18
n. stations	16	4
n. points	34 470 504	13 227 381
sections	15	5

Table 3. Summary table of points clouds parameters, by using laser scanner Leica HDS 3000

The extraction of horizontal and vertical cross-sections from points clouds was realized in semi-automatic way, in CAD system, by using Cloudworks tools.

In detail, at first we extracted a cross-section of points (with tools *clip point to slice* and *clip point to section*), about 20 cm thick; then we draft an interpolating line, controlled and modified in automatic way with *fit point cloud- section* Cloudworks tool. The horizontal and vertical cross-sections, extracted from points clouds, were used to integrate and to compare the geometries obtained with manual and topographic survey instruments; the result was a substantial coincidence between different data. In fact, the registered differences were between 20 mm and 30 mm; differences till 50 mm only in the most geometrically complicated areas or most hard reachable*.

---

* In particular in the area where we had some problems during the phase of levelling of cross-section plans, in absence of provisional structures.

Figure 3. Extraction of four horizontal cross-sections from laser scanner points clouds
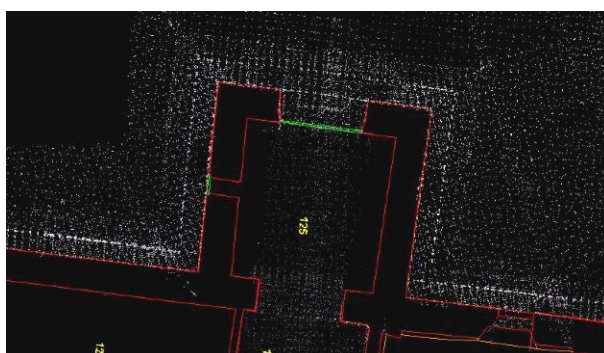

Figure 4. Detail of ground floor plan: superposition between plan realized with manual-topographic survey (red colour) and points cloud horizontal slice

Figure 5. In yellow the horizontal cross-section extracted by laser scanner data; in red the plan realized with manual and topographic techniques
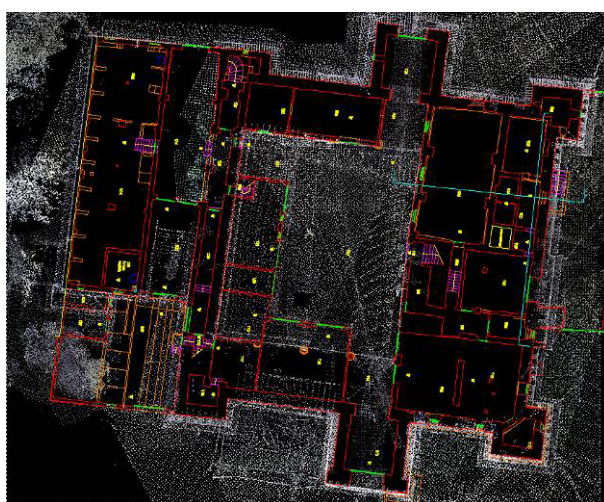

Figure 6. Ground floor plan (red colour), inserted in horizontal points cloud section

We obtained the same quantitative results by comparing vertical cross-sections, realized with different survey techniques. The vertical points cloud slices were especially used to fast integrate the data when we didn't have them or when they asked too much time to be registered with manual instruments.

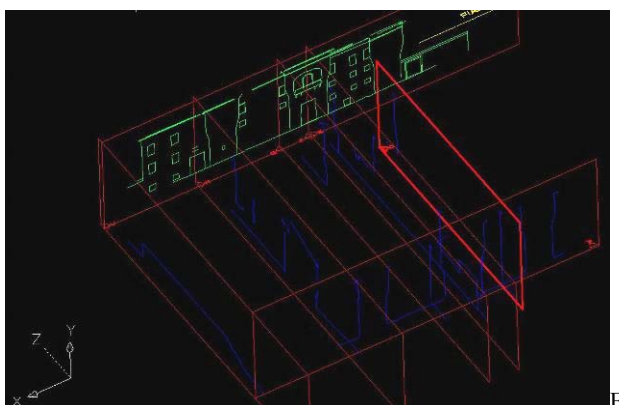Figure 7. Vertical cross-section of points cloud

Figure 8. Vertical cross-sections drawing: construction of geometries from laser scanner points cloud

Figure 9. Cross-section and internal front of Rocca realized with laser scanner data

Therefore, the integrated check of measurements allowed to draw the exact geometry of the rooms, the thickness of party and external walls, the right shape of vaults and wooden attics, in order to delineate accurately all the discontinuity lines of the walls, the empties of the structures, the areas interested by bending of the floor, and all the eventually patchiness. All those elements were indispensable for the subsequent steps of stratigraphic and structural investigations.

2.2 Rectified images and orthophotos for thematic mapping

To realized rectified images and orthophotos, in 1:50 scale, of the interior and of the outer fronts of the Rocca, were used both topographic support points and points extracted by laser clouds. In particular, there were registered about 500 topographic points, inside general plano-altimetric network.

Those photos rectifications, entered in cross-sections and fronts, represent an indispensable bases for thematic mappings (materials, degradation, stratigraphy, etc.).

Figure 10. East front of Rocca toward Park

Finally, the 3D synthesis model of Rocca Rangoni, obtained by laser scanner, was mapped with thematic rectified images and utilized to create different views of the complex.
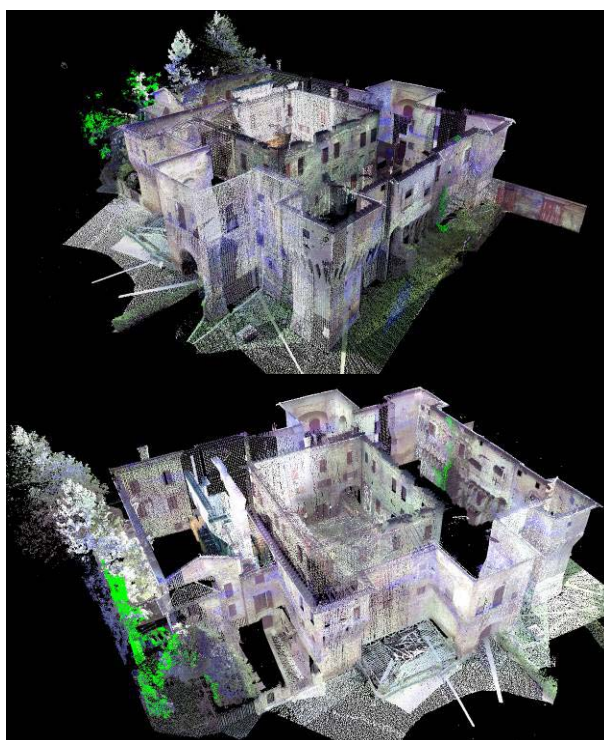

Figure 11. 3D laser scanner views of Rocca: there are visualized all the scans, georeferenced with colour information

2.3 The square and the Castle of Spilamberto: laser scanner, GPS survey and GIS data management*

The need to survey at smaller detail scale (1:200) and in short time the plan, two vertical cross-sections and the fronts of the buildings in the square, caused the use of different techniques.

---

* At least, by using GPS Leica 1200, all the measurements of Rocca were georeferenced in national reference system Roma40.

In order to draw the plan of the square, laser scanner data were integrated by a topographic survey of the buildings corners, inside general plano-altimetric network.

Then was realized a campaign of GPS measurements in RTK (Real Time Kinematic), that allowed to carry out DTM of square and Park of Rocca.

Finally, all the obtained data were managed in an information system (GIS).
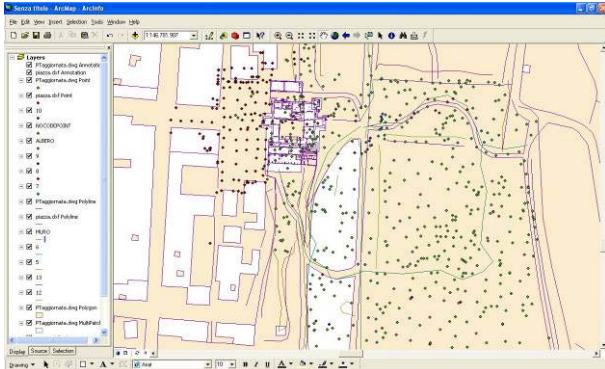

Figure 12. GIS data management

Figure 13. Drawing of the fronts of buildings, from laser scanner points cloud associated with colour information
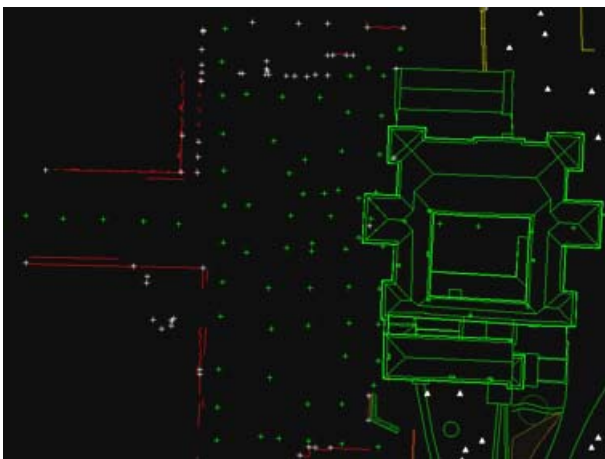

Figure 14. Grid points registered with Gps, inserted in the plan (red colour) realized from laser scanner data

Plan drawing were compared with cartography at scale 1:2000, in order to integrate data where it was necessary.

From laser scanner points cloud, there were extracted the fronts of the buildings on the square, draft in CAD.

Figure 15. Photo-mosaic of fronts: extraction from laser scanner cloud of points useful to rectify all the images

Finally, it was realized the survey of the Park of the Rocca, that had to become for the first time a public area. In order to value the right dimension of the Park, to figure the elevation difference of the ground, to survey the existent vegetation and network installations, it was necessary to register the measurement with GPS instruments. Also the data obtained with this survey methodology were georeferenced in the global reference system and were managed with GIS technology.

2.4 3D urban views: supporting to valorisation of historical perspective axis

The last step of our work consisted in laser scanner survey of buildings that are on the main axis of Spilamberto, the street that connects Rocca Rangoni and the entrance Tower of ancient Spilamberto Castle.

From urban analysis point of view, now there were opened new places and new perspective views toward the river: every citizen can walk from the Medieval Tower to the river, trough Rocca Rangoni.

It was realized a 3D laser scanner model of the building overlook the axis and the square.

The chance of creating different 3D views represents an additional reading instrument for urban analysis; moreover, it consents a quick mapping of the fronts of the buildings, the extraction of different slices and the drawing of a 3D model.
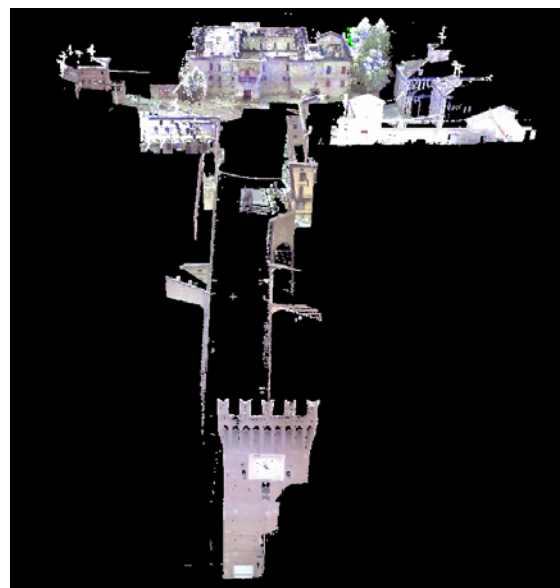

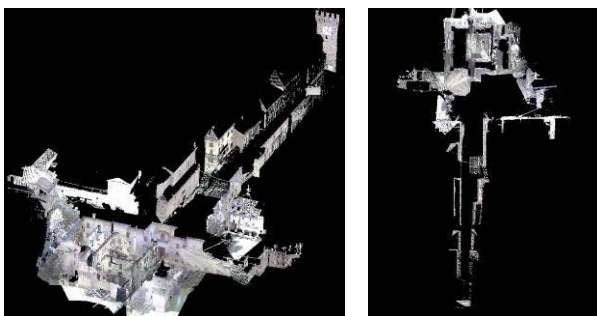Figure 16. 3D laser scanner model at urban scale. View from entrance Tower

Figure 17. 3D views of perspective axis

The main purpose was to underline some particular historical axis, in order to emphasize some ancient courses of the Medieval Castle, and to give to the Municipality an useful instrument of planning.

Figure 18. View of main perspective axis, from Rocca toward Medieval Tower

Figure 19. Ortophoto of Spilamberto. In red Rocca Rangoni (top) and the entrance Tower (down); in yellow the tracing of ancient Wall. In green the Park; in orange the main axis and the visual perspective cones

3. CONCLUSION

This experience represented a right opportunity to study the difference between the results obtained by using on the same object various measurement techniques.

The information obtained, inside an unique reference system, confirmed one to each other, and the error due to the different instruments hardly ever exceeded the tolerance of representation scale.

So we can assert that laser scanner survey could be the fastest solution in particular when we need to obtain the right external geometry of big buildings, in order to extract plans, cross-sections and fronts. Instead it's more complicated to use it to represent the internal spaces of a building characterized by little rooms on different levels (as in Rocca Rangoni). Infect, in this case, it will be necessary to measure topographically the position of a large quantity of targets, in order to georeference the different scans; so, in similar circumstance, it's maybe easier and faster to realize a traditional manual-topographic survey.

The integration of different geometrical data is however always fundamental for the comprehension of the structures and it forms the unavoidable support for the project of conservation and restoration, especially of complicated historical buildings.